DISSERTATION

MANAGING THROUGH MEASUREMENT: OCCUPATIONAL HEALTH AND SAFETY IN THE CONSTRUCTION INDUSTRY

Submitted by

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ABSTRACT

MANAGING THROUGH MEASUREMENT: OCCUPATIONAL HEALTH AND SAFETY IN THE CONSTRUCTION INDUSTRY

The purpose of my dissertation was to describe five original research activities designed to characterize and enhance the health and safety of U.S. construction workers. The sequence of research activities illustrates my focus on occupational health and safety (OHS) measurement methods (i.e., lagging and leading measures), as well as an interest in translating this research into practical methods for industry stakeholders. First, I investigated a vulnerable sub-population of construction workers, the aging workforce, via a literature review and analysis of workers' compensation (WC) data. Through the results of these studies, I found that aging workers may have a different OHS experience than younger workers (e.g., greater lost work time costs), but the frequency and cost of injuries and illnesses was high regardless of worker age. Furthermore, in the cost regression models, the age of the claimant only accounted for a small amount of variance, which suggests that other factors influence the cost of a WC claim (e.g., organizational factors such as safety climate). Second, I investigated safety climate measurement methods, and translated prior safety climate research into an intervention for construction site supervisors. I demonstrated that safety climate could be measured via worker perceptions of top management, supervisor, *and* co-workers' response to safety on the job. Furthermore, a supervisor workshop focused on safety climate concepts could improve the safety participation behaviors of supervisors, and their crewmembers. Taken together, my findings demonstrate that both lagging and leading measures are valuable indicators of safety performance. Lagging measures such as WC data may serve as motivators for contractors to make decisions regarding safety. Leading measures such as safety climate and safety behaviors may also be useful, because we can use them to identify hazards and their associated risks before they result in serious negative outcomes. Since it was beyond the

scope of my dissertation to measure both lagging and leading measures simultaneously, it is important for future research to evaluate the predictive validity of these measures of OHS.

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DEFINITION OF TERMS AND ACRONYMS

Term	Definition
ANOVA	Analysis of variance
BLS	Bureau of labor statistics
CPI	Consumer price index
CPWR	Center for construction research and training
CSC	Co-worker safety climate
EMR	Experience modification rate
FTE	Full time equivalent
HSUP	Supervisor safety climate
HTM	Top management safety climate
Lagging indicator	An after-the-fact measure of OHS performance (e.g., workers' compensation data)
Leading indicator	A proactive measure of OHS performance (e.g., safety climate)
LGM	Latent growth modeling
MSD	Musculoskeletal disorder
NEISS-Work	National electronic injury surveillance - Work
NIOSH	National institute for occupational safety and health
NORA	National Occupational Research Agenda
OHS	Occupational health and safety
OHS Act	Occupational Health and Safety Act of 1970
OSHA	Occupational Safety and Health Administration
Safety behaviors	Activities at work designed to 1) comply with company safety rules, and 2) support safety in the work environment
Safety climate	Shared worker perceptions among the members of a social unit, of policies, procedures, and practices related to safety in the organization
Safety culture	Deeply held but often unspoken safety-related beliefs, attitudes, and values that interact with an organization's systems, practices, people, and leadership to establish norms about how things are done in the organization
SC	Safety compliance behaviors (i.e., comply with company safety rules)
SCK	Safety climate knowledge
SD	Standard deviation

SOII	Survey of occupational injuries and illnesses
SP	Safety participation behaviors (i.e., support safety in the work environment)
SSTL	Safety specific transformational leadership (i.e., a style of leadership that involves stimulating, motivating, and active caring for workers safety and well-being)
TTB	Training transfer behaviors
US	United States
WC	Workers' compensation
WSR	Workshop reaction

PART I

Dissertation Review

Chapter 1

Introduction

1.1. Dissertation overview

Though the construction industry has improved its safety performance over the past couple of decades, the industry continues to be one of the most dangerous. Industry stakeholders have relied on lagging or after-the-fact measures of surveillance (e.g., workers' compensation (WC) data) to identify injury, illness, and fatality prevention strategies. These measures offer a "results" perspective on safety performance, and only offer a limited approach to prevention efforts. Using leading measures of surveillance, on the other hand, allow for the prediction of hazards and their associated risks before they result in poor safety outcomes (Hale, 2009). Worker safety climate perceptions are an example of a leading indicator. They represent the shared worker perceptions among the members of a social unit, of policies, procedures, and practices related to safety in the organization. The purpose of my dissertation is to highlight novel research activities designed to characterize and enhance the occupational health and safety (OHS) of construction workers.

The approach of my dissertation was to utilize both lagging and leading indicators of OHS to characterize and enhance the OHS experience of construction workers. This was accomplished by carrying out a sequence of five studies, starting with lagging and leading indicators, and ending with a method to proactively manage OHS. In my first two studies, I investigated the influence of a construction workers' age on injury susceptibility and injury costs (e.g., medical and lost-work time) via a literature review and an analysis of WC data. Through the results of my studies, I found that aging workers may have a different OHS experience than younger workers (e.g., greater lost work time costs), but the frequency and cost of injuries and illnesses is high regardless of worker age. Furthermore, the methods use by the authors in the review studies were limited to lagging, after-the-fact measures, and were poor sources of surveillance to be used to identify proactive OHS interventions. Thus, in my third, fourth, and fifth studies I expanded upon a leading indicator of OHS performance, safety climate, to identify ways to improve the OHS of all construction workers. I investigated safety climate measurement methods, and I translated prior safety climate research into an intervention to help construction site supervisors (e.g., foremen and superintendents) proactively influence the OHS of their crewmembers on job sites.

My dissertation is structured such that the introductory chapter synthesizes all doctoral research activities, and is followed by one original review article and four original research studies (see Table 1). The specific aims of my dissertation are as follows:

1.2. Aims of dissertation

1. To characterize the OHS experience of construction workers in the United States by measuring both lagging and leading indicators of safety performance.
2. To expand the concept of safety climate, a leading indicator of safety performance, by evaluating its measurement methods and translating previous research findings into a practical OHS intervention for the construction industry.

Table 1. List of original studies

Study	Location in dissertation	Article	Study purpose	Specific aim
1 – "Literature review"	PART II	Schwatka, N.V., Butler, L.M., & Rosecrance, J. C. (2012). An aging workforce and injury in the construction industry. *Epidemiologic Reviews* 34(1), 156-167.	To summarize published literature on the aging workforce	1
2 – "WC data analysis"	PART III	Schwatka, N.V., Butler, L.M., & Rosecrance, J. C. (2012). Age in relation to worker compensation costs in the construction industry. *American Journal of Industrial Medicine* 56(3), 356-366.	Investigate the association between worker age and injury type and workers' compensation claim cost	1
3 – "Co-worker response to safety"	PART IV	Schwatka, N. V. & Rosecrance, J. C. (Under review). From management to co-workers: The impact of safety climate perceptions on safety behaviors. *Safety science*.	Evaluate a model of safety climate that is untested in the United States, which focuses on top management, supervisors, *AND co-workers'* response to safety and how each influences personal safety behaviors	1 & 2
4 – "Safety climate knowledge"	PART V	Schwatka, N. V., Henry, K. & Rosecrance, J. C. (Under Review). Construction supervisors' safety performance: The impact of safety climate perceptions and safety climate knowledge on safety behaviors. *Journal of construction engineering and management*.	Determine if supervisors' safety climate knowledge mediates the relationship between supervisors' safety climate perceptions and supervisor's safety behaviors	1 & 2
5 – "Supervisor intervention"	PART VI	Schwatka, N. V., Grosch, J., Henry, K., & Rosecrance, J. (In preparation). Safety climate and safety leadership training for construction supervisors. *Journal of Occupational Health Psychology.*	Develop and evaluate a intervention targeted towards supervisors' safety leadership, but with intended effects on supervisors and their crewmembers	2

1.3. History and future of OHS

Towards the end of the 18th century and throughout the 19th century, a great industrial revolution swept the modern world up in a storm of advancement in living standards, international trade, innovations, and manufacturing processes. Innovations such as James Watt's steam engine and Frank and Lillian Gilbreth's motion study showed that society was progressing towards a more technological society (Konz & Johnson, 2008). Despite these impressive advancements, their effect on worker health and safety was unchecked. Abrams (2001) noted that understanding the history of OHS requires understanding the context between labor and capital. "Historically, the commitment to economic advancement through technology has made us blind to the toll on community and worker health" (Levy, Wegman, Baron, & Sokas, 2006 pg. 24).

Many notable events drew attention to hazardous working conditions, and towards the late 19th century, social reformers worked together to improve working conditions. In 1907, a coal mine explosion killed 362 people in Monogah, West Virginia leading to the U.S. Bureau of Mines (MMWR, 1999). In 1906, Upton Sinclair's book, *The Jungle,* depicted working conditions in the meatpacking industry. It raised much awareness to the plight of the immigrant-working class, but only resulted in new meat inspection laws. Interestingly, Upton Sinclair hoped his undercover research would raise the public's awareness of the working conditions specifically. To his dismay he said, "I had been made a celebrity not because the public cared anything about the sufferings of workers, but simply because the public did not want to eat tubercular beef" (Abrams, 2001). In 1911, as a result of poor fire standards and work practices, the Triangle Factory Fire killed 146 workers leading to many new labor laws and fire safety measures (ILR School, Cornell University,, 2011). Many more events like these helped to push society towards measures to protect the rights of workers to have a healthy and safe work environment.

In the early 20th century, most US states adopted no fault workers' compensation (WC) laws, which requires companies to compensate worker's injuries, illnesses and fatalities. Compensation includes full medical coverage, partial wage replacement coverage, disability, and death benefits. With the advent of the Occupational Safety and Health Act (OSH Act) of 1970, "safe and healthful working conditions for working men and women" were ensured for all workers in the US. The Act made provisions for standards that all companies should meet, penalties for failing to meet the standards, recordkeeping requirements, inspections, and responsibilities of employers and employees (OSHA, 1996). Since the Act was passed, there is now a greater understanding of job site hazards and the methods to control them. This is due to effort from all industry stakeholders to identify and control hazards. This includes the research efforts of the National Institute for Occupational Safety and Health, which was created by the OSH Act of 1970 (Howard, Stafford, Branche, T, & Froetschet, 2010). Society's attention to OHS Act and subsequent governmental efforts to regulate OHS, has led to a decrease in worker fatalities and injuries (MMWR, 1999).

While workers now operate in a safer environment than previous generations, much work remains to be done. In the construction industry specifically, workers have a greater chance of sustaining an injury during the course of their working career, as compared to other industries like the service or healthcare sector (Kachan et al., 2012). When injured, many workers often fail to report injuries to their employer because they believe that reporting is unnecessary, it is a natural part of their job, and/or negative consequences will follow (Moore, Cigularov, Sampson, Rosecrance, & Chen, 2013). The authors of one study bluntly titled their article, "Safety, incentives, and the reporting of work-related injuries among union carpenters: "You're pretty much screwed if you get hurt at work" (Lipscomb, Nolan, & Patterson, 2013). Underreporting also occurs at the contractor level, as contractors may fail to report injuries to the Occupational Safety and Health Administration (OSHA) (Probst, Brubaker, & Barsotti, 2008). Compared to white collar workers, construction workers have an increased odds of developing many chronic diseases, such as back problems (Dong, Wang, Daw, & Ringen, 2011). The injuries that construction workers sustain cost society millions of dollars per year in direct medical costs and indirect costs associated with lost work time and disability (Schwatka, Butler, & Rosecrance, 2012). While the OSH Act of 1970 made provisions for job site inspections to insure compliance with government regulations, only 4% of construction establishments were inspected in 2010 (CPWR, 2013). The future of OHS in the construction industry may require surveillance and prevention efforts that proactively address hazards and their risks before they escalate to cause serious outcomes (e.g., injury).

1.4. Structure of the United States (US) construction industry

Businesses in the construction industry are classified based on the type of work they do and the types of job sites they work on. Contractors can be general contractors, specialty-trade contractors, or construction managers, and sometimes contractors can be a combination of the three. General contractors are responsible for all aspects of the construction project. Specialty-trade contractors are responsible for a specific aspect of construction work, such as masonry or piping. Construction managers manage the completion of the job, but do not perform any of the actual work (Abrams, 2001). Job sites can vary broadly based on whether or not they are residential, commercial, or heavy civil construction job sites. Residential home building involves constructing single-family and multi-family residential buildings. Commercial construction involves the construction of business for commerce. Heavy civil construction involves engineering projects (e.g., highways or dams) (US Census Bureau, 2013). Any of these construction projects can be new builds or renovations.

The “nature of the construction industry” is often cited as a major challenge to managing and controlling OHS (Loushine, Hoonakker, Carayon, & Smith, 2006). Namely, multi-employer worksites and industry instability are major factors that influence OHS. Job sites consist of project owners/customers, general contractors, sub-contractors, unions, and tradesmen. Within one contractor, there is a hierarchy composed of top management and engineers/designers and those that actually work on the job sites (i.e., superintendents, foremen, journeymen and apprentices). All involved in a project must deal with a supply chain as well (Carty, 1995). Additionally, sites may be union, non-union, or mixed. Workers who belong to a union have ties to both their union brotherhood as well as their contractors. The construction industry is unstable because contractors move between job sites very frequently. Workers move between job sites and contractors as project contracts arise, and thus many have many employers in a short period of time.

The construction process itself leads to OHS management challenges as well. A construction project begins with competitive bidding. Within each contractor and sub-contractor, project estimators put together the project bid, and effectively set the stage for the project. They analyze the cost, risk, and quantity of work. Bidding focuses on these “bottom line” issues, but many contractors are moving towards a pre-qualification or partnership bidding process. This means that many owners/general contractors prefer to work with sub-contractors with proven records, and with sub-contractors they have worked with in the past (Carty, 1995). Regardless of a sub-contractor’s track record, contractors are still always under pressure to finish on time and within budget. This is because construction projects commonly encounter project setbacks and delays (e.g., weather), design changes, and construction quality issues (ILR School, Cornell University,, 2011; Loushine et al., 2006). Once the project begins, the operations department oversees the project’s progression. Depending on the construction firm’s size, this department can oversee many projects across cities, regions, and countries. At the site-level, the project staff is responsible for the day-to-day operations of the site. They must interact with their own workers as well as with other contractors to coordinate work. Depending on the contractor, each of these departments (estimating, operations and site-level management) can be fully integrated or disjointed. It is especially important for the estimating department to understand job-site level working conditions. If OHS costs can be anticipated at the bidding level, they can be properly accounted for before any issues arise. Additionally, sub-contractors move in and out of the job site as needed. This means that many contractors, with their own methods of managing OHS interact on the same job site. The general contractors will have their own OHS standard for the job site (Xinyu & Hinze, 2006), but its effectiveness is susceptible to each sub-contractor's culture of safety (Lingard, Cooke, & Blismas, 2010). Thus, even if a sub-contractor has a good OHS management system, their workers will be susceptible to other sub-contractor's OHS practices.

1.5. Characterization of injuries, illness and fatalities in the construction industry

According to the North American Industrial Classification System, the construction industry is considered part of the "goods producing" super sector group (Bureau of Labor Statistics, 2014). The goods producing classification includes industries dealing with natural resources (agriculture, forestry, fishing, and hunting, mining, quarrying, and oil and gas extraction), manufacturing, and construction. The construction industry is similar to these industries in that it is a high hazard industry. While the service-providing super sector group also has serious hazards, the incident rate of injuries requiring days away from work in the goods producing super sector is higher (119.7 versus 97.7 per 10,000 full time employees (FTE) in 2012) (Bureau of Labor Statistics, 2013b).

Within the goods producing super sector, the construction industry is one of the most hazardous. Compared to the sector average (119.7 per 10,000 FTEs), the incident rate of non-fatal injuries and illness resulting from days away from work was much higher (143.4) in the construction industry in 2012 (Bureau of Labor Statistics, 2013b). Both the construction and agriculture, forestry, fishing, and hunting sub-sectors had a higher incident rate of workers with 31 days or more away from work compared to the manufacturing sub-sector, 46 versus 30 per 10,000 FTEs, respectively (Bureau of Labor Statistics, 2013d). The construction industry accounted for 44% of all fatalities in the goods producing super sector in 2012, but the fatal injury incident rate was highest among the agricultural, forestry, fishing, and hunting industry (9.5 versus 21.2 per 100,000 FTEs, respectively).

OSHA identified the hazards that most commonly result in injury or fatality in the construction industry, and labeled them the “focus four hazards.” These hazards are falls, caught-in or-between, struck-by, and electrocution (OSHA, n.d.). Fatal and non-fatal injuries involving days away from work in 2012 were most commonly caused by these hazards. Non-fatal injuries were most commonly caused by contact with objects (caught-in or-between and struck-by hazards) (48 per 10,000 FTEs). Falls to a lower level (17 per 10,000 FTEs), overexertion in lifting/lowering (15 per 10,000 FTEs), falls on the same level (12 per 10,000 FTEs), and exposure to harmful substances or environments (e.g., electrocutions) (5 per 10,000 FTEs) were the next most common causes of non-fatal injuries (Bureau of Labor Statistics, 2013b). The most common injuries from these exposures were sprains, strains, and tears (44 per 10,000 FTEs), fractures (17 per 10,000 FTEs), cuts (17 per 10,000 FTEs), and bruises and contusions (9 per 10,000 FTEs) (Bureau of Labor Statistics, 2013c). Fatal injuries were most commonly caused by transportation accidents (38%), falls, slips, and trips (36%), and contact with objects and equipment (17%) (Bureau of Labor Statistics, 2013a).

1.5.1. Impact of the aging workforce

Specific sub-populations, such as small contractors, Latinos, and aging workers may be more susceptible to poor OHS outcomes. The majority (80%) of all construction contractors are small employers (1-9 employees) (Center for Construction Research and Training, 2013). Small businesses may the lack resources needed to manage OHS, and researchers found some evidence that they experience more injuries and illnesses than larger firms (Center for Construction Research and Training, 2013; Dong et al., 2011; Lowery et al., 1998; Schwatka et al., 2012). Latino construction workers are particularly susceptible to injury and death (Dong, Men, & Ringen, 2010; Dong & Platner, 2004; US Census Bureau, 2013). This population of workers experience a language barrier, legal citizenship issues, literacy issues, poor training, and may continue work despite hazards for fear of losing their job (Brunette, 2004; Carty, 1995; Loushine et al., 2006; Roelofs, Sprague-Martinez, Brunette, & Azaroff, 2011). Latino construction workers may be more likely to be injured, but may be less likely to be compensated for their injury than their non-Latino counterparts (Dong, Ringen, Men, & Fujimoto, 2007). Lastly, the construction industry's aging workforce may also be more susceptible to injury and death. Workers experience many physical and mental changes as they get older, such as changes in cardiac output and muscle mass (Fitzgerald, Tanaka, Tran, & Seals, 1997; Thomas, 2010). There is some evidence that older construction workers experience more serious injuries than younger construction workers (Arndt et al., 2005), and may retire early from such injuries (Welch, Haile, Boden, & Hunting, 2010). This trend is especially important to understand, because the average age of a construction worker is increasing and the demand for construction labor may exceed the labor pool in the coming decade (Center for Construction Research and Training, 2013; Goodrum, 2004).

1.6. Safety performance measurement

Surveillance is an important component of OHS hazard prevention that can be used to understand OHS trends. The goal of surveillance is to identify new prevention opportunities, define the magnitude and distribution of problems, track trends, set priorities, and disseminate the results to facilitate decisions that improve OHS (Levy et al., 2006). Surveillance can occur at three levels: hazard, exposure, and outcome (Thacker, Stroup, Parrish, & Anderson, 1996). These levels correspond to the three levels of injury and illness prevention: primary, secondary, and tertiary. Understanding potential *hazards* before they harm workers represents a *primary prevention* effort. Determining what workers are *exposed* to offers a chance to catch injuries, illnesses and fatality risk before its effects become too advanced (i.e., *secondary prevention*). Lastly, quantifying *outcomes* from exposures (e.g., sprain) can lead to *tertiary prevention* efforts that seek to mitigate complications and disability. There are a number of different government and industry surveillance sources, such as WC and OSHA logs. These sources are somewhat easier to track overtime as companies must report their injuries, illnesses and fatalities to OSHA and their WC carrier. These measures, however, are fraught with underreporting (Boden, 2013) and can only account for injuries, illnesses, and fatalities after they occurred. Surveillance measures (i.e., leading measures) that capture the qualities of the work environment that lead to these negative outcomes may be more useful. Leading measures can act as a means of primary and secondary prevention efforts.

1.6.1. Lagging measures

Surveillance measures such as WC data and OSHA logs are lagging indicators of OHS. This means that they measure OHS outcomes (e.g., death) rather than hazards (e.g., poor scaffolding). WC data are generated from a worker's first report of injury form, which is given to the company's WC provider and an injury claim is generated. Throughout the life of the claim, costs related to medical, lost-work time, disability and death benefits are paid to the employee and their families. With each injury claim that a company files, their experience modification rate (EMR) increases. WC providers use the EMR to estimate a company's past and future claim costs, so that providers can charge companies an appropriate insurance premium. More claims result in higher premiums, and an increased EMR can stay on a company's record for three years (Hoonakker et al., 2005). Employers with more than 10 employees must maintain and report their OSHA logs yearly. All injuries and illnesses resulting in more than first aid care, restricted duty, days away from work, loss of consciousness, chronic diseases, and death must be reported on the log. OSHA logs help the government conduct OHS surveillance, and help companies compare their trends with others in their industry. There are other national data sets that one can utilize for surveillance, such as the National Electronic Injury Surveillance System that originates from emergency room visits. There are some benefits to using these sources of data, such as easy access to a large amount of data and cost effectiveness because it has already been collected.

However, both of these systems are susceptible to underreporting and cannot account for the root cause(s) of injuries, illnesses, and fatalities. Workers may not report their injury to their employer for 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). Conversely, companies may not report all injuries, illnesses, and fatalities. Company underreporting can benefit companies by keeping their injury, illness, and fatality rates and EMRs low. This reduces the amount of money they have to spend on WC premiums, and helps to keep OSHA inspectors at an arms length. In the construction industry specifically, many project contracts require contractors to have OSHA rates and EMRs below a certain level. Thus, low OHSA log rates and EMR's can help contractors win project bids. Underreporting ultimately means that an accurate monitoring of OHS trends cannot be made with these types of data. Furthermore, these data cannot account for contributing factors such as lifestyle factors (e.g., smoking), exposure to specific job-site hazards, or the way OHS is managed by the company (Dembe, Erickson, & Delbos, 2004).

1.6.2. Leading measures

1.6.2.1. Safety climate measures

Safety climate perceptions are example of a leading measure of OHS. The measurement of safety climate has a three-decade long history of scholarship. It entered the academic literature in 1980 when Dov Zohar (1980) developed and tested a safety climate perception survey in the manufacturing industry. He followed other organizational climate researchers who argued that a company's total organizational climate is an *area of research rather than a holistic measure of general company climate* (Schneider, 1975). Thus, when describing organizational climate one must specify what kind of climate they are focusing on (e.g., climate for creativity, ethics, safety, etc.). He argued that safety climate perceptions develop from observations of one's work environment. Such observations lead to perceptions and eventually behavior-outcome expectancies. Thus, safety climate perceptions "[serve] as a frame of reference for guiding appropriate…behaviors" (Zohar, 1980 pg. 96). Since 1980, numerous researchers have studied safety climate in a variety of industries, and have found it to be a meaningful and predictive measure of OHS. Multiple researchers found through their meta-analyses that significant relationships between safety climate and increased safety knowledge and motivation, positive safety behaviors, health and well-being and decreased accidents/injuries (Christian, Bradley, Wallace, & Burke, 2009; Clarke, 2010; Nahrgang, Morgeson, & Hofmann, 2007). In the construction industry specifically, researchers have found evidence of safety climate's ability to predict safety behaviors (Pousette, Larsson, & Törner, 2008) and influence on the severity (Gillen, Baltz, Gassel, Kirsch, & Vaccaro, 2002) and reporting of injuries (Probst et al., 2008).

Safety climate measurements tap into workers' perceptions of safety on the job, not their affective reaction to safety on the job. They ask workers to be "observers and rapporteurs of shared perceptual phenomenon" (Kines et al., 2011). The development of a shared safety climate among organizational members originates with company leadership. At its core, safety climate reflects perceptions of the priority of safety over competing organizational goals. This inference is based on the *enacted* policies rather than the *espoused* policies. The consistency of *enacted* policies may differ by group or department due to supervisory discretion. A climate for safety ultimately forms from *shared* worker perceptions of these *enacted* policies. One of the key mechanisms that drive these shared perceptions is company leadership (Zohar, 2011). Perceptions of leadership are not based on a single observation of leadership actions, but rather an observed pattern of events that are interpreted in psychologically meaningful ways (Rentsch, 1990). When leadership consistently prioritizes safety, for better or for worse, workers collectively perceive the true priority of safety. As Lewin said in 1939, "leaders create climate" (Lewin, Lippitt, & White, 1939). Perhaps that is why management priority and commitment to safety has been consistently cited as a key dimension of safety climate (Flin, Mearns, O'Connor, & Bryden, 2000; Guldenmund, 2000) and leadership style has been found to be a key antecedent (e.g., Barling, Loughlin, & Kelloway, 2002; Kelloway, Mullen, & Francis, 2006; Mullen, Kelloway, & Teed, 2011).

Safety climate perceptions are measured via worker perception surveys. Safety climate cannot be directly measured like a person's weight, because it is an "unobservable" or "latent" construct. Its value must be triangulated by multiple perception-based questions. While some researcher's safety climate questions represent a global safety climate factor, a lot of safety climate questions can be grouped based on specific sub-dimensions of safety climate. These dimensions include management commitment, safety system, risk, work pressure, and safety communication. Management commitment to safety, however, is the most common dimension measured (Flin et al., 2000).

1.6.2.1.1. Top management, supervisors, and co-workers response to safety

Zohar (2000) argues that management commitment to safety should reflect both top management and supervisors commitment to safety. He calls this a multi-level model of safety climate because safety climate perceptions can be distinguished by organization and work group levels (Zohar, 2000). Zohar et al. (2005) found that group-level safety climate fully mediates the relationship between organizational safety climate and observed safety behaviors. Group differences develop from supervisory discretion in applying organizational policies. In work settings where work is less routinized, supervisors have more discretionary power (Zohar, 2011). Unlike the manufacturing industry, supervisors and crews in construction are most likely working away from the main office on various job sites with a host of variable working conditions. Supervisors must routinely implement company policies for their crews in varying situations. Zohar (2011) states that worker perceptions of top management should refer to policies (e.g., the financial aspect of safety and reducing production in favor of safety) whereas perceptions of supervisors should refer to practices (e.g., monitoring and rewarding and willingness to interrupt production in favor of safety).

In addition to perceptions of top management and supervisors, Melia et al. (2008) and Brondino et al. (2012) argued that perceptions of co-workers also play a critical role in safety climate measurement. Chiaburu et al.'s (2008) meta-analysis found that, even after accounting for the influence of leaders, co-workers predicted perceptions, attitudes, and behavior outcomes of co-workers. While co-workers do not hold any formal power, the way they respond to safety may influence safety outcomes just as much as their top management or supervisor's response to safety. Melia et al. (2008) and Brondino et al. (2012) both found support for this effect. Namely, both levels of managements' responses to safety predicted co-worker response to safety, and co-workers' responses to safety predicted safety behaviors. The role of co-workers in the construction industry may be especially important because construction workers work on job sites away from the contractor's main office with their crewmembers. Only Melia et al (2008) tested this model in the construction industry, but it was in Spain and Hong Kong. Thus, this extend model of safety climate has yet to be tested in the US construction industry.

1.7. OHS interventions

The practice of OHS is evolving and research is needed to develop and test interventions that can help reduce the burden of poor safety performance. Historically, micro-level determinants of accidents (i.e., human error) invoked a need to control the hazards around the worker by putting up various "defenses" (e.g., personal protective equipment, safety and health training, etc.). Recently, researchers acknowledged the need to incorporate macro-level factors (i.e., organizational level) (Khanzode, Maiti, & Ray, 2012; Reason, 1997). In the construction industry, specifically, researchers have advocated the use of systems models that seek to understand the work system factors that create hazards and shape worker behaviors (Mitropoulos & Abdelhamid, 2005). The United Kingdom's Health and Safety Executive's analysis of construction accidents is a testament to this fact. There are multitude of factors that lead to construction industry accidents, but originating factors, like safety climate and company leadership, ultimately influence and shape safety and health performance (Haslam et al., 2005; Health Safety Executive, 2003).

1.7.1. Leader focused interventions

Relatively little intervention research aimed at improving an organization's safety climate is available, and those that do exist have focused on leadership. The style of leadership that management can employ ranges from passivity to proactivity (i.e., transactional to transformational). Passive leaders exhibit a poor concern for employee welfare, and will only address safety if standards are not met or in some instances will refuse their safety leadership role. Proactive leaders care for employee welfare and actively engage and inspire their employees to be safe (Bass, 1990; Zohar, 2003). Active leaders who display transformational qualities are more likely to have a positive influence on safety (Kelloway & Barling, 2010). Safety-specific transformational leadership theory focuses on four characteristics. First, they are role models that convey their personal value for safety. Second, they inspire employees to go beyond their own needs to be safe for the sake of the group by motivating them to achieve high safety levels. Third, they challenge workers to confront long held views about safety and to enhance the way they deal with safety. Lastly, they convey an active interest and real concern in worker's safety that goes beyond company or government requirements (Barling et al., 2002).

There are several advantages of focusing an OHS intervention on supervisors' leadership (Kelloway & Barling, 2010; Zohar, 2002). First, relatively few individuals within the company need to be trained to see positive safety outcomes, saving a company's valuable resources (e.g., time and money). This is because the intervention is implemented at the front-line leadership level (e.g., foremen), but positive changes are also expected at the crew level (i.e., journeyman, apprentice, etc.). Second, involving front-line leadership in crew safety takes the burden off of safety managers, who cannot be with crews during the entire workday. Furthermore, training leadership to be attuned to crew safety offers a chance for immediate feedback and learning. Through this, crews will learn that safety is an integral aspect of work performance that is expected of them. Third, leadership training that focuses specifically on safety may be advantageous because leaders may not exhibit positive leadership qualities in all areas of work (e.g., production, but not safety) (Mullen & Kelloway, 2009). Due to the link between leadership, safety climate, and other organizational outcomes, construction companies can use the leader-focused intervention to enhance their existing health and safety efforts (Christian et al., 2009; Clarke, 2010; Kelloway & Barling, 2010). Ultimately, the program could become a fixture in a company's health and safety management system.

1.8. Dissertation significance

My dissertation addresses several novel aspects of OHS identified by the National Occupational Research Agenda (NORA) research goals (NORA Construction Sector Council, 2008). First, in Strategic Goal 12.0, the NORA Construction Sector Council called for the reduction of "injuries and illnesses among groups of construction workers through improved understanding of why some groups of workers experience disproportionate risks in construction work." The National Research Council and Institute of Medicine (2009) also called for an investigation of how aging impacts OHS. A minimal amount of research has investigated aging trends among a large cohort of workers in the construction trade that report on the nature and costs of work-related injuries. The first two studies in this dissertation represented the first comprehensive effort to identify aging related trends in the construction industry.

Second, my dissertation addresses the NORA strategic goal 8.0, "to increase understanding of factors that comprise both positive and negative safety and health cultures; and, expand the availability and use of interventions at the policy, organizational, and individual level to maintain safe work practices 100% of the time in the construction industry." Specifically, my third and fourth studies address the research goal 8.2.4, "Validate measurement methods that consistently identify the positive and negative aspects of construction safety and health culture." I investigate novel models of safety climate in the US construction industry, and seek to understand how safety climate impacts aspects of OHS knowledge and behaviors. In my fifth study, I address research goal 8.3.1., "Identify and evaluate interventions for improving construction safety and health cultures." In my fifth study, I translate previous safety climate research into a proactive method to improve OHS in the construction industry.

1.9. Dissertation hypotheses and research questions

Study 1

1.1. What are the injury and illness trends of older construction workers in the previously published literature?

Study 2

2.1. The positive association between age and WC cost would differ by cost type (e.g., total, medical, and indemnity costs).

2.2. The relationship between injury type and cost would vary by age.

Study 3

3.1. There are direct relationships between all safety climate factors and safety behavior factors.

3.2. There are indirect relationships between all safety climate factors and safety behavior factors.

Study 4

4.1. There are direct relationships between safety climate, safety climate knowledge, and safety behaviors.

4.2. The relationship between safety climate and safety behaviors is partially mediated by safety climate knowledge.

Study 5

5.1. An intervention composed of a workshop plus progress checks results in positive safety outcomes.

5.2. The addition of progress checks enhances the treatment effect.

Chapter 2

Methods

Since my dissertation represents five separate studies, the methods for each study vary. In my *first study,* I reviewed research published between 1998 – June 2011 that specifically addressed the construction industry's aging workforce. In my *second study*, I utilized a large database of WC claims from the Colorado construction industry to describe how the age of a worker impacts injury type and cost (direct and indirect). In my *third study*, I evaluated the role that top management, supervisors, and co-workers play in safety climate perceptions, and how each of them influences safety behaviors on the job. In my *fourth study*, I investigated construction supervisor's safety climate knowledge, and how it mediates the relationship between their safety climate perceptions and their safety behaviors. Lastly, in my *fifth study*, I developed and evaluated a safety climate intervention aimed at site-supervisors and their crews. See Appendix 6.I. for details on the intervention. See Table 2 for an overview of the methods used in each study. The specific methods of each study are described below.

Table 2. Overview of materials and methods for all 5 dissertation studies

Study	Study participants	Study design	Predictors	Outcomes	Primary statistical method
1 – "Literature review"	Construction workers	Review of literature (N=21 articles)			
2 – "WC data analysis"	Colorado construction workers who filed a WC claim from 1998-2008 (N = 107,065)	Cross-sectional	•Age •Injury type	•WC claim cost: •Total cost ($) •Medical cost ($) •Indemnity cost ($)	ANOVA; Linear regression
3 – "Co-worker response to safety"	Baseline data from study 5 - Construction workers (*supervisors and crewmembers*) from 3 medium sized contractors in the US PNW (N=300)	Cross-sectional	•Top management safety climate •Supervisor safety climate •Co-worker safety climate	•Supervisor safety climate •Co-worker safety climate •Safety participation behaviors •Safety compliance behaviors	Structural equation modeling
4 – "Safety climate knowledge"	Baseline data from study 5 - Construction workers (*supervisors only*) from 3 medium sized contractors in the US PNW (N=91)	Cross-sectional	•Safety climate •Supervisor safety climate knowledge	•Supervisor safety climate knowledge •Safety participation behaviors •Safety compliance behaviors	Path analysis
5 – "Supervisor intervention"	Construction workers (*supervisors and crewmembers*) from 3 medium sized contractors in the US PNW (N = 205-350)	Intervention: •Pre-post repeated measures •Quasi-control group •• Workshop + Progress checks •• Workshop only		•Top management safety climate •Supervisor safety climate •Co-worker safety climate •Safety participation behaviors •Safety compliance behaviors •Supervisor safety climate knowledge •Supervisor training transfer behaviors •Supervisor reaction to workshop	Latent growth modeling

2.1. Study participants and data collection procedures

In my *first study*, I reviewed all previously published articles discussing OHS in relation to the industry's aging workforce. The articles must have mentioned the construction industry and older workers, and at least one of the following topics: injury cause, injury type, or injury cost. Only 21 articles from 1998 – June 2011 fit the study criteria. These studies represented construction workers from the US, Sweden, The Netherlands, Canada, and Germany. While some researchers looked at construction workers in general (e.g., state level WC claims), others focused on specific trades (e.g., roofers and carpenters) or construction workers with specific characteristics (e.g., Department of Energy workers or workers who filed for disability).

In my *second study* I conducted a cross-sectional analysis of 107,065 WC claims filed by Colorado construction workers from June 30, 1998 to June 30, 2008. The claims were extracted from Pinnacol Assurance's database of claims. Pinnacol Assurance is Colorado's insurer of last resort, which means they must insure any company who wishes to buy WC insurance from them. However, the majority of Colorado contractors (80%) use Pinnacol Assurance as their WC carrier (Actuarial from Pinnacol Assurance, oral communication, 2010). Although the dataset represented claims not workers, approximately 14,000 contractors and 124,000 construction workers were represented in the dataset per year (Statistics of U.S. Businesses, 1998-2008). The Colorado State University Institutional Review Board (IRB) deemed this study exempt from IRB since the dataset represented claims, not individuals.

My *third, fourth, and fifth studies* were representative of a cohort of construction workers from three medium sized contractors (60-400 employees) in the US Pacific North West. The construction workers were unionized sheet metal workers, plumbers, and pipefitters. All of the contractor's supervisors (i.e., foremen, superintendents, project managers) and crewmembers (i.e., pre-apprentices, apprentices, journeymen) were asked to fill out questionnaires. I used surveys to ask supervisors questions relating to safety climate, safety climate knowledge, safety behaviors, training transfer behaviors, and workshop reaction questions. Crewmembers were asked questions relating to safety climate and safety behaviors. The surveys were handed out during normal working hours during breaks or pre-scheduled meetings such as toolbox talks or safety meetings. All workers were told that it would take 15-20 minutes to complete the survey, their participation was voluntary, and that their surveys would be anonymous and maintained at Colorado State University. I distributed and collected the majority of the surveys, but when I could not be present the surveys were collected, sealed in an envelope, and handed to me.

Both supervisors and crewmembers were surveyed before and after the intervention described in *study five*, and their surveys were tracked via a unique identifier code that the worker wrote on the top of their survey (i.e., 2 digits of day of birth, last 2 digits of phone number, last 2 digits of social security number). *The third and fourth studies* were based on the baseline data of *study five*, which was collected in December 2012. *The fifth study*, the intervention study, was based on multiple waves of data starting in December 2012. The number of waves of data collection varied depending on the worker's position (supervisor or crewmember) and the variable measured. For example, supervisor's safety climate knowledge was assessed on five occasions (baseline 1, baseline 2, immediate-post test, 3-month follow-up, and 6-month follow-up). However, for crewmembers, all variables were assessed on three occasions (baseline 1, 3-month follow-up, and 6-month follow-up). See Figure 7 in Part VI for detailed description of the study design. The Colorado State University IRB approved all study methods.

2.2. Variables studied

In my *second study*, the claimant's injury type and age at the time of injury were the explanatory variables of interest. Pinnacol Assurance entered the injury type into their WC claim database by following the National Council on Compensation Insurance standard coding scheme. I collapsed injury type into a smaller number of categories, because 60% of all claims represented three injuries (i.e., strains, contusions, and lacerations). All other types of injuries were categorized as "other." Claimant age was treated as a continuous variable as well as a categorical variable (i.e., 18-24, 25-34, 35-44, 45-54, 55-64, and 65+). Three outcome variables were studied: medical cost ($), indemnity costs ($), and total cost ($). Medical cost represented all healthcare related expenses (e.g., physician visits and prescriptions). Indemnity costs represented wage-replacement, disability, impairment, and death benefits. Total costs represented the combined medical and indemnity costs as well as other costs such as legal fees. All costs were inflation-adjusted to 2010 dollars.

In my *third study*, supervisors and crewmember's combined responses to safety climate and safety behavior variables were assessed. The safety climate variable was split into three factors: top management safety climate, supervisor safety climate, and co-worker safety climate. Top management safety climate was represented by three sub-factors: top management safety commitment (4 items), top management safety empowerment (3 items), and top management safety justice (3 items). Supervisor safety climate was represented by three sub-factors: supervisor safety commitment (5 items), supervisor safety empowerment (4 items), and supervisor safety justice (3 items). Co-worker safety climate represented co-worker's commitment to safety (6 items). The safety climate factors were adapted from the Nordic Safety Climate Questionnaire (NOSACQ-50) (Kines et al., 2011). The safety behavior variable was split into two factors: safety compliance (3 items) and safety participation (3 items). The safety behavior factors were adapted from Neal et al.'s (2000) measure of safety behaviors. All variables were scored on a 0-5 Likert scale, never to always. See Appendix 4.I for a list of all safety climate and safety behavior questions.

In my *fourth study*, supervisor's responses to safety climate, safety climate knowledge, and safety behavior variables were assessed. The same safety climate and safety behavior variables in the third study were used in this study. However, safety climate was represented as a global safety climate factor (i.e., all questions averaged to obtain one score). Safety climate knowledge was assessed via a knowledge test developed by the researchers (10 items). The questions represented a combination of multiple choice and open-ended questions that assessed supervisor's knowledge of safety climate and safety leadership concepts. Two members of the research team graded the open-ended questions, and the total points for each question was based on the average of their scores. There was a total possible score of 14 points. See Appendix 5.I for a list of all safety climate knowledge questions.

In my *fifth study*, supervisors and crewmembers were asked the same questions as in studies three and four. Additionally, supervisors were asked workshop reaction questions to gauge their reaction to the workshop's content and delivery (7 items). Supervisors were also asked questions related to training transfer behaviors (5 items). Training transfer behaviors represented actions that they had undertook to transfer what they learned in the workshop to their job site (e.g., discussing workshop with supervisor), and were adapted from Al Eisa el al. (2009) and Machin et al. (2004). See Appendix 6.II for a list of all workshop reaction and training transfer behavior questions.

2.3. Statistical analyses

In my *second study*, the univariate relationship between age and claim cost was assessed via Pearson correlations, analysis of variance (ANOVA) and linear regression. The relationship between age, injury type, and claim cost was assessed via multivariate linear regression. SAS version 9.2 was used for all analyses.

In my *third and fifth studies*, Mplus version 7.0 (L. K. Muthen & Muthen, 2012) was used to analyze the variables within a latent variable framework. This means that each of the variables (e.g., top management safety commitment) were "latent" or "unobservable," and had to be measured with multiple questions (i.e., "observable variables"). The pattern with which each question loaded onto its hypothesized latent variable represented its measurement structure, and provided the evidence needed to average multiple questions to get a variable score. When there are multiple latent variables being assessed, this type of analysis can help to provide construct validity to a questionnaire by providing convergent and discriminate validity evidence. Furthermore, unlike ordinary least squares methods like multiple regression, this type of analysis allows for measurement error (Brown, 2011).

In my *third study*, the factor structure (i.e., measurement model) of all study variables was tested via confirmatory factor analysis (CFA). A CFA is used to confirm a hypothesized latent structure of all questions. Once adequate model fit of the measurement model was obtained via CFA, relationships between variables were determined via structural equation modeling (SEM). SEM is a multi-equation method that can test the relationship between multiple independent and dependent variables while accounting for the latent structure of the variables. All analyses were completed in Mplus version 7.0 (L. K. Muthen & Muthen, 2012).

In my *fourth study*, Mplus version 7.0 (L. K. Muthen & Muthen, 2012) was used to analyze the study variables via path analysis. A SEM procedure would have been preferred, but a sample size restriction hindered the model identification (i.e., too small of a sample size for the number of parameters needed to be estimated). Thus, the measurement model could not be included in this analysis. Instead, all variables represented mean variable scores generated in SPSS version 21. Justification for averaging questions was made by calculating the internal consistency reliabilities (Chronbach's alpha) of all study variables. A high Chronbach's alpha (> 0.70) indicates good variable reliability, which means that all of the questions hypothesized to measure the same variable produced similar scores.

In my *fifth study,* a latent growth modeling (LGM) approach was used to determine within and between individual changes over time on all study variables. Furthermore, differences between intervention groups (workshop plus progress checks versus workshop only) were assessed in the models. Like in my *fourth study*, mean variable scores were used for all LGMs, and thus it could not account for measurement model of the variables. LGM is similar to a multi-level model of change; however, the intercept and slope are treated as latent variables and scores on the variables at each wave of data collection are treated as the observed variables.

In my *third and fifth studies*, various model fit indices were used to determine how well the hypothesized model of variable relationships fit the data. These fit indices included: chi-square model test statistic, RMSEA, CFI, TLI, SRMR, and Akaike AIC. A low RMSEA and SRMR (< 0.08), and a high CFI and TIL (> 0.95) are indicative of a good fitting model. A chi-square test statistic indicates a good fitting hypothesized model when the statistic value is low, $p > 0.05$ and/or the ratio of the chi-square test statistic over the degrees of freedom is < 2.0. When comparing nested models (e.g., adding or removing paths between variables) to find the best model fit, the chi-square difference test was used. A failure to reject the chi-square test indicates that the more restrictive (null) model with fewer paths estimated is favored more than the less restrictive model (alternative) with more paths estimated (Kline, 2011). When comparing non-nested models (e.g., adding and removing variables), Akaike AIC values were compared. Lower AIC values were favored.

Chapter 3

Results

The results of all five studies will be presented separately since they represent five separate original studies. See Table 3 for the main findings of each of the five studies.

Table 3. Summary of results for all 5 dissertation studies

Study	Main findings
1 – "Literature Review"	• Of the 22 identified articles most focused on musculoskeletal disorders, and the severity of older workers injuries compared to younger workers.
	• Many studies were limited to the study of one trade or one specific injury type.
2 – "WC data analysis"	• WC claims cost an average of $8,432 (SD = $37,637) per claim.
	• The average cost of a claim increased significantly with increasing claimant age.
	• Older claimants had significantly more costs associated with lost work time, disability/impairment, and death than younger claimants.
3 – "Co-worker response to safety"	• Safety climate can be measured by asking workers about their perceptions of the safety response of top management, supervisors, *and co-workers*.
	• Co-worker's safety response mediated the relationship between both top management and supervisor safety response and safety behaviors.
4 – "Safety climate knowledge"	• Among supervisors, knowledge of safety climate did not mediate the relationship between safety climate perceptions and safety behaviors (safety compliance and safety participation).
	• However, supervisor's safety climate perceptions were significantly associated with both types of safety behaviors.
5 – "Supervisor intervention"	• The interventions' workshop was implemented with great fidelity, but there was poor participation in the progress checks after the workshop.
	• Regardless of the type of intervention the workers participated in (workshop plus progress checks or workshops alone), supervisor safety climate knowledge increased significantly as did their personal safety participation behaviors.
	• Despite not being directly involved in the intervention, crewmembers also significantly increased their safety participation behaviors post intervention.

3.1. Results: Study 1

Articles were identified by a PubMed database search and via the author's prior knowledge of their existence or were listed in the reference section of the previously identified articles found in the database search. Six of the 22 articles were based on studies outside of the United States. See Table 4 in Part II Chapter 3 for highlights of the most relevant findings.

Of the 22 articles, the most common study focus was on musculoskeletal disorders. Other less commonly discussed injury characteristics included falls, slips, and trips, fractures, and illnesses (e.g., hearing loss). The articles also discussed increased costs associated with medical issues, lost work time, and disability among older construction workers, compared to younger construction workers.

While the researcher's articles suggest that older construction workers do have a different injury and illness experience than younger workers, the results, however, were limited to specific injury types and construction populations (e.g., union carpenters). Furthermore, Crawford et al. (2010) noted that there is a serious gap in the literature regarding interventions for older workers. Some researchers suggest utilizing ergonomic principles to fit the job to the worker (Choi, 2009).

3.2. Results: Study 2

I found that, generally, as the age of the claimant increased, so did the cost of the WC claim. However, few of the claims represented older workers (see Figure 1). Workers over the age of 45 filed approximately 20% of the claims. The total cost of all claims was $931,234,994, and the average cost of a claim was $8,432 (SD = $37,637). An equal amount was spent on medical costs and indemnity costs (approximately $400 million each). However, only a fraction of the claims (23%) had both medical and indemnity costs. Older workers over the age of 65 filed more of the medical plus indemnity claims than workers aged 18-24 ($\chi^2 = 91.68$, $p < 0.0001$).

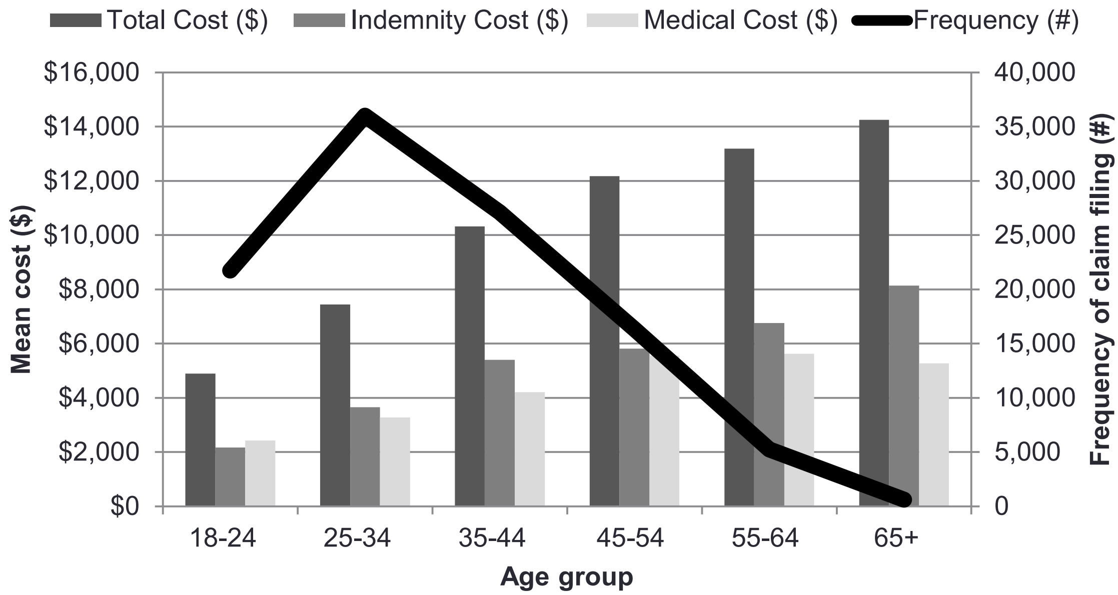

Figure 1. Frequency and mean cost of WC claim by age group

Medical costs were greatest amongst workers aged 35-44, 45-54, 55-64, and 65+ years, but indemnity costs were greatest amongst workers aged 45-54, 55-64, and 65+ (see Table 8 in Part III, Chapter 3). My linear regression analyses also indicated that claim cost increased with age. There was a 3.51% increase in the indemnity cost of a claim with each year increase in age, and a 1.11% increase in the medical cost of a claim (see Table 9 in Part III, Chapter 3). This supports hypothesis 2.1. by demonstrating that claimant age has a greater effect on indemnity costs than medical costs.

The most common injuries among all claims were strains, contusions, and lacerations (65% of all claims). The mean total cost of a claim was greatest among strain types of injuries (M = $10,917, SD = $30,795). My simple linear regression analyses with type of injury predicting indemnity claim cost revealed that strains were more costly than the other types of injuries. Contusions were 46% less costly than strains, and lacerations were 53% less costly than strains. The average indemnity cost of a strain injury increased with increasing age group. When the age of the claimant was added to the linear regression model predicting indemnity cost, the indemnity cost of strains and contusions both increased with increasing age group (see Table 10 in Part III, Chapter 3). For example, the indemnity cost of a strain injury among workers over the age of 65 was 261% greater than the cost of a strain injury among workers aged 18-24. The indemnity cost of laceration injuries, however, was relatively similar among all age groups. In all regression models, only a small percent of the variance was explained by the age of the claimant (< 2.0%). This supports hypothesis 2.2. by demonstrating that the claim cost of various injuries depends on the age of the claimant.

3.3. Results: Study 3

The first step in this study was to test the relationship between the safety climate questions asked in the survey (34 questions), and how each of them related to their hypothesized safety climate latent factors (see Appendix 4.I for a description of the factors). This was accomplished by running a series of CFAs. First, the hypothesized relationships between the questions and the latent factors were estimated, but the resulting model fit was poor. To improve the fit of the model, questions that performed poorly (low or insignificant factor loadings) were removed (5 questions), a correlated error term between two questions with similar wording was added, and one question was allowed to load onto two factors (i.e., supervisor safety commitment and supervisor safety empowerment). After doing this, model fit improved. This means that the questions were adequately represented by the hypothesized safety climate and safety behavior latent variables. Furthermore, each identified variable was significantly correlated with each other, but distinct enough from each other to warrant investigations into how they may affect each other. See Appendix 4.II for all question factor loading estimates, standard errors and significance levels as well as all factor reliability estimates. Note that only questions identified by the CFA as significant were utilized in all subsequent analyses involving these variables (i.e., in studies four and five). This analysis provided the necessary justification to move onto an analysis that tested the relationship between the variables.

First, the hypothesized relationships in were estimated via SEM (see **Figure 2** in Part IV). Namely, all three safety climate variables (top management, supervisor, and co-worker) were estimated to directly influence both types of safety behaviors (safety compliance and safety participation) (see Figure 2 in Part IV, Chapter 1). These hypothesized direct relationships fit the data well, but alternative models were estimated to determine if mediation was at play. Ultimately, a partial mediation model fit the data best (see Figure 4 in Part IV, Chapter 3). My mediation model suggests that perceptions of top management and supervisor's response to safety influence safety compliance and safety participation behaviors *through* perceptions of co-worker's response to safety. In other words, construction workers must perceive that their co-workers value safety in order for both levels of management to influence safety behaviors on the job. These findings partially support hypothesis 3.1., because top management and supervisor safety climate did not have a direct relationship with both types of safety behaviors. They fully support hypothesis 3.2. by demonstrating that there were indirect relationships between the study variables.

3.4. Results: Study 4

The relationship between supervisor safety climate perceptions, safety climate knowledge, and both types of safety behaviors was assessed via path analysis (see Figure 5 in Part V, Chapter 1). The reliabilities of each variable was calculated and found to be of adequate significance ($\alpha < 0.70$). Thus, all questions hypothesized to measure each variable were averaged, and the average scores for each variable were analyzed in the path analysis.

My results indicated that safety climate knowledge was not related to any of the other study variables. The direct paths to and from safety climate knowledge were non-significant, and the indirect paths from safety climate to safety compliance and safety participation were also non-significant. However, safety climate had a significant direct relationship with safety compliance and a marginally significant direct relationship with safety participation. These results partially support hypothesis 4.1., but fail to support hypothesis 4.2. See

Figure 6 in Part V, Chapter 3 for the results of the path analysis.

3.5. Results: Study 5

A process evaluation of the intervention's implementation demonstrated that the intervention reached the majority of the supervisors in each participating company, and that the majority of the supervisors continued to work for their respective contractor at 3 and 6 months follow-up. However, the intervention components (i.e., workshop and progress checks) had differing implementation fidelity. Namely, all workshops occurred as planned and with the majority of each contractor's supervisors, but the progress checks did not occur at both scheduled time points for all supervisors in the workshop plus progress check intervention group.

Many supervisors found the workshop content and design relevant to their job, sufficiently challenging, engaging, and many would recommend the training to others in their industry. At 3 and 6 months post intervention, the majority of the supervisors indicated that they were discussing the training with their supervisor and co-workers, using what they learned on the job, found it to be useful, and felt that it helped to improve their job performance.

My outcome evaluation of the intervention via LGM showed that there were similar results among supervisors and their crewmembers. Supervisors' and crewmembers' surveys at each wave of data collection were matched via a unique identifier written on top of the survey. This resulted in a total of 608 unique construction crewmembers (i.e., pre-apprentices, apprentices, and journeymen) and 107 unique construction supervisors (i.e., foremen, superintendents, project managers, project engineers). Since the number of waves of data available for the LGM varied based on position (i.e., crewmember or supervisor) and the variable studied, multiple separate LGMs were run. Supervisors' safety climate knowledge significantly increased from baseline to follow-up, but the largest gain in knowledge was immediately after the workshop (see Table 16 in Part VI, Chapter 3). Supervisors' safety participation behaviors increased from baseline to follow-up (see Table 16 in Part VI, Chapter

3), as did the safety participation behaviors of their crewmembers (see Table 17 in Part VI, Chapter 3). However, both supervisors and crewmembers' safety climate perceptions and safety compliance behaviors did not significantly change overtime. Thus, partial support was found for hypothesis 5.1. The addition of the intervention group covariate into each LGM model did not improve the fit of the model, which fails to support hypothesis 5.2. Thus, supervisors who participated in an intervention with a workshop and progress checks experienced the same outcomes as supervisors who participated in the workshop alone. The same result was found for their crewmembers too.

Chapter 4

Discussion

The purpose of my dissertation was to highlight five original research activities that sought to characterize and enhance the health and safety of construction workers. My dissertation began with an investigation of a vulnerable sub-population of construction workers, the aging workforce. It ended with an investigation of safety climate measurement and enhancement methods, which can influence the OHS of all construction workers. The sequence of research activities highlights my particular interest in OHS measurement methods, as well as an interest in translating this research into practical methods for industry stakeholders to use. The combined results from each of my studies suggest two things. First, the hazards of the construction industry result in a significant amount of costs, direct and indirect, regardless of worker age. Second, it is important for all members of a construction organization (top management, supervisors, and crewmembers) to consistently value and prioritize safety. When this becomes rote, contractors may have a workforce that carries out their daily work in a safe manner. My dissertation findings suggest that focusing on safety climate as an indicator of OHS may improve the OHS of construction job sites. However, future research should test the predictive validity of safety climate and safety behavior measures and the supervisor intervention in study five against lagging outcomes like WC data.

Successful management of OHS depends on the ability to accurately measure OHS trends. As the saying goes, “What gets measured gets managed.” Hale (2009) notes that safety performance measures are used for three reasons: 1) Monitoring how safe a work environment is, 2) If the work environment is unsafe, making decisions on when and where to act, and 3) Motivating decision makers to take action. My second study showed that WC data could be a good source of motivation for industry stakeholders to take action. Yet, I could not use the WC data to identify when and where to act, because it only spoke to injuries and their costs. Injuries could come from a multitude of sources and root causes (Haslam et al., 2005). My findings in studies three, four, and five demonstrate that safety climate measures may be valid representations of how individuals in a company respond to safety policies and procedures. Furthermore, my studies indicate that safety climate is associated with worker's safety behaviors on the job. Thus, safety climate measures may be used to account for not only what value or priority individuals at all company levels place on safety, but also how well safety policies and procedures are being used in practice. Such efforts are representative of leading measures of OHS, and can help companies monitor work environments and act to improve OHS before injuries occur and a WC claim is filed.

The usefulness as well as limits of lagging indicators of OHS was demonstrated in my first and second studies. In my first study, all of the reviewed articles used a variety of lagging measures of OHS trends among aging construction workers. The researchers used national datasets such as OSHA logs, and self-report surveys to gauge musculoskeletal pain. I expanded this research by examining a large database of WC claims to determine the impact of age on injury and their associated costs. Unfortunately, in both my first and second study, I could not investigate how the quantity and quality of OHS policies, procedures, and practices affected the OHS experience of younger and older construction workers. However, my results in study two do an especially good job of showing the monetary cost of construction OHS hazards. When a construction worker filed a claim for an injury or illness, their claim cost just over $8,000 on average, and about half of that cost came from the lost work wages, disability or impairment compensation, or death benefits. This estimate is likely an understatement for a number of reasons. A significant amount of underreporting is prevalent in these lagging measures, and not all construction workers are covered by WC insurance (Boden, 2013; Leigh, Marcin, & Miller, 2004). Also, it cannot account for other costs like productivity loss, quality of life, and household productivity loss (e.g. Lipscomb, Dement, & Behlman, 2003; Waehrer, Dong, Miller, Men, & Haile, 2007). Thus, the cost of injuries and illnesses is likely to be significantly greater than estimated. While the use of lagging measures has its limits, it does provide some preliminary justification needed to focus attention on OHS hazards.

In my third, fourth, and fifth studies, I found support for prior research that demonstrates a leading measure of OHS, safety climate, is positively associated with another leading measure, worker's safety related behaviors on the job (Christian et al., 2009). I measured safety climate by asking workers questions about "who" performs what safety actions (top management, supervisors, and co-workers) rather than "what" safety actions (e.g., safety training) are performed. This method of safety climate measurement is similar to Zohar's (Zohar, 2000; Zohar & Luria, 2005) typical safety climate measure that discusses top management and supervisors, and Melia et al. (2008) and Brondino et al.'s (2012) extension of Zohar's model to include perceptions of co-workers as well. The combined evidence suggests that the more workers feel like these individuals value safety, the more likely workers are to behave safely. Furthermore, my third study indicates that in order for perceptions of both levels of management commitment to safety to influence worker's safety behaviors, it may be important for workers to perceive that their co-workers value safety. Practically speaking, a commitment to safety should be built among individuals at all company levels. This could be done during safety meetings or toolbox talks. However, causal claims between perceptions of co-workers and safety outcomes cannot be made based on the results of this study and Melia et al. (2008) and Brondino et al.'s (2012) studies. Only Zohar (2005) measured safety behaviors after measuring safety climate perceptions of top management and supervisors.

Given the relationship between workers' safety climate perceptions and worker safety behaviors, I investigated OHS enhancement methods that leveraged safety climate research in studies four and five. In both studies I postulated that if supervisors understand safety climate concepts, they would be more likely to perform more safety behaviors themselves. Furthermore, via principles of safety climate and safety leadership, this effect would be translated into positive outcomes (safety climate and safety behaviors) for crewmembers as well

(Mullen & Kelloway, 2011; Zohar & Luria, 2010). I found some mixed results to these questions in studies four and five. Study four, a cross sectional study of supervisors only, I found that supervisor safety climate knowledge was not related to supervisor safety behaviors. However, after supervisors participated in a workshop focused on safety climate concepts in my fifth study, their safety climate knowledge and safety behaviors improved.

The disparity in findings between studies four and five may be due to the validity of the safety climate knowledge measure. Prior research links knowledge to behavior (Borman, Illgen, & Klimoski, 2003; Christian et al., 2009; Neal et al., 2000). Thus, findings in study four might be due to the validity of the safety climate knowledge measure rather than a null relationship between safety climate knowledge and safety behaviors. This notion is strengthened by my findings in study five, which demonstrates that safety participation behaviors significantly increased post-workshop. Interestingly, safety climate knowledge in study five also increased. The increase in knowledge could not have been due to grader bias, because graders were blinded to when the questions were answered. Potentially, supervisors may have remembered seeing the questions previously, and after having had time to think about it they changed their answer. Unfortunately, studies four and five cannot be directly compared, because in study five I did not investigate whether or not the increase in safety climate knowledge immediately post intervention predicted safety participation behaviors at follow-up.

Beyond influencing worker safety behaviors, I also postulated in study five that supervisors who participate in the intervention would be more equipped to influence crewmember safety climate perceptions. Contrary to this hypothesis, I did not find any significant changes in safety climate perceptions. My findings are similar to the only previous leader focused OHS intervention in the construction industry that measured safety climate (Kines et al., 2010). While Kines et al.'s (2010) study had a different focus, safety-specific communication only, neither my fifth study nor their study significantly changed safety climate perceptions related to supervisors. My findings in this dissertation may have been due to high baseline safety climate perceptions. Also, Kines et al. (2010) noted that the lack of change may be indicative of the time needed to change safety climate perceptions. Since safety climate perceptions develop overtime as supervisors demonstrate their value of safety to their workers, it may be that the short term positive changes in safety participation behaviors observed in my fifth study may lead to more positive safety climate perceptions down the line. Such questions could have been answered if I had measured safety climate at more time intervals post intervention (e.g., 1 year post intervention).

Although not reported on in my dissertation, the age of the construction worker was significantly, but poorly correlated with some of safety climate and safety behaviors variables. Pearson correlations between these variables were calculated within each wave of data collected in my fifth study (i.e., baseline 1, baseline 2, 3-month follow-up, and 6-month follow-up). The relationships between the age of the worker and safety climate and safety behaviors were inconsistent between data collection waves. Age had a significant positive correlation with perceptions of co-worker safety climate in only three of the four waves, but an insignificant correlation with both top management and supervisor safety climate at all waves of data collection. Only a small amount of safety climate research in the construction industry has studied these relationships, and those that have found a significant positive relationship between age and safety climate perceptions in Asian construction samples (Fang, Chen, & Wong, 2006; Siu, Phillips, & Leung, 2003). Within the safety climate construction industry literature, it is more common to focus on variables related to an organization (e.g., leadership style of supervisor) rather than demographic or personal factors. Cooper et al. (2004) notes that differences in safety climate perceptions by work departments, work activity or other situational conditions is more important than personal variables. Indeed Cooper et al. (2004) notes that,

> Safety climate measures…try to capture people's perceptions about how safety is operationalized in their organization…[not] how the prevailing safety climate affects them as individuals who have longer work experience, as older or younger workers, or as accident or non-accident victims (pg., 508).

The only consistent relationship observed between all waves of data in my fifth study was a small positive correlation between age and safety participation behaviors (r = 0.10 - 0.27, $p < 0.05$). This finding is interesting, because safety participation behaviors are contextual aspects of safety performance. They represent efforts to go above and beyond what's required in one's job description (e.g., wear safety glasses at all times) to actively promote the safety program. This may reflect older construction worker's experiences on the job (e.g., witnessing prior injury and death as a result of poor safety practices). It may also reflect the leadership roles that many older construction workers are in. They may feel responsible for their crewmembers, and may put in extra effort to ensure their safety.

Though my first two dissertation studies addressed a need to specifically focus on the aging workforce, I transitioned towards more proactive OHS concepts. This was because the frequency and the cost of the WC claims were high regardless of claimant age. Furthermore, only a very small percent of the variance was explained by age in the cost regression models (< 2%) in study two. Thus, there are many other factors besides age that influence WC costs. Many of which may include organizational factors, like safety climate, return to work practices, and ergonomics practices. Thus, I sought to investigate safety climate perceptions as a means to measure and manage OHS. My results suggest that all construction workers could benefit from working with individuals that value safety. Furthermore, supervisors who learn about safety climate concepts may be able to create an environment where workers are voluntarily engaging in, promoting and putting in extra effort for safety. This could be especially useful in terms of any OHS effort that a company undertakes, because it could create valuable employee participation needed to make the effort successful. The ultimate test will be whether or not these leading indicators and the supervisor intervention can translate into a reduction in injuries, illness, and their associated costs.

4.1. Dissertation strengths and limitations

My dissertation has a number of strengths. First, my first study was the only paper at the time of its writing to comprehensively review all prior research pertaining to the construction industry's aging workforce. Second, in my second study I was able to analyze a large database of WC claims that was representative of approximately 80% of Colorado construction policyholders. My third, fourth, and fifth studies represented novel approaches to safety climate measurement and intervention efforts. In my fifth study I utilized participatory action research to develop and implement the study's intervention. Such efforts helped to ensure the intervention's content was understandable and applicable to construction supervisors. The majority of supervisors (> 90%) who worked for all three participating contractors attended the workshops. Lastly, the results of my fifth study were based on a pre-post, quasi control group design that evaluated all study outcomes within a LGM framework.

My dissertation findings, however, may not be generalizable to other construction populations. In my second study, the WC claims were only representative of Colorado construction workers. In my third, fourth, and fifth studies, the participants came from three unionized medium-sized mechanical contractors (e.g., plumbing and sheet metal work) in the US Pacific Northwest. My study findings have yet to be tested among different construction environments such as different trades, non-union workers, small contractors, and other geographical regions.

Other limitations include study design, non-randomization, and an inability to account for the nested nature of the data. In my second study, denominator data were not available, and so claim-filing rates by age group could not be calculated. My second, third, and fourth studies were cross-sectional in nature, and thus causal claims cannot be made with their findings. In study five, I measured outcomes on multiple occasions before and after the intervention, thus some degree of causal implications can be made. However, the contractors were not randomly chosen to participate and randomly assigned to the two intervention groups. None of my studies were designed to evaluate either lagging or leading indicators simultaneously. Thus, associations between WC and safety climate, for example, could not be made. All variables within each of my studies came from the same sources, and thus common method bias may have influenced the results. Finally, none of my studies were able to account for the multi-level nature of the construction industry.

4.2. Recommendations for future research

An apparent limitation of my dissertation was the inability to measure both lagging and leading measures of OHS performance simultaneously. Future research should investigate the correspondence between the safety climate measure in this study, safety behaviors, and other lagging outcomes (e.g., WC data). This would strengthen the evidence for using leading indicators as measures of OHS surveillance and prevention efforts (Amick et al., 2000; eg. Wurzelbacher & Jin, 2011). The intervention in my fifth study should also be tested to determine if it could influence other leading and lagging measures. For example, Amick et al. (2000) found that several organizational practices (i.e., people oriented culture, safety climate, ergonomic practices, and disability management) predicted return to work success 6 months after carpal tunnel surgery. Thus, the intervention may influence the use of and effectiveness of return to work programs. Given my second studies findings, this may be especially important for older workers who are injured on the job.

Future research should also investigate the relationships in my third, fourth, and fifth studies in a variety of construction settings. This includes different trades, non-union companies and job sites, sizes of contractors (i.e., number of employees), and among vulnerable populations such as Latino workers. Furthermore, future research should test the multi-level effect on the study outcomes, which can include work group, contractor, general contractor, job site, and union affiliation. Lingard et al. (2010), for example, found a correspondence between the general contractor's top management and supervisor safety climate and their sub-contractor's top management and supervisor safety climate in an Australian construction sample. It may be possible for a general contractor to utilize study five's intervention to improve not only their supervisor's safety leadership skills, but also the supervisor leadership skills of their sub-contractors. Given common practice of contractors working with other familiar contractors, this approach may have a significant impact on the OHS of construction job sites.

4.3. Conclusions

The purpose of my dissertation was to highlight novel research activities designed to characterize and enhance occupational health and safety (OHS) in the United States (US) construction industry. My dissertation accomplished this by addressing three specific aims. In my first, second, third, and fourth studies I addressed specific aim one by using lagging and leading indicators of OHS performance to characterize the OHS experience of construction workers. In my third, fourth, and fifth studies I addressed specific aim two by expanding the concept of safety climate, a leading indicator of OHS, and by developing and evaluating a supervisor intervention focused on safety climate concepts.

The combined results of my studies suggest that OHS should be evaluated in the construction industry with both lagging (WC data) and leading (safety climate and safety behaviors) indicators of safety performance. Furthermore, an intervention based on leading indicator concepts (safety climate principles) may influence other leading indicators (safety behaviors). Individually, these measures can be valuable measures of safety performance. Lagging measures such as workers' compensation data may be good sources of motivation for contractors to make decisions regarding safety. Leading measures such as safety climate and safety behaviors may also be useful, because they can identify hazards and their associated risks before they result in serious negative outcomes. Since I could not measure both types of measures simultaneously in my dissertation, it is important for future research to evaluate the predictive validity of this dissertation's leading measures of OHS. Additionally, if the intervention in my fifth study is found to influence lagging outcomes, the validity of the intervention will be strengthened and contractors may be more motivated to adopt the intervention.

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PART II

Aging workforce and injury in the construction industry

Chapter 1

Introduction

The relatively large birth cohort between 1946 and 1964 combined with the recent economic recession during the first decade of the 21st century have led to an increase in the proportion of older workers in the United States (US) workplace. For example, a reversal of the 20th century trend towards earlier retirement has been observed as a growing number of employees are planning for longer working careers (Shuford & Restrepo, 2005; Silverstein, 2008). As workers continue to delay retirement, understanding the health and safety needs of an older-aged workforce will become increasingly important in the near future.

Why is there a need to address injuries among older workers in the construction industry? First, construction is a physically demanding industry (Choi, 2009). Second, injuries and illnesses among construction workers are among the most costly across all industries (Waehrer, Dong, Miller, Haile, & Men, 2007). Third, construction workers experience increasing chronic health conditions over time, compared to white-collar workers (X. Dong, Wang, Daw, & Ringen, 2011). Lastly, workers from about age 50 and older have been considered to be at increased risk of injury, compared to younger workers. This hypothesis was based on the notion that reduced physical capabilities associated with older age in areas such as strength, balance, and processing speed would increase risk of injury (Maertens, Putter, Chen, Diehl, & Huang, In press). In fact, this is not the case. Analyses of workers' compensation claims data indicate that older workers typically have a lower frequency of workplace injuries, but higher injury-related costs, compared to younger workers (Shuford & Restrepo, 2005).

The goal of this review is to summarize the published epidemiologic literature that examined the cause and type of injuries and related costs with respect to age for the construction industry. Evaluating injury trends among older workers among the construction industry is a strategic goal for the following agencies: the National Institute of Occupational

Safety and Health (NIOSH), the NIOSH National Occupational Research Agenda (NORA) and the Center for Construction Research and Training (CPWR). There is a knowledge gap in the field of occupational injury especially in terms of characterizing the type and cause of construction worker injuries among older workers. These data are needed to design targeted interventions aimed at preventing work-related injuries among older construction workers in order to keep them employed, as well as to reduce injury costs (Kisner & Fosbroke, 1994; Schoenfisch, Lipscomb, Shishlov, & Myers, 2010).

Chapter 2

Methods

A PubMed search was conducted that included combinations of the following terms: older workers, construction, construction industry, injury, and age to identify original research articles published from 1998 through June 2011 among US populations. We did not include articles that were published prior to 1998, because there was a major shift that occurred in the early to mid 1990's that included the development of a national construction safety and health research agenda that makes studies conducted prior to this time less representative of the present-day construction industry environment (Howard, Stafford, Branche, T., & Froetschet, 2010). When construction, injury and age were searched together, one hundred and ninety-one papers were identified but only ten were used (Forde, Punnett, & Wegman, 2005; Jackson & Loomis, 2002; Janicak, 2008; H. Lipscomb, Leiming, & Dement, 2003; Lowery et al., 1998; Welch, Haile, Boden, & Hunting, 2008; Welch, Haile, Boden, & Hunting, 2010). When construction industry and older workers were searched together, twenty-two papers were identified and only eight were used (John M. Dement, Ringen, Welch, Bingham, & Quinn, 2009; Jackson & Loomis, 2002; Janicak, 2008; Shishlov, Schoenfisch, Myers, & Lipscomb, 2011). Articles were excluded if they did not pertain to the construction industry, older workers and included at least one of the following topics: injury cause, injury type or injury cost. Once the first author (NVS) completed the search, the second author (LMB) conducted the same search to ensure that no relevant papers were missed. We identified an additional nine relevant articles that were either seminal papers in the field based on the authors' knowledge, or were articles included in the reference list of one of the articles identified by the PubMed search (J. M. Dement, Ringen, Welch, Bingham, & Quinn, 2005; X. Dong et al., 2011; Friedman & Forst, 2009; G. LeMasters, Bhattacharya, Borton, & Mayfield, 2006; G. K. LeMasters et al., 1998; Schoenfisch et al., 2010; Waehrer et al., 2007), some of which were studies based outside of the US (Arndt et al., 2005; Colantonio, McVittie, Lewko, & Yin, 2009; de Zwart, Frings-Dresen, & van Duivenbooden, 1999; Hoonakker & van Duivenbooden, 2010; Kemmlert & Lundholm, 2001; Suarthana, Moons, Heederik, & Meijer, 2007).

Chapter 3

Results

3.1. An aging US workforce

The proportion of US workers who are 55 years and older will increase as the participation rate of workers 16 to 24 years of age declines within the next decade. The participation rate of US workers 55 years and older has increased from 31.3 percent in 1998 to 39.4 percent in 2008, and is estimated to reach 43.5 percent by 2018 (Toossi, 2009). According to analyses of data from the Health and Retirement Study, possible reasons for the increase in retirement age include decreases in Social Security benefits, diminishing value of private pension portfolios, and increasing health and longevity (Cahill, Giandrea, & Quinn, 2005).

Prior to the mid-1980’s there were incentives to retire early. Retirement was a planned phase of life in the early 1900’s that was encouraged by the government and private sectors. The Social Security Act of 1935 legislated a social insurance program that provided income for retired workers over the age of 65. Then in 1961, the retirement age requirement was lowered to 62 years. In addition, corporate pension plans designed to supplement Social Security benefits only needed to provide income until around age 70.2, the average life expectancy in 1961 (Ezzati, Friedman, Kulkarni, & Murray, 2008; Hedge, Borman, & Lammlein, 2006). As of 2008, the average life expectancy in the US has reached 78.4 years ("The world bank: World development indicators,"). Overall, the legislative and corporate climate until recently has encouraged retirement as early as 55 years of age (Wiatrowski, 2001).

Within the past few decades, a typical retirement age has become less defined. Legislative changes, such as the Age Discrimination in Employment Act of 1986 and the Pension Protection Act of 2006 have enabled workers to delay retirement without penalties. In addition, delaying retirement has in some cases become an economic necessity. Defined contribution retirement plans have become more popular than defined-benefit plans for some, while Social Security may be the only means of retirement for others (Weller, 2005). Thus, workers are encouraged to stay on the job longer in order to maximize retirement benefits (Toossi, 2009).

3.1.1. An aging workforce in the US construction industry

The US non-profit Center for Construction Research and Training (CPWR) reported a 70 percent increase in the number of paid construction workers from 1977 to 2002 (Center for Construction Research and Training, 2008). The number of jobs in the construction industry is expected to continue to grow by 19% from 2008 to 2018, compared to a projected 11% for all industries combined (U.S. Bureau of Labor Statistics, 2010). The growth of the construction industry is expected to be hindered in the future by a shortage of skilled workers (Goodrum, 1999). Thus, keeping skilled workers employed in the industry for as long as possible is a high priority in the US (Welch et al., 2010).

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

Chronic disease and functinal impairment cause serious limitations for construction workers as they age (G. LeMasters et al., 2006; Welch et al., 2008). Dong et al. (2011) analyized data from a 10-year follow-up study (1998-2008) of older construction workers and found a persistent disparity in health status between construction and white-collar workers as they age. For example, the risk was higher for older construction workers, compared to white-colar workers for back problems (OR=1.54, 95% CI=1.10, 2.14) and functional limitations, such as not being able to reach/extend arms up (OR=2.18, CI=1.40, 3.39) or to lift/carry ten or more pounds (OR=1.67, 95% CI=1.03, 2.72). The disparity reported for musculoskeletal diseases by Dong et al. (2011) is likey related to the physically demanding tasks required in the construction trades (Choi, 2009; Hoonakker & van Duivenbooden, 2010).

3.1.2. Susceptibility to injury among an aging workforce

Benjamin, et al. (2008) contend that older workers may not be able to reduce work hours or switch to less physically demanding work without risking the loss or reduction in pension and or health benefits. Thus, older workers may find themselves in a difficult financial situation when making a decision whether to remain in the workforce. If they continue working for financial reasons, they may be unable to perform the same tasks as well, or as safely as their younger counterparts.

The aging process involves many physical changes that can make construction work tasks more difficult for older workers. For example, physically demanding work may be difficult due to decreased cardiac output and reduced tolerance to physical activity (Fitzgerald, Tanaka, Tran, & Seals, 1997). Older workers are also susceptible to loosing muscle mass and subsequent decreases in 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 more susceptible to chronic inflammatory disorders, which are associated with arthritis and other conditions that can limit joint range of motion and function (Spector et al., 1997; Strandberg & Tilvis, 2000). Body composition and weight also tend to change with age in a way that predisposes workers to diabetes, hypertension, and reduced flexibility and mobility (Houston, Nicklas, & Zizza, 2009). Overall, the aging process can involve significant physical changes that challenge a worker's ability to perform physically demanding tasks, such as those in construction, without incurring injury.

3.2. Age-related injury in the construction industry

Due to the nature of the trade, most construction workers experience a physically demanding work environment on a daily basis. The industry is characterized by stressful environmental conditions (e.g., harsh weather) (Nguyen, Kneppers, Garcia de Soto, & Ibbs, 2010), long work hours (Haslam et al., 2005), irregular work periods (Forde & Buchholz, 2004; Goldenhar, Hecker, Moir, & Rosecrance, 2003), unpredictable workplaces and non-continuous employment (Ringen & Stafford, 1996). The physical demands of the job involve exposure to heavy lifting and materials handling, use of vibrating tools, awkward postures, prolonged static positions, and working while injured or in pain (Rosecrance, 2004). These demands can eventually result in injury, missed work, and disability (G. LeMasters et al., 2006; Merlino, Rosecrance, Anton, & Cook, 2003; Rosecrance, Cook, & Zimmerman, 1996). Additionally, most construction tasks involve a combination of multiple physical exposures further increasing the probability of injury and disability (Choi, 2009). Therefore, one method to reduce the burden of injury among construction workers is to identify susceptible populations, such as older workers, and characterize the their injuries in terms of cause, type and severity (i.e. cost) in order to appropriately focus on the best available prevention strategies.

In Table 4 the most relevant studies related to the cause, type and/or cost of injuries in the construction industry, with respect to age are shown. In summary, the findings from these studies indicate that injuries are less frequent but more severe among older construction workers, thus requiring older workers to take a longer to recover compared to injuries that occur among younger workers (Choi, 2009; Hoonakker & van Duivenbooden, 2010; 2010). These injury characteristics among older workers translate into higher compensation costs, due in part to longer lost work time and disability.

Table 4. Studies evaluating age and injuries among construction workers

Reference	Study design and population	Research objective	Main findings
(Kemmlert & Lundholm, 2001)	Cross-sectional analysis of Swedish Occupational Injury Information System data (N=1,620)	To report and discuss major factors contributing to slip, trip and fall accidents	• 26% of occupational accidents among workers aged 45 years and older were due to slips, trips and falls, compared to 17% of occupational accidents among workers aged 45 years and younger
(Shishlov et al., 2011)	Cross-sectional analysis of NEISS-work database of ER-treated injuries (N=555,700)	Provide national estimates of non-fatal construction industry injuries resulting from falls	• Injury rates were twice as high for workers <45 years than for workers ≥45 years • Workers >50 years had approximately equal frequencies of contusions/abrasion, sprain/strain, and fracture injuries whereas younger workers <29 years and 30-39 years had more contusions/abrasions and strains/sprains than fractures • 10% more injured workers <29 years were treated and released, compared to workers >50 years
(Schoenfisch et al., 2010)	Cross-sectional analysis of NEISS-work database ED-treated injuries (N=3,216,800)	• Identify injuries/illnesses • Estimate number and rate of injuries treated in ED's	• Workers 20-24 years old were injured at a rate of 720 per 100,000 FTE while workers 65+ years old were injured at a rate of 140 per 100,000 FTE • Workers 20-24 years old were treated and released from the ED 97% of the time but workers 65+ years old were released 89% of the time
(Hoonakker & van Duivenbooden, 2010)	Cross-sectional health survey among Dutch construction workers (N=174,090)[a]	Compare health and injury characteristics among workers by age group	• Workers >55 years old had fewer injuries (7%) compared to workers <20 years old (20.1%) • 34% of workers >55 years old and 11% workers <20 years old reported back and neck complaints • 47% of workers >55 years old and 13% of workers <20 years old reported upper extremity complaints • 44% of workers >55 years old and 15% of workers <20 years old reported lower extremity complaints • 25% of workers >55 years old and 7% of workers <20 years old reported that their health problems were work related • 45% of workers >55 years old and 60% of workers <20 years old reported being absent because of injury or illness

Table 4. Continued

Reference	Study design and population	Research objective	Main findings
(Welch et al., 2008)	Cross sectional study of roofers aged 45-59 (N=979)	Investigate the prevalence of medical and MSD conditions among working roofers and examine its relationship with age, physical functioning and work limitations	• 54% of workers reported at least one MSD conditions and 42% reported at least one medical condition. Lower back/sciatica was the most reported type of MSD condition • 50% of subjects with a reported MSD condition were estimated to be younger than 45 when the problem began • 31% reported missing work due to MSD condition two years prior to interview • The most common medical conditions were cancer (55%), heart problems (53%), diabetes (33%), burns (38%) and lower back/sciatica problems (35%) • Increased age was associated with reduced physical functioning, regardless of MSD or medical condition
(Colantonio et al., 2009)	Cross-sectional study of concussion/intracranial injury that resulted in days off work from the Ontario Workplace Safety and Insurance Board database (N=218)	Examine work-related traumatic brain injuries (TBI) and the associated demographic and injury-related factors	• Workers 25-34 years old experienced the most TBIs (27.5%) and workers 55-64 years old experience the least amount of TBIs (9.7%) • Workers 35-64 years old experienced TBIs by falls more often and workers 17-34 years old experienced TBIs by being struck by/against more often • Compared to all other construction trades, trade helpers/laborers experienced the most TBIs. Trade helpers/laborers aged 17-24 years old were especially susceptible to TBIs.
(Friedman & Forst, 2009)	Cross-sectional study of injuries in the construction industry using the Illinois Workers' Compensation Commission claims database (N=19,734)	Describe characteristics of injured construction workers filing claims	• Workers 16-24 incurred a mean cost of $17,558 whereas workers 55-64 years old incurred a mean cost of $53,125; compensation decreased among workers >65 years old where mean costs were $31,618 • A $520 increase in total cost for every 10 year increase in age was observed
(Suarthana et al., 2007)	Cross-sectional study of Dutch natural stone and construction workers with potentially high quartz dust exposure (N=1,291)	To develop a simple diagnostic model to estimate the probability of individual workers having pneumoconiosis	• Workers aged >40 years were at 3.3 times the risk of pneumoconiosis, compared to workers ≤40 years of age

Table 4. Continued

Reference	Study design and population	Research objective	Main findings
(Waehrer et al., 2007)	Cross-sectional study of fatal and non-fatal injuries in the US construction industry using self-reported data from the BLS survey and the National Census database of fatal occupational injuries	Determine the costs of injuries and illnesses in the construction industry	• Workers 25-44 years old were injured the most frequently and incurred the greatest amount of costs • Frequency and cost of injury declined with age after 44 years old except for medical costs. Workers ≥65 years old incurred a mean of $5,831 and workers ≤24 years old incurred a mean of $2,903 medical costs
(G. LeMasters et al., 2006)	Cross-sectional analysis of self-reported health data among retired union construction workers and retirees from non-construction unions (e.g., Communication Workers of America and American Federation of Teachers) (N=780)	Determine if retired construction workers have poor self-reported quality of life and higher levels of self-reported physical functioning than more sedentary occupations.	• 42% of construction workers reported poor health • Male construction workers were five times more likely to report poor health, compared to non-construction workers • 19% construction workers reporting being in severe pain vs. 3% of non-construction workers
(H. Lipscomb et al., 2003)	Cross-sectional study of injuries among carpenters using Washington state workers' compensation claims data (N=16,215)	Describe the leading cause of morbidity and mortality due to falls	• Compared to workers ≥45 years old, workers <30 years old were less likely to fall on the same level (RR=0.73, CI=0.58, 0.93) • Compared to workers ≥45 years old, workers <30 years old were less likely to have a fall from the same level that resulted in paid lost time (RR=0.48, CI=0.32, 0.72) • Workers 45-54 years old claims due to falls from a same level cost a mean of $21,621 whereas workers <30 years old cost a mean of $4,638. Mean cost for workers >55 years old declined to a mean of $15,468 • Workers >55 years old had a mean cost of $21,071 for a fall from elevation where as workers <30 years old had a mean cost of $9,034 for a fall from elevation

Table 4. Continued

Reference	Study design and population	Research objective	• Main findings
(de Zwart et al., 1999)	Cross-sectional study of self-reported health of Dutch construction workers (N=44,486)	Identify age-related work and health issues that can be included in a questionnaire of older construction workers health	• Compared to younger workers (16-30 years), older workers (45-64 years) experienced more complaints about their neck (PR=3.44, CI=2.77, 4.28), upper extremities (PR=2.56, CI=2.23-2.94), back (PR=1.75, CI=1.57, 1.96) and lower extremities (PR=1.73, CI=1.53, 1.96)
(G. K. LeMasters et al., 1998)	Cross-sectional study of self-reported health among union carpenters in Ohio (N=522)	Determine prevalence and risk factors for work related MSDs	• Age and job duration were strongly correlated • Age was a statistically significant predictor of MSD's shoulders, hands and wrists when age was substituted for job duration in the multivariable model • When job duration was added to the model, the association with age was attenuated and lost statistical significance
(Lowery et al., 1998)	Cross-sectional study of injury at a DIA construction site using workers compensation claims data (N=4,634)	Determine the risk factors for injury	• The rate of injury (20.5 per 100 workers) among older workers (>60 years) was higher than younger workers (15-19 years) rate of injury (6.6 per 100 workers) • The rate of lost work time injury (3.8 per 100 workers) among older workers (>60 years) was higher than younger workers (15-19) rate of injury (0.9 per 100 workers)
(John M. Dement et al., 2009)	Prospective cohort study of building trade workers from nuclear weapons facilities followed from 1998-2004 (N=8,976)	Investigate the mortality among construction and trade workers who work at nuclear weapons facilities who may be exposed to serious hazards.	As a function of length of employment in construction trades, there was an increase in risk of mesothelioma and asbestosis • Workers who started work when <30 years of age had an increased risk for mesothelioma (SMR=6.59) and asbestosis (SMR=53.35)

Table 4. Continued

Reference	Study design and population	Research objective	Main findings
(Arndt et al., 2005)	Prospective cohort study of male construction workers given medical exams at baseline and the subsequent recipients of disability pension at a 10 year follow-up (N=14,474)	Study the disability risk of construction workers	• Workers 60-64 years old experienced occupational disability at a rate of 8551 per 100,000 person years whereas workers 25-39 years old experienced a rate of 134 per 100,000 person years • Compared to other non-construction blue collar workers, workers 55-59 years old had a SIR of 2.42 (CI=1.79,3.21) for incidents that caused disability and a SIR of 1.61 (CI=1.47,1.75) for MSDs that caused disability • Compared to other non-construction blue collar workers, workers who had worked for ≥30 years had a SIR of 2.54 (CI=1.93,3.3) for incidents that caused disability and an SIR of 1.72 (CI=1.59,1.87) for MSDs that caused disability
(Welch et al., 2010)	Prospective cohort of roofers in the United States (N=979)	Describe the characteristics of roofers who left the trade within one year of a baseline interview and the subset who left due to a health condition	Characteristics of roofers who left the trade due to health reasons: • Older (OR=1.18, CI=1.09, 1.27) • Had lower physical functioning (OR=0.91, CI=0.88, 0.94) • More diagnosed MSD conditions (OR=7.92, CI=0.98, 64.29) • More diagnosed medical conditions (OR=6.83, CI=0.80, 58.09) • More MSD and medical conditions combined (OR=4.63, CI=0.55, 39.15) • More likely to have missed work in the 2 years prior to baseline (OR=1.97, CI=0.95, 4.10) • Moderate economic impact was most common among younger workers (OR=0.87, CI=0.80, 0.95), poor physical functioning (OR=0.93, CI=0.89, 0.97), any missed work (OR=2.8, CI=1.15, 6.81) and former roofers who left for health-related reasons (OR=19.04, CI=4.96, 73.06)

Table 4. Continued

Reference	Study design and population	Research objective	Main findings
(X. Dong et al., 2011)	10-year follow-up study (1998-2008) of male workers (N=7,200) that utilized the Health and Retirement Study	To examine the health status of older construction workers in the US and how occupation and the aging process affect health in workers' later years	• Construction trades vs. white-collar workers at follow-up had increases in: • Arthritis (OR=1.93, CI=1.39, 2.67) • Chronic lung disease (OR=1.93, CI=1.17, 3.20) • Stroke (OR=1.67, CI=1.14, 2.44) • Back problem (OR=1.54, CI=1.10, 2.14) • Fair/poor physical health (OR=1.74, CI=1.23, 2.46) • Fair/poor hearing (OR=1.74, CI=1.23, 2.46) • Functional limitations of reach/extended arms up (OR=2.18, CI=1.40, 2.39) and lift/carry 10lbs (OR=1.67, CI=1.03, 2.72) • Health problem limits work (OR=2.05, CI=1.47, 2.87) • Injury at work (OR=3.12, CI=1.10, 8.87) • Construction trades had an increased risk of stroke (OR=1.69, CI=1.13, 2.53) compared to other blue-collar workers at the time of follow-up At follow-up, the rate of full-time work among construction workers was greater than the rate of all workers combined but many of the construction workers had switched to non-construction industries
(Jackson & Loomis, 2002)	Cross-sectional study of North Carolina Medical Examiner records of construction work related deaths (N=535)	To describe fatal occupational injuries within the construction industry and to identify risk factors	• Crude death rate was highest among workers aged 65-74 and lowest among workers aged 18-24, 31.8 and 18.3 per 100,000 person years, respectively

Table 4. Continued

Reference	Study design and population	Research objective	Main findings
(Janicak, 2008)	Cross-sectional study of construction electrocution fatalities using the BLS Census of Fatal Occupational Injuries (N=492)	Identify differences in the proportion of fatalities by type of electrocution and to identify differences in proportions of fatalities by age of the worker	• Among workers over the age of 65, 56% electrocution fatalities were due to contact with electrical wiring, transformers or other electrical components and 22% were due to contact with overhead power lines • More than 50% of deaths among younger workers (ages 16-19, 20-24, 25-34) were due to contact with overhead power lines • Significantly greater proportions of deaths from electrocutions were observed among younger workers aged 16-19 (PMR=144.72, *M-H* X^2=4.74, p<.05), compared to older workers aged 64 years and older (PMR=75.69, *M-H* X^2=45.75, p<.5)
(J. M. Dement et al., 2005)	Cross-sectional study of Department of Energy (DOE) construction workers (N=3,510)	Determine hearing loss among older construction workers who are exposed to high-noise levels	• 92.7% of workers over the age of 65 had hearing loss • Compared to the control group (<80 dBA exposures), DOE workers with more than 33 years of trade work had a greater odds of material hearing impairment (OR=2.2, CI=1.5, 3.2)

Abbreviations: Bureau of Labor Statistics, BLS; confidence interval, CI; Denver International Airport, DIA; Department of Energy DOE; Emergency room, ER; Full time equivalents, FTE; Musculoskeletal disorder, MSD; National Electronic Injury Surveillance System, NEISS; Odds ratio, OR; Prevalence ratio, PR; Proportionate Mortality Ratios, PMR; Rate ratio, RR; Standardized incidence ratios, SIR; Standardized mortality ratios, SMR; Traumatic brain injury, TBI; United States, US.

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

3.2.1. Causes of injuries in the construction industry

Injuries due to falls are a major concern for the construction industry. Falls are the most common cause of fatal injury and are ranked among the top three most common causes of non-fatal injuries (e.g., Center for Construction Research and Training, 2008; J. M. Dement & Lipscomb, 1999; Friedman & Forst, 2009). However, the data regarding frequency of fall-related injuries among older workers are inconsistent.

Kemmlert and Lundholm (2001) reported that the proportions of slip, trip and fall incidents were greater among male workers aged 45 years and older, compared to workers less than 45 years of age. The study consisted of 1,620 reports of slip, trip and fall incidents from the Swedish Occupational Injury Information System and included construction work as well as electrical, agricultural, metal machine work, building metal work, and material handling work (Kemmlert & Lundholm, 2001). Coantonio, McVittie, and Lewko (2009) analyzed workers' compensation data from Ontario, Canada and found that 76% of the traumatic brain injury claims of construction workers aged 55-64 were from falls, compared to 45% of claims from workers aged 17-24. In contrast, Shishlov, et al. (2011) reported a two-fold decrease in the fall-injury rate among workers 55 years and older [45/10,000 full-time equivalents (FTE)], compared to workers less than 20 years of age (114/10,000 FTE). The study by Shishlov, et al. used data from the National Electronic Injury Surveillance System collected by NIOSH to obtain US hospital emergency department data for construction-related injuries (*N*=555,700). Possible reasons for the inconsistent results between the Kemmlert (2001), Colantonio (2009) and Shishlov (2011) studies may be due in part to differences in record keeping practices between the two countries, occupations included in the study, or that the focus was on severe injuries (e.g. those requiring an emergency department visit) in the US study, but not in the Swedish study.

Injuries due to falls are categorized in terms of fall location (e.g. same or different level) and contributing factor (e.g. ladder, scaffold, snow, grease). Falls from elevations have been cited as the most frequent types of falls in the construction industry as a whole. However, among older workers in the carpentry trade, falls from the same level have been found to be most frequent (H. Lipscomb et al., 2003). In a study using self-reported data from injured carpentry workers (*N*=4,429), the contributing factors to falls from the same level were found to be tripping over debris, difficult work terrain (rocky, muddy, uneven), the slope of the lot, lack of backfill around the foundation, and difficult access and/or egress from the building (H. J. Lipscomb, Dement, Li, Nolan, & Patterson, 2003). Studies involving construction-related falls treated in the emergency department indicated that older workers were more likely to be hospitalized due to falls, indicating a greater severity of injury among older workers (Layne & Pollack, 2004; Schoenfisch et al., 2010; Shishlov et al., 2011).

Motor vehicle incidents occur infrequently (Friedman & Forst, 2009; Glazner, Bondy, Lezotte, Lipscomb, & Guarini, 2005), but result in some of the most severe injuries among construction workers (Glazner et al., 2005; Schoenfisch et al., 2010) and are the second leading cause of occupationally related deaths in the construction industry (Center for Construction Research and Training, 2008). Using the National Traumatic Occupational Fatalities Surveillance System (1980-1992), Ore and Fosbroke (1997) found that the motor vehicle incident fatality rate for the construction industry was 2.4 per 100,000 workers across all ages but increased to 6.9 for workers over the age of 65. Possible contributing factors in motor vehicle incidents among older workers include age-related degradation in vision, reaction time, cognitive function, muscle strength, and range of motion (NIOSH, 2005; Pratt, 2003). The little knowledge we have on older construction worker's motor vehicle incidents is based on national sources of data. Such data cannot account for exposure (i.e. hours driving), thus caution should be used when interpreting findings from national data. There is a major gap in our knowledge of motor vehicle incidents among older construction workers and factors that affect their abilities to drive should be considered in the development of injury prevention strategies for workers in the construction industry.

3.2.2. Types of injuries in the construction industry

Musculoskeletal disorders (MSDs) are of particular concern for construction workers. Older workers experience a significant burden of musculoskeletal disorder conditions and continue to work with pain and limitations (Welch et al., 2008). de Zwart et al. (1999) utilized the Dutch Periodic Occupational Health Survey (1983-1993) to determine the prevalence of age-related health issues among older construction workers (45-64), compared to younger construction workers (16-30). They found an increased prevalence ratio of complaints related to the upper and lower extremities, back, and neck. Hoonakker and van Duivenbooden (2010) utilized the same survey for the years 1989-2003 and found similar results. LeMasters et al. (1998) found that the odds of having an MSD of the shoulders, hands/wrists, and knees among union carpenters were greatest among workers with more than 20 years of employment in the industry. Age did not remain a significant predictor in the final multivariate logistic regression model when job duration was added to the model. MSDs among older workers may predispose them to reoccurring injuries. Lipscomb, et al. (2008) found that carpenters who experienced a back injury were at an increased risk for a second back injury within three years of the initial injury. Musculoskeletal disorders may also put older workers at risk for retirement from the construction trades earlier than anticipated. Welch, et al. (2010) found that the odds of leaving the roofing trade early were eight times higher for workers with a musculoskeletal disorder than workers without a musculoskeletal disorder.

A minimal amount of research has evaluated other types of injuries besides musculoskeletal disorders among older construction workers. Fractures, contusions/abrasions and sprains/strains are the most common injury among construction workers over 40 years of age, while contusions/abrasions and sprains/strains are the most common among workers under 29 years of age (Shishlov et al., 2011). Occupational illnesses such as pneumoconiosis (Suarthana et al., 2007), mesothelioma, asbestosis (John M. Dement et al., 2009) and hearing loss (J. M. Dement et al., 2005) are primarily seen among older construction workers, likely due to the well-recognized latency between first exposure and disease onset.

3.2.3. Injury-related costs in the construction industry

Given the precarious and physically challenging work conditions in the construction industry, coupled with the increasing average age of the workforce, it seems inevitable that the cost of occupational injuries among construction workers will also increase. While construction workers represent only six percent of the US workforce, they account for a disproportionate 15 percent of costs related to injuries and fatalities for all US industries (Waehrer et al., 2007). Vulnerable populations, such as older workers, contribute to much of these costs. In general, workers' compensation claim costs increase with the age of workers (Friedman & Forst, 2009). For example, Lipscomb, et al. (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. Data from Lowery et al. (1998) indicated that lost work time and related indemnity costs, increased with age. Schoenfisch et al. (2010) determined that, although injury rates among older construction workers were lower than younger workers, the injuries among the more senior workers were more likely to cause more serious problems that required longer hospitalization stays, indicating a decreased ability to recover from an injury. Physical disability among older construction workers is a major concern because of its effect on overall productivity. The ability to fully recover from an injury becomes increasingly difficult with increasing age. Therefore, the proportion of disability is likely to be higher among older, compared to younger workers in the construction industry (Arndt et al., 2005; Welch et al., 2010). Relative to younger workers, older workers miss more days of work when injured (Kucera, Lipscomb, Silverstein, & Cameron, 2009; Schoenfisch et al., 2010).

Previous research has found that older construction workers are more likely to die from an occupational injury than younger construction workers. For example, CPWR utilized the Bureau of Labor Statistics (BLS) Census of Fatal Occupational Injuries (CFOI) and found that

44% occupationally related fatalities in 2005 occurred among construction workers over the age of 45 (Center for Construction Research and Training, 2008). Jackson et al. (2002) utilized the North Carolina Medical Examiner's database of occupational fatalities for the construction industry and found that the crude death rate was highest among workers aged 65-74 and lowest among workers aged 18-24, with rates of 31.8 and 18.3 per 100,000 person years, respectively. There may be differences in cause of death among different aged construction workers. Janicak (2008), for example, found that construction workers aged 16-19 (PMR=144.72, *M-H* χ^2=4.74, $p<0.05$) had a greater proportion of electrocution fatalities than expected and construction workers aged 65+ (PMR=75.69, *M-H* χ^2=45.75, $p<0.05$) had a lower than expected proportion of electrocution fatalities.

Chapter 4

Discussion

4.1. Promotion of work ability

The promotion of work ability can enable older construction workers to remain employed and injury free. The Finish work ability index (WAI) was developed in order to understand how long workers are able to work and whether job demands and job content affects their ability to continue work (Ilmarinen, 2009). Previous research has used the WAI to predict sickness absence (Alavinia, de Boer, van Duivenbooden, Frings-Dresen, & Burdorf, 2009) and disability among older workers (Burdorf, Frings-Dresen, van Duivenbooden, & Elders, 2005) in the construction industry. A work ability promotion program was developed and modeled around four different actions: 1) adjustments to the physical environment, 2) adjustments in the psycho-social environment, 3) health and lifestyle promotion and 4) updating professional skills (Ilmarien & Rantanen, 1999). Tuomi et al. (2001) utilized data from a 16 year follow-up study of Finish municipal workers and found that the model of work ability was strongly associated with the WAI. In addition, a high WAI score was associated with high quality work, high productivity, the ability to function well and to stay in good health upon retirement (Tuomi et al., 2001).

The work ability promotion program has not been studied within the construction industry specifically but the model could be a useful guide for future interventions. Welch (2009) reviewed literature pertaining to the WAI and construction work and recommended rehabilitation programs for injured workers, ergonomic programs to prevent musculoskeletal disorders, and comprehensive health promotion programs. In regards to ergonomic programs developed to reduce the risk of injury, contractors could integrate knowledge regarding workstation and task adaptations appropriate for older workers into their commonly held pre-task planning meetings on the construction site. Disseminating information that older workers may need to work at lower elevations, need more breaks during heavy physical work, or need more time to complete a task may enhance the safety at the job site. Employers may consider providing lighter materials to handle or manual material handling equipment and eliminate long or heavy reaches from ladders (Choi, 2009). Providing reasonable accommodations for all older workers may be difficult to achieve in physically demanding industries like construction. Thus, older construction workers may be placed in a difficult situation of having to weigh the costs and benefits of continuing to work in such a physically demanding profession. This may result in a feeling of "job lock" or the inability to leave a job due to financial or benefit needs, or working while ill (e.g. presenteeism) (Benjamin et al., 2008) if retirement is not financially feasible. Improving construction work ability for all ages and physical limitations will require a concerted effort from workers, contractors, unions, owners, policy makers, regulators and the occupational health and safety community to implement effective programs that can adapt to the unique challenges facing the construction industry (Ilmarinen, 2009; Welch, 2009).

4.2. Recommendations for future research

Though older workers may experience physical limitations, their ability to add value to an organization is a notable strength. A recent meta-analysis examined the relation between age and several job performance measures. The worker's age was not found to be related to core task performance or level of creativity, but it was related to increased safety performance and decreased counterproductive work behavior (Ng & Feldman, 2008). Employers who resist adapting work to older workers are susceptible to losing valuable workers and paying more in hiring and training costs (Yeatts, Folts, & Knapp, 1999). Given the dominant role that 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 and to minimize the risk of injury they face on the job (Ng & Feldman, 2008). For example, researchers have suggested using ergonomic principles to fit the job to the worker (Choi, 2009), wellness programs to keep older workers physically fit (Kowalski-Trakofler, Steiner, & Schwerha, 2005) and good housekeeping (Kemmlert & Lundholm, 2001).

Despite the increased awareness and epidemiologic research related to construction worker 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, needs to be studied in greater depth to determine specific interventions aimed at preventing age-related injuries and helping older workers remain employed (Kisner & Fosbroke, 1994; Schoenfisch et al., 2010). The data available on injury trends among older workers is limited in depth (Table 4). The available literature has focused primarily on injuries due to falls and injuries that result in musculoskeletal disorders, but the characteristics of other types of causes and types of injuries have not been reported in as much detail for older construction workers (Table 5). It is important to note that publication bias may contribute to the paucity of publications in this area. However, the larger issue is that there are too few studies that have been conducted that focus on older workers in the construction industry.

In addition to older workers, Hispanic construction workers are another vulnerable population have been found to be at increased risk of injury (X. S. Dong, Men, & Ringen, 2010) and death (X. Dong & Platner, 2004; X. S. Dong, Fujimoto, Ringen, & Men, 2009), compared to non-Hispanic construction workers. Hispanic construction workers are generally younger than non-Hispanic workers (Center for Construction Research and Training, 2008) but when older Hispanic workers are injured on the job they are more likely to die from the injury. For example, research using the BLS CFOI (1992-2000) has found that the fatality risk index among older (65+) Hispanic construction workers was greater than older non-Hispanic workers, 5.5 versus 2.7, respectively (X. Dong & Platner, 2004). While the topic of injury among Hispanic construction workers was beyond the scope of the present review, it is clearly a topic in need of further research.

Table 5. Injury and age studies of construction workers by injury cause, type, body part affected, and cost

Cause of injury and Type of Injury	Body part affected	Associated cost of injuries
Falls, slips and trips (Colantonio et al., 2009; H. Lipscomb et al., 2003)	Back (de Zwart et al., 1999; Hoonakker & van Duivenbooden, 2010)	Hospitalization days increased (Schoenfisch et al., 2010; Shishlov et al., 2011)
MSD (Arndt et al., 2005; de Zwart et al., 1999; Hoonakker & van Duivenbooden, 2010; G. LeMasters et al., 2006; G. K. LeMasters et al., 1998; Shishlov et al., 2011)	Neck (Hoonakker & van Duivenbooden, 2010)	Retirement (Welch et al., 2010)
Fractures (Shishlov et al., 2011)	Upper extremities (Hoonakker & van Duivenbooden, 2010)	Lost work days (Lowery et al., 1998)
Pneumoconiosis (Suarthana et al., 2007)	Lower extremities (Hoonakker & van Duivenbooden, 2010; G. LeMasters et al., 2006)	Disability (Arndt et al., 2005)
Mesothelioma (John M. Dement et al., 2009)		Increased monetary costs (H. Lipscomb et al., 2003; Waehrer et al., 2007)
Asbestosis (John M. Dement et al., 2009)		Functional Limitations (X. Dong et al., 2011; G. LeMasters et al., 2006)
Contusion/abrasion (Shishlov et al., 2011)		Death (Center for Construction Research and Training, 2008; Jackson & Loomis, 2002)
Hearing loss (J. M. Dement et al., 2005)		

Future research should utilize a combination of leading and lagging safety and health performance metrics to determine the relations 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, BLS's Survey of Occupational Injuries and Illnesses, or National Electronic Injury Surveillance System-Work). By tracking a combination of leading and lagging indicators, the relation between age, safety, and injury can be determined and the appropriate interventions can be developed.

Crawford, et al.'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 identification of specific injury trends and subsequent analytical research efforts designed to identify risk and protective factors among older construction workers can provide the necessary guidance needed to develop appropriate interventions aimed at maintaining their employment. The American College of Occupational and Environmental Medicine states that it is imperative that more attention and resources be devoted to protecting the employability of older workers to mitigate the impending consequences of the health care crisis brought on by chronic disease among the baby boomers (Special committee on health, 2009). A recommended priority for researchers is to make concerted efforts towards disseminating their research results and translating these results into workable recommendations that have the potential to reduce workplace injury among older workers in the construction industry.

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PART III

Age in relation to workers' compensation costs in the construction industry

Chapter 1

Introduction

The proportion of workers 55 years of age and older will grow to nearly a quarter of the United States (US) labor force by 2018, a 43% increase from 2008 (Toossi, 2009). As aging workers remain on the job longer, understanding the health and safety needs of an aging workforce will be critical. This will be especially true for physically demanding jobs, such as those in the construction trades, where older workers may be at higher risk of injury and illness. The injuries and illnesses sustained by workers in the construction industry often result in a significant financial burden for the worker, industry and society as a whole (X. W. Dong, Ringen, Men, & Fujimoto, 2007; G. Waehrer, Dong, Miller, Haile, & Men, 2007).

Construction workers have higher rates of injuries than workers in other industries (U.S. Bureau of Labor Statistics, 2009) and the average total cost of their injuries is significantly greater. In the US, the estimated average total cost of construction-related injury was $27,000, with a greater proportion of the total costs related to indirect costs (e.g., wage loss) rather than direct costs (e.g., medical costs), compared to $15,000 across all industries in 2002 (G. Waehrer et al., 2007). Waehrer et al. (2007) estimated that $13 billion is spent annually in the US on workers' compensation (WC) costs in the construction industry, making it one of the most expensive industries to insure. According to the National Compensation Survey in 2011, the construction industry spent on average, $1.32 per hour worked on WC. This is triple the cost spent across all industries ($0.44 per hour worked) (U.S. Bureau of Labor Statistics, 2011).

Given the high cost of work-related injuries and illnesses in the construction industry, it is important to understand what factors contribute to these costs. Older construction workers (>55 years of age) are responsible for a disproportionate risk of work-related health issues (X. Dong, Wang, Daw, & Ringen, 2011; NORA Construction Sector Council, 2008; Schwatka, Butler, & Rosecrance, 2012), but their contribution to the total cost of injuries and illnesses has yet to be quantified. Previous research has either limited their discussion to specific construction trades, types of injuries or WC claims (e.g., Friedman & Forst, 2009; H. Lipscomb, Leiming, & Dement, 2003; H. J. Lipscomb, Dement, Silverstein, Cameron, & Glazner, 2009). As construction workers age, they will likely experience physical limitations and co-morbidities (X. Dong et al., 2011; Welch, Haile, Boden, & Hunting, 2008). These vulnerabilities will adversely affect their ability to perform physically demanding work in the construction industry, leaving them more susceptible to injuries such as musculoskeletal disorders (MSDs), fractures and contusions (Maertens, Putter, Chen, Diehl, & Huang, 2012; Schwatka et al., 2012). Despite these findings, older worker age does not appear to be associated with higher injury rates (Restrepo & Shuford, 2011; Rogers & Wiatrowski, 2005; Schoenfisch, Lipscomb, Shishlov, & Myers, 2010).

Older construction workers, however, may be more likely to experience severe-type injuries compared with younger construction workers. This trend may result in higher indemnity, rather than medical costs, as older construction worker's injuries may require more days away from work and may result in disabilities and physical limitations (Choi, 2009; Schwatka et al., 2012). Although injuries among older construction workers may result in greater indemnity costs, it is not clear whether they may not reflect a greater total cost per claim as compared to their younger coworkers. In the present study, we performed a comprehensive investigation of the association between worker age, injury type and WC costs (overall and by cost type) among claimants employed in the construction industry. Over 100,000 construction WC claims filed in the state of Colorado between 1998 and 2008 were analyzed in order to test the hypothesis that the positive association between age and WC cost would differ by cost type (e.g., total, medical and indemnity costs), and that the relationship between injury type and cost would vary by age.

Chapter 2

Methods

2.1. Workers' Compensation Database

A database of closed WC claims filed between June 30, 1998 and June 30, 2008 by construction workers in Colorado was created using data from the one of state's largest WC insurers, Pinnacol Assurance. A description of the Colorado WC system can be found in previously published articles (Douphrate, Rosecrance, Reynolds, Stallones, & Gilkey, 2009aa; Douphrate, Rosecrance, & Wahl, 2006). The claims represented approximately 80% of all construction company policyholders in the state of Colorado, as referenced by National Council on Compensation Insurance codes [Actuarial from Pinnacol Assurance, oral communication, 2010]. Using the US Census's Statistics of US Businesses, we estimated the Pinnacol dataset represents about 14,000 construction establishments and about 124,000 construction workers per year in Colorado (Statistics of U.S. Businesses, 1998-2008).

This study includes WC claims that are "closed" rather than claims that are still "open" and actively incurring costs related to the injury. In order to capture the claims at a time in which the majority of costs have been incurred, a 24-month period following the initial date of claim filing was chosen. This timeframe was chosen because >99% of claim costs occur during this time span [Actuary from Pinnacol Assurance, oral communication, 2010]. For example, for a claim that was submitted on June 30, 1998, all costs incurred through June 30, 2000 would be included for that claim. Thus, the dataset includes claim costs incurred from June 30, 2000 to June 30, 2010 (see Supplement Figure I). The Institutional Review Board (IRB) at Colorado State University declared in a letter that the project was exempt from IRB since individuals within the dataset were not identifiable. Thus, informed consent was not necessary.

2.2. Statistical Analyses

The following variables were used in these analyses: claimant age at time of first report of injury (year), injury type (strain, contusion, laceration and other), total cost ($), medical cost ($) indemnity cost ($), and claim type (medical-only cost claims or medical plus indemnity cost claims). The total cost of a claim included all costs associated with the claim (medical, indemnity and other expenses). Medical expenses included all healthcare related services and products (e.g., physician visits, treatment, rehabilitation, diagnostic testing, adaptive equipment and prescription medications). Indemnity expenses included wage-replacement, disability, impairment and death benefits. Other expenses included ancillary costs such as legal fees. All cost variables were adjusted for inflation to 2010 US dollars by using the Consumer Price Index (CPI-U) (Chairman of the Council of Economic Advisors: United States Government Printing Office, 2012). Although medical costs generally increase at a greater rate than the overall inflation rate, adjusting the medical costs by the specific medical CPI did not result in meaningful changes in the results. The only change observed was an increase in mean medical cost by an approximate $400 increase for all age groups. Thus, all results are presented with adjustment using CPI-U.

Descriptive statistics were generated for all variables in the study. Age of the claimant was evaluated as a continuous (≥18 years) and categorical variable (18-24, 25-34, 35-44, 45-54, 55-64, ≥65years). More than 60% of all the claims were due to the three most frequent types of injuries (strains, contusions and lacerations). Thus, type of injury was collapsed into four categories, ‘other’ being the forth category. The number of claims, type of injury frequency and mean cost of a claim (total, medical and indemnity) were determined for each age group. For all inferential statistical analyses, the cost variables were log-transformed in order to correct for non-normality. Analyses of variance (ANOVA) were used to evaluate whether there were statistically significant differences in the mean cost of claim (total, medical and indemnity) across age groups. Bonferroni adjusted multiple pairwise comparisons were conducted to determine which age groups had significant mean differences. Pearson correlation coefficients were obtained in order to determine if there was a significant linear trend between age (years) and cost (total, medical and indemnity).

Linear regression analyses were used to evaluate the effect of the explanatory variable (i.e. claimant years of age) on the outcome variables (i.e. total cost, medical cost and indemnity cost) overall, and stratified by injury type. Each cost variable was assessed in separate simple linear regression models with age of claimant as the predictor. Multiple linear regression analyses were used to evaluate the potential modification of the age of claimant on the indemnity cost of different types of injuries. The final multiple regression model was run without the intercept in the final model in order to determine specific slope estimates for each type of injury by claimant age group. Statistical computing was conducted using SAS PC software version 9.2 [SAS Institute Inc., Cary, NC, USA]. All *P*-values were two-sided and considered statistically significant if less than 0.05.

Chapter 3

Results

In our dataset of 107,065 WC claims among construction workers in Colorado, the mean claimant age was 34 years (*SD* = 11) and the median was 33 years (*IQR* = 26-43). The majority of injured workers who filed a claim were male (97%). Workers under the age of 45 filed approximately 80% of the WC claims. After adjusting all costs to 2010 dollars, the total cost of the 107,064 claims was $931,234,994. The total medical cost and total indemnity cost were $408,613,710 and $461,084,685, respectively.

Of all claims filed, 23% (n = 24,846) were WC claims with medical plus indemnity costs and 77% (n = 82,219) were WC claims with medical only costs. Claimants over the age of 65 filed more medical plus indemnity-type claims (34%) than claimants between the age of 18 and 24 years of age (18%) ($\chi^2 = 91.68$, $p < .0001$). When the costs ($) of the claim types were compared, claimants over the age of 65 had a higher percentage of indemnity costs (e.g., 63% of the total costs were due to indemnity costs), compared to claimants aged 18-24 years (e.g., 51% of the total costs were due to indemnity costs) (Table 6).

Table 6. Inflation adjusted mean and median workers' compensation costs by claimant age and cost type

	Total	Age group					
		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
Type of cost							
Total ($)							
Mean	8,432	4,899	7,439	10,320	12,176	13,194	14,253
(std) [a]	(37,637)	(31,935)	(34,063)	(39,287)	(48,943)	(44,404)	(37,170)
Median	563	474	544	642	706	775	861
IQR [b]	280-2,022	254-1,143	285-1,671	296-3,059	305-4,707	308-5,464	295-7,056
Medical ($) Mean	3,709	2,424	3,284	4,207	5,551	5,632	5,275
(std) [a]	(20,672)	(14,026)	(16,665)	(17,387)	(35,944)	(25,971)	(14,291)
Median	521	450	507	582	631	674	718
IQR [b]	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) [a]	(21,676)	(20,295)	(20,710)	(24,075)	(19,851)	(24,386)	(25,809)
Median	0	0	0	0	0	0	0
IQR [b]	0-0	0-0	0-0	0-157	0-690	0-1,004	0-2,380

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

The majority of claims were related to strains (27%), contusions (21%) and lacerations (17%). Other injuries included: foreign body (7.5%), sprain (6.6%), puncture (6.3%), fracture (3.6%), crushing (1.5%) burn (1.47%), and all other injuries (8.6%). The other category included injuries that represented <1% of the claims and “all other” injuries, as defined by the insurer who provided the database of claims. Strains were the most common type of injury among all age groups except for the oldest age group, ≥65, where strains and contusions occurred at similar frequencies, 26% and 27% of all claims, respectively. Lacerations occurred more frequently among younger age groups (18-24 years) compared with older age groups (≥65 years), accounting for 21% and 12% of all injuries, respectively. There were no meaningful differences between age groups for the other types of injuries (data not shown). The mean cost of a claim related to each type of injury (strains, contusions, lacerations, other) generally increased with increasing age group Table 7 with the greatest proportion of total costs attributed to indemnity expenses. For example, the proportion of the total WC costs attributable to the indemnity costs for a strain type of injury were 59% for claimants ≥65, compared to 52% for claimants 18-24 years. The proportion of the total WC costs attributable to the medical cost of a strain type of injury was and 35% for claimants ≥65 years and 39% for those 18-24 years, respectively (data not shown).

Table 7. Inflation-adjusted mean and median workers' compensation costs by claimant age, cost type and type of injury

Type of injury	Total	Age group 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
Strain							
Total (*n*)	28,855	4,437	9,501	8,115	5,052	1,594	156
Percent (%) of claims	(26%)	(20%)	(26%)	(30%)	(31%)	(30%)	(26%)
Total cost ($) Mean	10,917	5,385	9,464	13,428	14,392	15,373	11,834
(std) [a]	(30,795)	(17,180)	(20,020)	(33,194)	(41,146)	(38,150)	(24,742)
Median	384	577	750	965	1,147	1,149	976
IQR [b]	289-430	281-1,732	326-2083	328-6,329	344-9123	339-9,599	381-11,439
Medical cost ($) Mean	4,083	2,103	3,365	4,714	5,629	5,750	4,143
(std) [a]	(14,846)	(6,518)	(9,755)	(15,529)	(26,819)	(13,977)	(6,662)
Median	694	504	642	795	913	929	879
IQR [b]	287-2,360	256-1,256	291-1,834	294-3,064	304-4,096	289-4,531	349-4,612
Indemnity cost ($) Mean	6,253	2,840	2,840	5,379	7,734	8,671	7,008
(std) [a]	(19,089)	(5,417)	(11,289)	(16,834)	(22,170)	(25,517)	(18,982)
Median	0	0	0	0	0	0	0
IQR [b]	0-909	0-0	0-0	0-420	0-1,687	0-2,872	0-3,888
Contusion							
Total (*n*)	22,406	4,608	7,231	5,646	3,542	1,215	164
Percent (%) of claims	(21%)	(21%)	(20%)	(21%)	(22%)	(23%)	(27%)
Total cost ($) Mean	8,463	4,803	7,638	10,578	11,608	11,979	17,208
(std) [a]	(41,753)	(36,871)	(39,012)	(52,774)	(38,649)	(38,075)	(41,308)
Median	549	456	539	612	640	712	893
IQR [b]	269-1,882	246-1,081	278-1,704	282-2,630	300-3,645	276-3,566	324-6,411
Medical cost ($) Mean	3,829	2,371	3,482	4,251	5,295	4,858	6,133
(std) [a]	(19,617)	(17,725)	(21,406)	(18,372)	(21,217)	(15,930)	(15,219)
Median	515	434	501	559	593	644	729
IQR [b]	255-1,453	230-940	259-1,307	259-1,737	281-2,391	266-2,461	292-3,181
Indemnity cost ($) Mean	4,294	2,116	3,645	5,536	5,496	6,350	10,201
(std) [a]	(25,641)	(22,150)	(21,125)	(32,118)	(19,469)	(24,627)	(30,770)
Median	0	0	0	0	0	0	0
IQR [b]	0-0	0-0	0-0	0-0	0-220	0-255	0-2,691

[a] Standard deviation [b] Inter-quartile range [c] The "other" injury types include: burn, crushing, foreign body, fracture, puncture, sprain, and all other. *Note.* Costs ($) adjusted for inflation to 2010 dollars. N=number of claims.

Table 7. Continued

Type of injury	Total	Age group 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
Laceration							
Total (*n*)	17,451	4,455	6,331	3,987	1,977	628	70
Percent (%) of claims	(17%)	(21%)	(18%)	(14%)	(12%)	(12%)	(12%)
Total cost ($) Mean	2,670	2,160	2,588	3,281	3,323	3,731	1,281
(std) [a]	(13,757)	(9,177)	(15,025)	(15,127)	(17,100)	(15,645)	(3,047)
Median	473	453	467	488	515	507	516
IQR [b]	289-844	273-806	295-825	294-923	310-944	309-936	289-1,011
Medical cost ($) Mean	1,622	1,404	1,504	1,802	2,030	2,011	856
(std) [a]	(6,188)	(4,565)	(5,621)	(7,176)	(8,572)	(6,158)	(1,384)
Median	465	446	458	480	508	501	514
IQR [b]	283-813	262-765	289-786	285-874	302-866	304-898	289-988
Indemnity cost ($) Mean	998	664	961	1,289	1,164	1,450	401
(std) [a]	(8,250)	(4,826)	(9,999)	(8,035)	(8,644)	(8,420)	(1,760)
Median	0	0	0	0	0	0	0
IQR [b]	0-0	0-0	0-0	0-0	0-0	0-0	0-0
Other [c]							
Total (*n*)	38,350	8,232	12,951	9,343	5,789	1,822	213
Percent (%) of claims	(36%)	(38%)	(36%)	(35%)	(35%)	(35%)	(35%)
Total cost ($) Mean	9,227	6,175	8,215	10,470	13,614	15,359	18,013
(std) [a]	(40,033)	(41,489)	(41,894)	(41,337)	(65,161)	(57,693)	(45,606)
Median	532	461	509	613	659	802	988
IQR [b]	262-2,101	239-1,182	259-1,656	284-3,364	283-5,533	301-7,520	235-11,349
Medical cost ($) Mean	4,607	2,765	3,984	4,766	6,41	7,292	6,897
(std) [a]	(28,723)	(17,556)	(20,718)	(22,613)	(52,130)	(39,833)	(19,514)
Median	503	441	479	552	590	687	795
IQR [b]	245-1,521	225-986	246-1,267	262-1,943	256-2,904	2753,234	126-4,334
Indemnity cost ($) Mean	4,351	2,649	3,732	5,052	5,942	7,198	9,930
(std) [a]	(24,790)	(27,014)	(26,099)	(21,659)	(22,063)	(56,562)	(29,527)
Median	0	0	0	0	0	0	0
IQR [b]	0-0	0-0	0-0	0-176	0-912	0-1,863	0-4,355

[a] Standard deviation [b] Inter-quartile range [c] The “other” injury types include: burn, crushing, foreign body, fracture, puncture, sprain, and all other. *Note.* Costs ($) adjusted for inflation to 2010 dollars. N=number of claims.

Claimant age (years) and WC costs had a small, but statistically significant correlation with total costs ($r = .07$, $P < .0001$), medical costs ($r = .05$, $P < .0001$), and indemnity costs ($r = .10$, $P < .0001$). Mean costs (total, medical and indemnity) of a claim increased with increasing age group, with one exception (Table 6). Mean medical cost per claim increased up to the 55 to 64 year age group then slightly decreased for the ≥65 year age group. The differences in mean cost by age group were statistically significant: 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, $P < .0001$).

A priori multiple pairwise comparisons using a Bonferroni-adjusted alpha level of .003 per test (.05/15) was used to evaluate mean costs between claimant age groups (Table 8). There were statistically non-significant differences in mean total cost between claimants 35-44 years of age and those ≥45 years of age [e.g., 45-54 (p = 0.02), 55-64 (p = 0.02), ≥65 years (p=0.33)]. In other words, total costs increased with increasing age category until ≥35 years of age when total costs plateaued. A similar pattern was observed for medical costs. In terms of indemnity costs, there were statistically non-significant differences in mean indemnity costs between claimants 45-54 years of age and those ≥55 years of age [e.g., 55-64 (p = 1.00) and 65+ (p = .014)]. In other words, indemnity costs increased with increasing age category until ≥45 years of age when indemnity costs plateaued.

Table 8. ANOVA multiple comparisons p-values for differences in mean costs by claimant age and cost type

	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). Mean total cost and medical cost by age group are significantly different up until the age group 35-44. However, mean indemnity costs are significantly different up until the age group 45-54.

Simple linear regression analyses were used to further evaluate the relationship between claimant age, type of injury and WC costs. The first step in assessing this relationship was to evaluate age of claimant and cost in univariate models (see Table 9). When age of claimant was included in the model as a continuous variable, the strongest association was observed between claimant age and indemnity costs. There was a 3.51% increase in the indemnity cost of a claim for each one-year increase in the age of a claimant. In contrast, there was a smaller 1.11% increase in the medical cost of a claim for each one-year increase in the age of a claimant. We also included age in the model as a categorical variable, because the ANOVA results indicated that age might not be a linear function of cost. Compared to claimant's aged 18-24, all other age groups exhibited a greater increase in cost, especially for indemnity costs. For example, a claimant ≥65 years had a 46% higher medical cost than a claimant aged 18-24 but a 372% higher indemnity cost. In summary, we observed the similar relationships between age and cost by type, regardless of whether age was included as a continuous or categorical variable in the linear models.

Table 9. Individual linear regression models for age (years & categorical) of claimant and cost of a claim by cost type

Outcome	β [a]	95% CI [a]	Percent (%) Increase [d]	% of variance explained by age
Total cost [b, c]				
Age continuous	1.017	1.016, 1.019	1.7	0.58
Age Groups				
18-24	Reference			
25-34	1.267	1.21, 1.32	26.7	0.04
35-44	1.582	1.51, 1.66	58.2	0.07
45-54	1.719	1.63, 1.81	71.9	0.24
55-64	1.801	1.66, 1.95	80.1	0.20
65+	2.026	1.63, 2.50	102.6	0.04
Medical cost [b, c]				
Age continuous	1.011	1.010, 1.013	1.1	0.27
Age Groups				
18-24	Reference			
25-34	1.187	1.14, 1.24	18.7	0.01
35-44	1.353	1.30, 1.41	35.3	0.04
45-54	1.428	1.36, 1.50	42.8	0.12
55-64	1.470	1.36, 1.60	47.0	0.09
65+	1.460	1.19, 1.79	46.0	0.01
Indemnity cost [b, c]				
Age continuous	1.036	1.033, 1.037	3.6	1.12
Age Groups				
18-24	Reference			
25-34	1.419	1.33, 1.51	41.9	0.14
35-44	2.240	2.10, 2.39	124.0	0.08
45-54	2.843	2.63, 3.06	184.4	0.44
55-64	3.074	2.75, 3.43	207.4	0.34
65+	4.716	3.50, 6.36	372.0	0.10

Costs ($) adjusted for inflation to 2010 dollars and log-transformed. CI = confidence interval.

[a]Estimates and corresponding 95% CI's have been back transformed (i.e., exp(beta)).

[b]Models with age as a continuous variable and a categorical variable were run separately.

[c]Outcome variables were log transformed.

[d]Percent (%) increase in the cost of a claim for each year increase in age or compared to the age group 18^24, depending on how age was imputed in the model. Percent (%) increase = {[exp(beta)] - 1} 100.

To further explore the relationship between age and indemnity costs, we conducted linear regression analyses with type of injury as one of the predictors (see Table 10). In the univariate model, a strain type of injury was more costly than the other three types of injuries. For example, a contusion type of injury was 46% less costly than a strain type of injury.

In multiple linear regression analyses by claimant age, we observed stronger associations for strains, contusions and other types of injuries with indemnity cost as age increased (all P for trends <0.05), with the strongest associations observed among claimants ≥65 years. We did not observe evidence for modification by age on the association between laceration type of injury and indemnity cost. The final interaction model for injury type by age group explained 3.1% of the variance in indemnity cost (Table 10).

Table 10. Linear regression models for type of injury and indemnity cost of a claim by age of claimant

Injury type	β (95% CI) [a]	Age adjusted β (95% CI)[a]	Interaction model β (95% CI) [a, b]					
			Age groups					
			18-24	25-34	35-44	45-54	55-64	65+
Strain	1.00	1.00	1.00	1.70	2.67	3.32	3.42	3.61
	-	-	-	(1.48, 1.92)	(2.33, 3.04)	(2.86, 3.84)	(2.77, 4.21)	(2.02, 6.50)
Contusion	0.46	0.48	1.00	1.507	2.34	2.78	2.86	6.53
	(0.43, 0.49)	(0.45, 0.51)	-	(1.32, 1.73)	(2.30, 3.70)	(2.37, 3.26)	(2.27-3.61)	(3.70, 11.53)
Laceration	0.19	0.20	1.00	0.943	1.12	1.12	1.03	0.826
	(0.17, 0.20)	(0.190, 0.22)	-	(0.82, 1.09)	(0.96, 1.31)	(0.92, 1.36)	(0.76, 1.40)	(0.35, 1.96)
Other [c]	0.53	0.56	1.00	1.31	2.04	2.692	3.35	6.69
	(0.50, 0.56)	(0.53, 0.59)	-	(1.18, 1.38)	(1.84, 2.78)	(2.38, 3.04)	(2.78, 4.04)	(4.07, 11.00)
r^2	.021	.029	.031					

[a] Estimates and corresponding 95% CI's have been back transformed (i.e., exp(beta))
[b] The interaction model betas represent a no intercept model where each estimate is considered the change in cost of a claim for type of injury by age group. For example, claimants ≥65 years have a 261% higher indemnity cost of a claim than claimants aged 18-24 for a strain type of injury. Percent (%) increase = {[exp(beta)]-1}*100.
[c] The "other" injury types include: burn, crushing, foreign body, fracture, puncture, sprain, and all other.
Note. Costs ($) adjusted for inflation to 2010 dollars and log-transformed. CI = Confidence Interval.

Chapter 4

Discussion

Using a large WC database that was representative of approximately 80% of Colorado construction industry WC policyholders, we evaluated the relationship between age, injury type and costs. The mean total cost of a claim filed by workers 65 years and older was about three times the cost of a claim filed by workers aged 18-24. Yet, workers under the age of 45 filed 80% of the claims. Linear regression analyses revealed that the increase in costs among older workers was driven by increases in indemnity costs, rather than medical costs. We also reported that the indemnity costs associated with specific injuries (e.g. strains and contusions) increased along with age of the claimant. These results suggest a major financial burden, particularly due to indemnity costs (i.e. lost days at work, disabilities, and physical limitations) among the companies that insure workers and the WC insurance agency that will incur among the aging construction workforce.

Our findings indicated that overall there were statistically significant differences by mean WC costs regardless of cost type by increasing age group (18-24, 25-34, …, ≥65 years). For individual age group comparisons, statistically significant differences in mean total costs were observed among increasing age groups up to age 35, while mean costs did not differ significantly between older age groups (35-44, 45-54, 55-64 and ≥65 years). Medical costs plateaued at 35-44 years of age but indemnity costs plateaued at 45-54 years of age. Our results suggest that how we define “older age,” in terms of a subset of the workforce most susceptible to injury, may need to be adjusted downward. Our results also highlight the importance of evaluating cost type, rather than just total cost when describing relationships between age and cost.

Our findings support previous research demonstrating that worker age was positively associated with WC costs, although the age at which costs begin to plateau differs across studies. In a study of over 20,000 WC claims among Illinois construction workers' between 2000 and 2005, the mean total cost of compensation peaked for workers aged 55 to 64 and then declined slightly for workers over the age of 65 (Friedman & Forst, 2009). Similar findings were reported by Waehrer et al.'s (2007) study of construction injuries (N = 162,371 injuries) where mean total cost of injuries and illnesses requiring days away from work peaked at ages 45-54 and declined for workers over the age of 55. Their database of occupational injuries, however, came from the Survey of Occupational Injuries and Illnesses (SOII) (2002 Annual Survey) collected by the Bureau of Labor Statistics (BLS) and only represents construction companies with ten or more employees. Of all construction establishments in the US, 79% have less than ten employees, and these establishments make up 24% of the construction workforce (Center for Construction Research and Training, 2008). These previous studies were either smaller in size (Friedman & Forst, 2009) or had an occupational injury database that was not representative of the entire construction industry (G. Waehrer et al., 2007). Our data, while only representative of the Colorado construction industry, suggest that that the age at which WC costs plateau may be younger than previously reported. A recent report from the National Council on Compensation Insurers found similar trends (Restrepo & Shuford, 2011).

We determined that strains and contusions were more common among construction workers and that age modified the association between injury type and indemnity cost. Our top three frequently occurring types of injuries (strains, contusions, and lacerations) were also cited as the top construction industry related injuries treated in hospital emergency rooms in a recent study using National Electronic Injury Surveillance-Work (NEISS-Work) database (Schoenfisch et al., 2010). The results of the present study suggest that the divergence in indemnity cost among older and younger workers becomes greater as injury severity increases.

While the present study determined that older workers filed a small percentage of claims related to minor injuries (i.e. lacerations), it is possible that older workers selectively report the most serious of injuries. Older workers may shy away from the negative attention related to injury reporting as they already face the stigma associated with being part an aging workforce. There may be additional fears related to being singled out for their “carelessness” or “unsafe acts” that could lead to retaliation. Additionally, throughout their careers, older workers may have had unpleasant experiences with the WC system and chose not to report minor injuries in order to avoid further frustrations. Despite these issues, older and younger workers who filed a claim for minor injuries had similar indemnity costs.

We reported that indemnity costs, rather than medical costs were driving the higher WC costs among older construction workers. Our findings supports previous research findings that indicate more lost workdays (Horwitz & McCall, 2004; Kucera, Lipscomb, Silverstein, & Cameron, 2009; Lowery et al., 1998) and increased disability (Arndt et al., 2005; Courtney, Matz, & Webster, 2002; Welch, Haile, Boden, & Hunting, 2010), and thus, higher indemnity costs among aging construction workers. Lowery et al. (1998) determined that rate of lost work time among construction workers at a large Owner Controlled Insurance Program site was greatest among workers over the age of 50. Kucera et al. (2009) found that among workers 45 years and older were 60% more likely to have a claim with delayed return to work (>90 days away after injury), compared to workers less than 30 years of age. A study that utilized WC claims from the Oregon construction industry found that the temporary total disability compensated days was greatest among workers 46 and 55 years of age (Horwitz & McCall, 2004). Our findings not only support previous findings, but also provide novel quantitative data on the increased financial costs associated with lost work time and disability among older construction workers.

Our study supports previous research that indicates injuries to the musculoskeletal system (e.g. strains) are of particular concern for aging construction workers (de Zwart, Frings-Dresen, & van Duivenbooden, 1999; Hoonakker & van Duivenbooden, 2010; Welch et al., 2008; Welch et al., 2010). In our database, approximately 50% of all strain injuries were to the spine/back/lower trunk among all age groups. Overexertions of the back are a major source of pain and injury among older construction workers (Hoonakker & van Duivenbooden, 2010; Welch et al., 2008). A significant amount of lost work time, delayed return to work, and disability from back injuries among aging construction workers has been reported among carpenters in Washington state (Kucera et al., 2009; H. Lipscomb, Cameron, & Silverstein, 2008). Lipscomb et al. (2009) reported that payment rates increased with age but the source of payments were not reported (i.e. medical vs. indemnity payments). Our results are consistent with these previous results, but also contribute new information about the actual dollar amount associated with strain-type injuries and how the association with indemnity costs increase with increasing age of the claimant.

4.1. Strengths and Limitations

The utility of WC 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 WC data, specifically, have been used to identify costs, characteristics and contributing factors of agricultural injuries and illnesses (Douphrate et al., 2009a; Douphrate, Rosecrance, Stallones, Reynolds, & Gilkey, 2009b; Douphrate et al., 2006). Unlike other databases of occupational injuries and illnesses, WC data are not limited to establishments with less than ten employees (BLS SOII) and workers who were treated in hospital emergency rooms (NEISS-Work) and includes incurred costs related to medical treatment and compensation. This allows for greater generalizability of the results obtained from WC data analyses that can then be used to inform policies aimed at reducing injury and illness in the workplace.

The data analyzed in the present study was originally created to manage insurance payments and thus the cost variables are relatively accurate and complete for all claims. The consistency of medical fees during the ten-year period from which this data was derived is unclear as fee schedule for medical care may have varied but these possible changes were likely to be small and thus would not have influenced our main findings. We also did not have information on the workers who filed the claim, which hindered our ability to adjust for potential confounders, such as race/ethnicity, body mass index, years of experience and other personal and occupational factors. Similar to the majority of studies that use WC claims data, information related to the incumbent workforce was not available, such as the number of hours worked and wages or salaries earned by each claimant. It is possible that the increase in indemnity costs seen in the present study may be due, in part to higher wages among older construction workers. Since age and type of injury explained only a small percentage of the variance in indemnity cost, there are likely to be several other, unexplained factors that contribute to costs that we were not able to account for. The present study likely underestimates the true frequency and cost due to potential underreporting of injuries that were covered by Social Security, unemployment insurance, disability coverage, Medicaid, and other private and public insurance systems (Dembe, 2001).

4.2. Conclusions

By the year 2018, the participation rate of workers over the age of 55 will have increased while the participation rate of workers between the ages of 16 and 54 will have decreased (Toossi, 2009). Maintaining the employability of older workers will be critical in order to compensate for the decreasing labor force participation rates of those in their prime working years. In physically demanding industries like construction, the impact of the aging population can be significant. The physical limitations that older construction workers experience (X. Dong et al., 2011) may limit older workers ability to perform physically demanding tasks in the construction industry without becoming injured (Schwatka et al., 2012). Older construction workers may be more likely to hold supervisorial positions due to experience and tenure, and thus may not have the same exposures to illness- and injury-related risk factors than younger workers. However, as the number of skilled construction workers in the labor force decrease, there may be an increased demand for older workers to remain in more laborious positions (U.S. Bureau of Labor Statistics, 2012). Thus, subsequent efforts to return to work after injury or illness may be hindered by the difficultly to make accommodations in the construction industry (Berecki-Gisolf, Clay, Collie, & McClure, 2012).

While this study indicated that older workers filed a small percentage of the total WC claims, the WC costs incurred by them were more costly on a per claim basis than their younger counterparts for indemnity rather than medical costs. This study illustrates the economic significance of injuries and illnesses among older construction workers. Additional research is needed to determine if older construction workers are selectively reporting injuries, which would likely have an effect on the medical and indemnity costs. The utilization of WC cost data is a useful but lagging indicator of the state of occupational health and safety among construction workers.   New research should be aimed at leading indicators (e.g., safety climate / culture) of health and safety that promote the development of proactive injury prevention strategies. Leading indicators have the potential to identify the risk of occupational injuries prior to their occurrence among construction workers of all ages.

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PART IV

From management to co-workers: The impact of safety climate perceptions on safety behaviors in the construction industry

Chapter 1

Introduction

More than thirty years ago, Herbert A. Applebaum wrote a case study on the culture within the construction industry titled "Royal blue: The culture of construction workers." In Applebaum's chapter titled "Accidents, danger, and death," he notes a lunchtime swapping of stories related to work-related accidents and why accidents occur. At the end of the discussion, one worker concluded, "What's the use of looking for a 'why'? An accident is something that happens. There is no 'why.' It just is. That's all there is." Applebaum noted that "this blunt realism epitomizes construction work culture" (Applebaum, 1981). Although this irremediable attitude persists today, there have been significant advances in improving safety culture within the United States construction industry. Since 1990, academics, safety professionals, construction organizations (e.g., Center for Construction Research and Training), and governmental agencies (e.g., National Institute for Occupational Safety and Health (NIOSH)) together have made significant strides in raising the awareness of health and safety issues and the importance of safety culture in the construction industry. Across the United States, the non-fatal injury rate among construction workers has decreased by 54% from 2002 to 2010 and the fatality rate decreased by 34% between 1992 and 2010 (Center for Construction Research and Training, 2013). The importance of the safety culture that Applebaum eluded to, is now a leading theme in construction health and safety research and practice (Matt Gillen and Gittleman, 2010). The importance of safety culture is echoed by the NIOSH construction sector goal 8.0, which focuses on the measurement of and interventions for safety culture in the construction industry (NORA Construction Sector Council, 2008).

Despite many new and effective control measures (from design to personal protective equipment) to reduce injury risk on the job-site, high rates of injuries and deaths continue in the construction industry. Construction workers account for a disproportionate number of the injuries and deaths among the United States (US) workforce. Compared to other industries, construction work still poses a significant risk for injuries (Kachan et al., 2012), chronic diseases, and functional limitations (Dong et al., 2011a). In 2011, 738 construction workers died on the job, which equates to about two worker fatalities each day. Their fatality rate was much greater than the average across all industries, 9.1 versus 3.5 per 100,000 full-time equivalent workers (FTE) (Bureau of Labor Statistics, n.d.). The number of injuries resulting in days away from work was 3.8 per 100 FTE's, compared to 3.3 for all private industries (Bureau of Labor Statistics, 2012). Over the course of a 45-year career, a construction worker has a 75% likelihood of sustaining a disabling injury (Dong et al., 2011b). Similar trends can be seen in Europe. Namely, 7% of construction workers reported health problems due to working conditions, and among them 75% attributed their health problem to a musculoskeletal health issues (eurostat, n.d.). The occupational non-fatal and fatal incident rates among construction workers in the European Union were 2,958 and 6.6, respectively, per 100,000 workers (eurostat, n.d.). In addition to the innovative designs that eliminate risk and new PPE that minimizes exposure, an understanding of macro-level (e.g., safety climate) factors that influence health and safety on the job may also facilitate the continued improvements in health and safety on construction jobsites.

1.1. Safety climate: Perceptions of top management, supervisors and co-workers

Safety climate represents "shared perceptions among the members of a social unit, of policies, procedures and practices related to safety in the organization" (Kines et al., 2011). Zohar (2011; 2010) notes that these perceptions reflect: 1) the relative priority of safety alongside other competing organizational goals, 2) how much of the espoused safety policies are used in practice, 3) the consistency with which the safety practices are carried out. Many studies have linked safety climate to other proximal (e.g., safety knowledge) and distal (e.g., safety behaviors and injuries) outcomes (Nahrgang et al., 2011). Measures of safety climate have also been used as an indicator of health and safety in the construction industry (Gilkey et al., 2012; Goldenhar et al., 2003; Kines et al., 2011). For example, after eight construction workers died within a period of 18 months on a large Las Vegas construction project, Gittleman et al. (2010) used safety climate measures focused on management commitment to understand major health and safety concerns. Although company management is often the focus of safety climate measures, co-workers may also contribute to safety climate but co-worker effects have been understudied.

1.1.1. Perceptions of management

One focal point in the safety climate literature is the prominence that company management plays in the development of climate. At the heart of safety climate are worker's perceptions of management's true priority or value of safety. Since management is responsible for setting company priorities and carrying them out in practice, their actions are key indicators of safety climate. Meta-analyses of safety climate studies conducted over a decade ago found that management related factors were the most common factors included in safety climate measurements (Flin et al., 2000; Guldenmund, 2000). Since then, management commitment to safety continues to be a common safety climate measurement factor (Griffin and Neal, 2000; Kines et al., 2011). Although other factors of safety climate are commonly considered (e.g., safety systems and safety training), it is becoming more common to think of safety climate perceptions in terms of "who" is or "who" is not carrying out company safety policies, procedures and practices. Recently, there has been greater emphasis on how a variety of "safety agents" within an organization *respond* to jobsite safety rather than the actual practices employed (Brondino et al., 2012; Meliá et al., 2008)? Conceptually, other previously researched dimensions of safety climate (e.g., safety training) are "at least partially dependent on management commitment to safety" (Huang et al., 2006).

Previous research suggests that it is not sufficient to assess safety climate based on perceptions of management as a whole. The multi-level concept of safety climate proposed by Zohar and Luria (2005) contends that measures tapping into the organization and group level are more useful than measures that address only the organization. While top management is responsible for setting company priorities and outlining procedures, supervisors are tasked with disseminating and integrating these concepts into daily practice within their work groups. Zohar and Luria's (2005) results demonstrated this effect by showing that perceptions of supervisors' commitment to safety fully mediated the relationship between perceptions of top management's commitment to safety and safety behaviors.

In the construction industry, this distinction is especially conspicuous. Typical construction work takes place on job sites away from company main offices. The distance created from this type of work gives supervisors and mid-level management a great amount of responsibility and discretion in carrying out day-to-day safety practices. This responsibility and discretion contributes to the development of safety climate perceptions beyond the organizational level. This means that workers develop distinct perceptions of top management safety climate and supervisor safety climate. Thus, the role of supervisors on construction job site safety cannot be understated (Zohar, 2011). In qualitative studies, researchers found that supervisors can be helpful when they model safe behaviors, put safety before production, and encourage reporting when workers feel unsafe (Marion Gillen et al., 2004). Construction workers also see their supervisor as having the second most influential position with respect to safety, with the safety manager being the first (Dingsdag et al., 2008). In quantitative studies, the amount of time supervisors spent talking with their crews about safety had a direct impact on their crew's safety performance (Kines et al., 2010).

1.1.2. Perceptions of co-workers

While previous research highlighted the role of safety climate perceptions of top management and supervisors, Kines et al. (2011), Melia et al. (2008) and Brondino et al. (2012) also emphasized the role of safety climate perceptions of co-workers. Kines et al. (2011) developed and tested the Nordic safety climate questionnaire (NOSACQ-50), which includes safety climate factors pertaining to co-workers. Their study found that there were shared perceptions of co-workers' safety commitment, priority, competence, and communication. Melia et al. (2008) and Brondino et al. (2012) extended Zohar and Luria's (2005) organizational and group level safety climate concept to include perceptions of co-workers. Their concept of safety climate emphasizes the role of "safety agents" on the job (i.e., top management, supervisors, and co-workers). Their research indicates that perceptions of co-workers are just as important as perceptions of top management and supervisor when assessing climate. In fact, Brondino et al. (2012), using structural equation modeling (SEM), found significant mediation effects, providing evidence for a concept consistent with a partially causal path of "safety agent" influences on safety behavior, starting from top management and ending at worker safety behavior.

In addition to having distinct perceptions of top management and supervisors in the construction industry, construction workers are also likely to have distinct perceptions of their co-workers. This is due to a mobile workforce, mixed union and non-union worksites, varying job sites away from the contractor's office, and sub-contracting. These characteristics lead to a workforce that is relatively disconnected with top management and more connected with their crews (i.e., supervisor and co-workers). While the management sets the stage for the safety of their job sites, safety climate perceptions of crews may be more likely to affect safety behaviors on the job.

Although the contribution of co-workers in the development of safety climate in the construction industry may be critical, the contributing effects are not well understood. Kines et al. (2011) tested the NOSACQ-50 in the Nordic construction industry and found that co-worker factors were significantly related to worker safety motivation and safety behavior. In a sample of construction workers from Hong Kong and Spain, Melia et al. (2008) also found support for the importance of co-workers in the development of safety climate and in the relationship between safety climate and safety behaviors.

In any models that highlight co-workers in the development of safety climate, it is important to understand the relationships between safety climate and safety behavior norms among work groups. Norms are “informal rules that groups adopt to regulate and regularize group members’ behavior” (Feldman, 1984). Norms are composed of both descriptive (what is actually done) and injunctive (what should be done) elements (Cialdini et al., 1990). They develop from what supervisors and co-workers say, memorable events, through primacy, and prior experiences (Feldman, 1984). On the other hand, safety climate represents worker perceptions of “how things are really done around here,” not what is espoused. According to Zohar (2011), safety climate stems from perceptions of the pattern with which safety is prioritized over competing organizational goals. The main referents of these perceptions are top management and supervisors, as they hold formal power to dictate safety policies, procedures and practices. Yet, evidence suggests that co-workers influence each other even after accounting for managerial influences (Chiaburu and Harrison, 2008). It is likely that that norms develop based on workers’ perceptions of managements’ response to safety as well as co-workers’ response to safety. Overtime, through the words and deeds of their responses to safety, workers learn what types of behaviors should be performed in order to get the job done. Ultimately, work group safety behavior norms develop that guide each worker’s personal safety behaviors. This is akin to the behavior-outcome expectancies described by Zohar (2001). Thus, workers’ perceptions of the safety response of all three referents do not represent group safety behavior norms, but rather inform them and ultimately influence the personal safety behaviors of all workers.

1.2. Present study

After interviewing 23 construction workers and supervisors, Torner and Pousette (2009) concluded that safety performance “is dependent on the development of open and mutually trustful vertical as well as horizontal relationships within the contractor company…[furthermore], the complexity of construction work demands…the need for collective norms favoring safety” (pg., 407). While the involvement of management in safety is essential, the perception of co-workers valuing and prioritizing safety may be just as important. Increasing our understanding of co-worker safety climate perceptions within a framework that includes top management and supervisors will allow for a more detailed understanding of how each “safety agent” influences one another and how their combined effect contributes to safety performance. Thus, the purpose of the present study is to evaluate the usefulness of Melia et al.’s (2008) and Brondino et al.’s (2012) concept of safety climate in the US construction industry. The present study is the first to assess the concept of co-worker safety climate perceptions as well as the cumulative effect of the safety climate factors on proximal safety outcomes (i.e., safety behaviors) in a US construction cohort.

The present study evaluated the hypothesized model in Figure 2. It is similar to the hypothesized relationships in Melia et al.’s (2008) and Brondino et al.’s (2012) studies; however, the present study distinguished between the two types of safety behaviors (i.e., compliance and participation). The purpose of including the two types of safety behaviors was to determine if there was a differential effect of the safety climate factors on the two kinds of safety behaviors. This is because previous research found that safety climate factors have a greater effect on behaviors related to promoting safety practices (i.e., participation) than behaviors related to complying with rules (i.e., compliance) (Christian et al., 2009). While previous research found significant relationships between safety climate factors and safety behaviors, little research investigated co-worker safety climate factors and safety behaviors.

Hypothesis 1: There is a direct relationship between all safety climate factors and safety behaviors.

Hypothesis 2: There is a indirect relationship between all safety climate factors and safety behaviors.

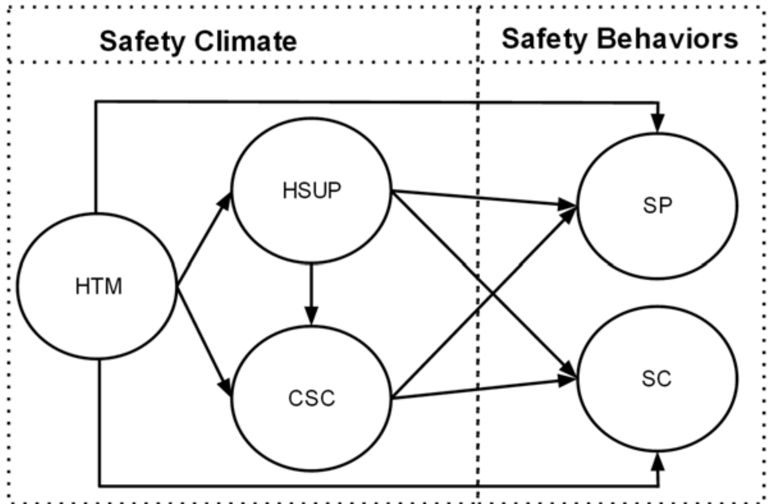

Figure 2. Hypothesized model of the effect of safety climate factors on safety behaviors

Note. HTM: Higher order top management, HSUP: Higher order supervisor, CSC: Co-worker safety commitment, SP: Safety participation, SC: Safety compliance

Chapter 2

Methods

2.1. Participants & Procedure

Three medium-sized mechanical construction firms (e.g., installation of plumbing and heating / ventilation systems) in the Pacific Northwest region of the US participated in the study. A total of 300 construction workers completed the surveys, which represents a response rate of 71%. The majority of participants were Caucasian (82%) and male (96%) with an average age of 41.4 years (SD = 11.6). Participants had been with their company an average of 38 months (SD = 50), with their immediate supervisor for 12 months (SD = 23), and had worked in their craft for an average of 15 years (SD = 10.7). The sample represented 18 pre-apprentices, 41 apprentices, 136 journeymen, 72 foremen, 5 superintendents, 5 top management, and 20 individuals from other positions (e.g., engineers). The main trades represented by this sample include unionized plumbers, pipefitters, and sheet metal workers. The University Institutional Review Board approved all study related methods.

Surveys were distributed during normal work hours during breaks or pre-scheduled meetings (e.g., morning huddles, tool box talks, or safety meetings). Before the surveys were distributed, all workers were informed that their participation was voluntary and that no individual identifying information would be collected from them. They were told the survey would take 15-20 minutes to complete. The majority of surveys were distributed to the workers by the research investigators at the jobsite. Members of the company's safety team distributed surveys to workers that were not present when the investigators were on the jobsite. Regardless of who distributed the survey, all surveys were collected upon completion and placed into a sealed envelope, in which the investigators collected and maintained at the university.

2.2. Measures

2.2.1. Safety climate

In the present study, safety climate was defined as *worker perceptions of company safety policies, procedures and practices*. Workers were asked to respond to questions referring to their top management, supervisors, and co-worker's safety response. The survey items were adapted from the NOSACQ-50 (Kines et al., 2011), which was tested in the construction industry and includes a variety of distinct safety climate dimensions that represent company safety policies, procedures and practices. Four of the seven dimensions of safety climate in the NOSACQ-50 were used in the present study. These included: 1) management safety priority, commitment, and competence 2) management safety empowerment, 3) management safety justice, and 4) co-worker's safety commitment. The three other dimensions were excluded because either they did not pertain to the present study (e.g., perceptions of their trust in the efficacy of their workplace safety systems) or because of survey length restrictions.

In order to evaluate safety climate factors that reflect perceptions of both top management and supervisors, Kines et al.'s (2011) management factors were altered to reflect the referents "top management" and "my current, immediate supervisor" instead of "management." This was accomplished by splitting Kines et al.'s (2011) management factors according to Zohar's (2011) conceptualization of the specific safety activities or focuses that each respective level of management is concerned with. For example, top management is concerned with financial expenditures, reducing production in favor of safety and providing workers with information; on the other hand, supervisors monitor and reward workers and stick to safety rules when production falls behind. An example question for top management was, "Top management places safety before production." An example question for supervisors was, "My current, immediate supervisor looks the other way when someone is careless with safety."

This resulted in seven factors: 1) top management safety priority, commitment, and competence (4 items), 2) top management safety empowerment (3 items), 3) top management safety justice (3 items), 4) supervisor safety priority, commitment, and competence (5 items), 5) supervisor safety empowerment (4 items), 6) supervisor safety justice (3 items), and 7) co-worker's safety commitment (6 items). All items were assessed on a 6-point likert scale (i.e., never to always). See Appendix 4.I for a description of each factor and their respective questions.

In Kines et al.'s (2011) original measure, the management factors had high factor correlations (r = 0.60 – 0.80), which suggests the possibility for a second order management factor. Thus in the present study, a second order factor was created for the top management safety climate factors and supervisor safety climate factors for the sake of parsimony.

2.2.2. Safety behaviors

Safety behaviors were assed by employing a measurement tool that asked questions related to self reports of safety compliance and participation behaviors (Neal et al., 2000). Three items of this measurement tool were used to assess safety compliance (e.g., "I use all the necessary safety equipment to do my job") and three items assessed safety participation (e.g., "I promote the safety program within the organization"). The measure was chosen because it was found reliable and valid (Griffin and Neal, 2000; Probst, 2004) and for its short length as compared to other measures of safety behaviors (Pousette et al., 2008). All items were assessed on a 6-point likert scale (i.e., never to always). Since Brondino et al.'s (2012) findings suggested that safety climate factors may have a different effect on each factor representing safety behaviors, a second order safety behaviors factor was not tested. See Appendix 4.I for a description of each factor and their respective questions.

2.3. Analyses

The psychometric properties of all factors included in the study (i.e., safety climate and safety behavior factors) were assessed via confirmatory factor analysis (CFA). The direct and indirect effects of all paths in Figure 1 were determined via SEM. Descriptive analyses in SPSS 21 revealed that the variables exhibited moderate non-normality. Thus, CFA and SEM models were estimated using maximum likelihood parameter estimates with standard errors and a chi-square test statistic that are more robust to non-normality in MPlus version 7.0 software (Mplus code: ANALYSIS=MLR). Additionally, MLR is also a full information maximum likelihood (FIML, also known as direct maximum likelihood) estimation method that can account for missing data. Unlike pairwise or listwise deletion, FIML estimates all parameters at once with all available data (Brown, 2011, p. 368; Kline, 2011, p. 177). Model fit was assessed by examining the chi-square model test statistic, RMSEA, GFI, CFI, and SRMR. Acceptable fit was indicated by values > 0.95 for CFI and TLI, < 0.06 for RMSEA and SRMR (Brown, 2011). The chi-square model test statistic indicates acceptable fit when the statistic value is low, $p > .05$ and/or the ratio of the chi-square test statistic over degrees of freedom (DF) is < 2.0 (Hinkin, 1995). When comparing nested models (e.g., adding or removing paths) to find the best model fit, the chi-square difference test specific to the MLR estimator was calculated (Mplus, n.d.). A failure to reject the chi-square test indicates that the more restrictive (null) model with fewer paths estimated is better than the less restrictive model (alternative) with more paths estimated (Kline, 2011). Finally, indirect effects (i.e., mediation effects) were estimated using the MODEL INDIRECT command and a bias-corrected bootstrapping method to estimate the significance of the effects (Williams and MacKinnon, 2008).

Chapter 3

Results

3.1. Confirmatory factor analysis

A confirmatory factor analysis with all 34 questions representing 7 first order safety climate factors, 2 first order safety behavior factors, and 2 second order safety climate factors (top management and supervisor) had poor to moderate fit, χ^2 = 810 (511), p = 0.000, RMSEA = 0.044 95% CI = 0.038-0.050, CFI = 0.918, TLI = 0.910, SRMR = 0.062. While a model *without* the 2 higher order factors fit the data better (χ^2 = 33 (20), $p < 0.05$), the higher order factors were retained because 1) the first order factor loadings onto the higher order factors were high (β = 0.70 – 0.97) and 2) the fit indices did not change appreciably. Thus, the higher order factors were kept for the sake of parsimony.

To improve the fit of the latter model, all items were inspected for insignificant or low factor loadings and low squared multiple correlations. Of the 34 items, 5 items had low factor loadings (β = 0.16 – 0.44) and squared multiple correlation values (0.02 – 0.19), but were statistically significant. Despite their significance, their low factor loadings indicated that the items were not related to their proposed factors. Removing the insignificant items resulted in a poor to moderately good fitting model, χ^2 = 595 (361), p = 0.000, RMSEA = 0.047 95% CI = 0.040-0.053, CFI = 0.928, TLI = 0.920, SRMR = 0.060.

Modification indices were inspected from the latter model to determine additional sources of model misfit. The largest modification index value was related to a correlated errors term for two of the co-worker safety commitment factor item's errors, and are indicative of variance that cannot be accounted for by the factors on which the items load. Theoretically, this inclusion made sense because the items were worded very similarly (Brown, 2011). Including the correlated error term in the model resulted in significantly improved model fit (χ^2 = 17 (1), p <

0.05), and resulted in moderately good fit, $\chi^2 = 549$ (360), $p = 0.000$, RMSEA = 0.042 95% CI = 0.035-0.049, CFI = 0.942, TLI = 0.935, SRMR = 0.056.

Additional modification indices from the latter model indicated that the fit of the model would be significantly improved if one item from the supervisor safety priority, commitment, and competence factor was allowed to cross-load onto the supervisor safety empowerment factor. Including the cross-loading item in the model resulted in significantly improved fit ($\chi^2 = 42.90$ (1), $p < 0.05$), and resulted in good fit, $\chi^2 = 501$ (359), $p = 0.000$, RMSEA = 0.036 95% CI = 0.029-0.044, CFI = 0.957, TLI = 0.951, SRMR = 0.048. All item factor loadings were significant ($p < 0.01$) and had standardized factor loadings ranging from 0.503 to 0.979. One factor loading, which cross loaded onto two supervisor factors as previously mentioned, had a significant but low factor loading ($\beta = 0.274$) on the supervisor safety priority, commitment and competence factor, but it was kept. Inter-item reliability scores were good ($\alpha = 0.68 - 0.85$). A detailed table with item loadings, standard errors, p-values, and Chronbach's alpha for each factor can be seen in Appendix 4.II. Table 11 shows the correlations for all factors in the final conceptual model.

Table 11. Means, standard deviations (SD) and factor correlations of all study variables

Variable	Mean	SD	1	2	3	4	5
1. Higher order top management (HTM)	4.14	0.73	1.00	0.66	0.55	0.45	0.40
2. Higher order supervisor (HSUP)	4.35	0.64		1.00	0.58	0.39	0.24
3. Co-worker safety commitment (CSC)	4.29	0.70			1.00	0.62	0.59
4. Safety compliance (SC)	4.41	0.63				1.00	0.63
5. Safety participation (SP)	3.83	0.94					1.00

Note. All correlations are significant (p < 0.001). Items were rated on a frequency scale from 0 to 5, Never to Always.

3.2. Structural equation modeling

The hypothesized model (see Figure 2) provided good fit, $\chi^2 = 507$ (359), $p = 0.000$, RMSEA = 0.036 95% CI = 0.029-0.044, CFI = 0.957, TLI = 0.951, SRMR = 0.048. However, since 1) the second order supervisor factor was hypothesized to mediate the relationship between the second order top management and co-worker factors, and 2) the co-worker factor was hypothesized to mediate the relationships between the second order top management and second order supervisor factors and both safety behavior factors, the hypothesized model was compared to two competing hierarchical models (see Figure 3). Compared to the hypothesized model in Figure 1, hierarchical model A did not result in significantly better fit ($\chi^2 = 15.68$ (5), $p < 0.01$), but hierarchical model B did result in better fit ($\chi^2 = 4.79$ (4), $p > 0.05$). This indicates that the direct paths of both second order management factors on both safety behavior factors did not improve the fit of the model. The final model with all significant standardized parameter path estimates and r^2 values is illustrated in Figure 4.

The strength of the mediation effects can be seen in Table 12. In relation to just the safety climate factors, the relationship between second order top management factor and co-worker safety commitment factor was significantly partially mediated by the second order supervisor factor. In relation to the safety behavior outcomes, the co-worker safety commitment factor significantly mediated the relationship between the second order top management and both types of safety behaviors. The present study hypothesized that the model (see Figure 2) proposed by Melia et al. (2008) and Brondino et al. (2012) would also be appropriate for an assessment of safety climate perceptions among US construction workers. Specifically, there would be significant direct (hypothesis 1) and indirect effects (hypothesis 2). The results indicated that Hypothesis 1 was only partially supported, because the direct effects from both second order management factors on both types of safety behaviors were non-significant. Hypothesis 2 was fully supported, because all estimated indirect effects were significant.

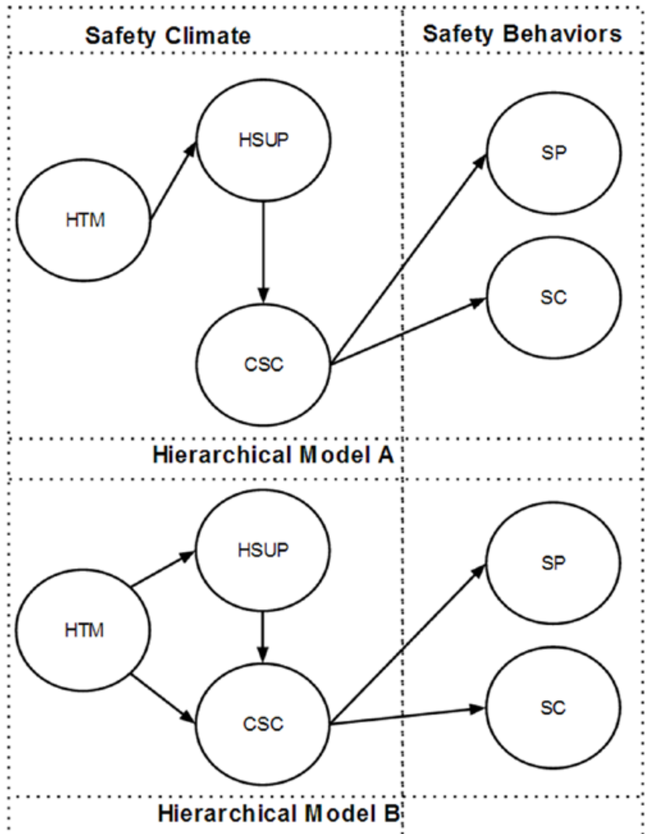

Figure 3. Hierarchical models compared to hypothesized model in Figure 2

Note. HTM: Higher order top management, HSUP: Higher order supervisor, CSC: Co-worker safety commitment, SP: Safety participation, SC: Safety compliance

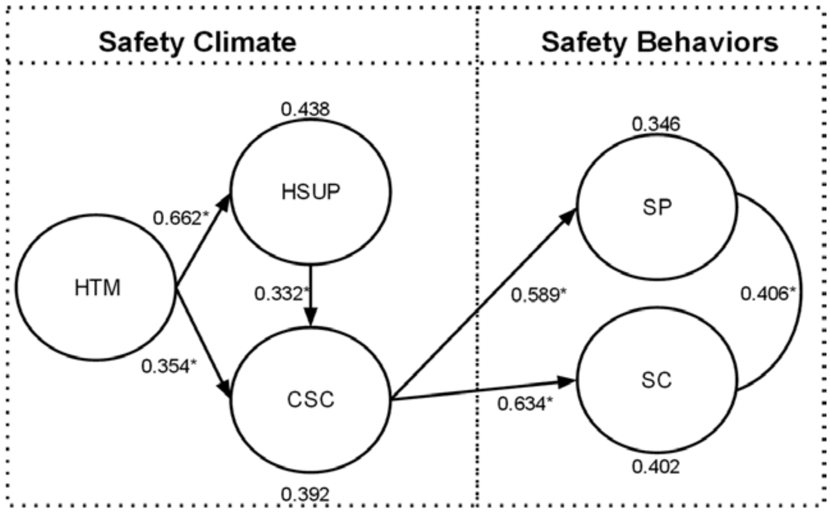

Figure 4. Final structural model with significant path estimates

Note. *Significant ($p < 0.001$). Only paths significant at $p < .001$ are shown. Values beside latent variables represent variance accounted for. HTM: Higher order top management, HSUP: Higher order supervisor, CSC: Co-worker safety commitment, SP: Safety participation, SC: Safety compliance

Table 12. Mediation effects in the final structural equation model

	Estimate (S.E.)	**95% CI**
<u>Safety climate specific</u>		
Effects from HTM to CSC		
HTM → HSUP → CSC	0.220 (0.085)	0.054-0.386
HTM → CSC	0.354 (0.109)	0.140-0.568
Total indirect effect	*0.220 (0.085)*	*0.054-0.386*
Total direct + indirect effect	*0.571 (0.056)*	*0.464-0.684*
<u>Effects on Safety Participation</u>		
Effects from HTM to SP		
HTM → HSUP → CSC → SP	0.130 (0.049)	0.033-0.226
HTM → CSC → SP	0.208 (0.057)	0.061-0.356
Total indirect effect	*0.338 (0.057)*	*0.227-0.449*
<u>Effects on Safety Compliance</u>		
Effects from HTM to SC		
HTM → HSUP → CSC → SC	0.139 (0.054)	0.034-0.245
HTM → CSC → SC	0.224 (0.076)	0.076-0.373
Total indirect effect	*0.364 (0.055)*	*0.256-0.472*

Note. HTM: Higher order top management, HSUP: Higher order supervisor, CSC: Co-worker safety commitment, SP: Safety participation, SC: Safety compliance

Chapter 4

Discussion

The present study was one of the first to test a concept of safety climate that focuses on perceptions of how individuals at each company level (top management, supervisors and co-workers) respond to safety and how these perceptions affect personal safety behaviors. This concept of safety climate was proposed by Melia et al. (2008) and Brondino et al. (2012) as an extension of Zohar's (2005) multi-level concept, which focused on top management and supervisors only. The present study evaluated the three-safety agent safety climate concept in the US construction industry and found similar results. Specifically, worker perceptions of their co-workers' commitment to safety is an important safety climate factor that explains the mechanism by which safety behaviors are affected by top managements' and supervisors' response to safety. The present study's comparable results strengthens the evidence for a concept of safety climate that focuses on "who" performs actions rather than relying solely on "what" actions were performed.

Melia et al. (2008) tested this concept of safety climate among four cohorts, two general cohorts from the United Kingdom and Spain and two construction cohorts from Hong Kong and Spain, using multiple regression. Brondino et al. (2012) tested the concept in the Italian manufacturing industry using multi-level SEM. In both Melia et al.'s (2008) and Brondino et al.'s (2012) studies, top management's safety response had a direct effect on safety behaviors. Yet, in the present study they did not. Supervisor's safety response affected some sample's safety behaviors in Melia et al.'s (2008) study (English general and Chinese construction cohorts), but they did not affect them in Brondino et al.'s (2012) or the present study's cohort. In both the previous and the present studies, co-worker safety response had a significant direct relationship with safety behaviors. Additionally, Brondino et al.'s (2012) and the present study found significant mediation effects among the safety climate factors and between the safety climate and safety behavior factors. Melia et al. (2008) did not test mediation in their study. Ultimately, these studies support the inclusion of perceptions of individuals at all three company levels in the measurement of safety climate and the prediction of safety behaviors.

While previous research found a direct relationship between both management levels and safety outcomes (Brondino et al., 2012; Kines et al., 2011; Meliá et al., 2008; Zohar and Luria, 2005), the present study indicates that the relationship is mediated by co-worker's commitment to safety. These findings broaden our understanding of how management's response to safety influences safety behaviors. It indicates that it is important to include the co-worker factor alongside the top management and supervisor factors in the safety agent concept of safety climate. It's inclusion helps to explain how top management and supervisor's safety response to safety influences safety behaviors. It is through positive perceptions of co-workers commitment to safety that top management and supervisors can influence safety behaviors. In other words, workers must perceive that their co-workers are committed to safety in order for management to positively influence safety behaviors on the job. In practice, co-workers' response to safety should be seen as just as important in forming a high safety climate as management's response to safety. Building a commitment to safety among co-workers should be emphasized in educational programs such as toolbox talks.

Perhaps the reason that co-worker safety climate factor had such a great influence on safety behaviors in this study is because the majority of the workers in the study belonged to unions. Unions provide workers training, they find job sites for them to work on, and negotiate wages and safety standards. Unions also provide a sense of belonging and brotherhood (Barbeau et al., 2005). Thus, union workers may feel closer to and responsible for the safety of their co-workers (who are also members of the same union). Additionally, workers are influenced by their co-workers commitment to safety and the pressure to conform to group norms of whether or not to be a "tough guy" (Choudhry and Fang, 2008). Thus, the present study lends support for the necessity to understand the influence of co-workers, not just management, in safety climate investigations (Chiaburu and Harrison, 2008).

4.1. Future directions & Limitations

4.1.1. Relationships to be addressed

While the present study provides corroborative evidence suggesting a causal relationship among the variables, the true causal effect cannot be inferred from this study's research design. To move towards an understanding of the causal relationships among the variables in the study, a few additional research activities should be completed (Antonakis et al., 2010).

The concept of safety climate could be strengthened by the inclusion of other potential explanatory variables. Since the present study found support for the co-worker safety climate factor, it is possible that team member exchange (TMX) might have a significant positive relationship with safety climate. TMX represents worker's relationship with their work group as a whole. Under high quality TMX, workers assist each other and share their ideas and feedback (Seers, 1989). Future research should consider TMX in the context of this safety climate concept and the potential causal or reciprocal relationship with leader factors that previous research linked with safety climate (i.e. transformational leadership style and leader member exchange) (Barling et al., 2002; Hofmann et al., 2003; Mullen and Kelloway, 2009). Additionally, the inclusion of empirical measures of safety behavior norms was beyond the intention and scope of the present study. Thus, future research assessing the mediating role of safety behavior norms between safety climate and personal safety behaviors may be of interest.

Reverse causation should be addressed through a longitudinal design. Reverse causation suggests that the outcome may actually occur before its predictor. Reverse causation can be ruled out with longitudinal study designs, as they help to distinguish which variables truly influence other variables over time. In the present study, it is unclear if the management safety climate factors predict the co-worker safety climate factor over time. Nor is it clear if one safety climate factor predicts safety behaviors better than the others over time. Furthermore, a longitudinal design may indicate that workers who perform more safety behaviors may influence perceptions of co-worker's commitment to safety or that a feedback loop exists between them. Within the context of the aforementioned additional leadership and team member variables to be included in the model, there may be reciprocal relationships between variables or paths that may work in an unexpected direction.

Finally, the model could be improved by testing its validity among and between other construction companies in different US geographical regions as well as other countries, trades, union and non-union contractors, and size of company (i.e., number of workers). Including fixed effects such as these in the model will allow commonalities between workers and companies to be addressed. For example, questions remain about how company size may affect safety climate perceptions. Larger companies have more resources for safety policies, procedures and practices, thus higher levels of safety climate perceptions may exist among larger companies. Yet, the majority of contractors in the US and Europe are small in size (i.e., 9 workers or less) (Center for Construction Research and Training, 2013; eurostat, n.d.). A large-scale multilevel study of safety climate perceptions among different contractors could answer this question, and offer potential avenues for safety climate intervention research.

4.1.2. Safety climate interventions

The present study supports the use of proactive work place interventions to improve health and safety. Efforts to improve safety climate on the job include transformational leadership training (Mullen and Kelloway, 2009) and feedback methods to increase safety specific communication between supervisors and workers (Kines et al., 2010; Zohar and Polachek, 2013). The present study supports the use of these kinds of interventions. Yet, it also supports team based interventions, as suggested by Brondino et al. (2012). Such interventions could improve the relationship between management and workers as well as among workers themselves. Specifically, interactive and engaging training among work teams may be an effective means of increasing safety knowledge and performance (Burke et al., 2011). Participatory ergonomics is an example of one such intervention (Rivilis et al., 2008).

4.2. Limitations

Many of the present study's limitations were addressed in the previous section 4.1.1. (i.e., cross-sectional design, omitted variables, omitted fixed effects, and common method variance). The present study also only represents one region of the US and a few construction trades, and thus may not be generalizable to the entire US construction industry. Finally, a main tenant of safety climate is that perceptions of it are *shared*, but the present study could not determine *sharedness* among work groups. Thus, the present study only addressed psychological safety climate.

4.3. Conclusions

The irremediable construction safety culture depicted in Applebaum's (1981) ethnography is slowly transitioning into a culture that rejects the fallacy that accidents just happen and can't be prevented. There is growing empirical evidence that as safety climate / culture improves injuries and fatalities are reduced. The present study evaluated a conceptual model of safety climate that focused on safety agents (top management, supervisors, and co-workers) within the US construction industry. The results indicated that the safety responses of top management, supervisors, as well as co-workers contribute to positively impact safety behaviors on the job. The present study indicated that worker's must perceive that their co-workers are committed to safety in order for top management and supervisors to influence safety behaviors on the job. These results support workplace health and safety interventions targeted towards not only leadership, but also work teams.

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Appendix 4.I

Safety behavior and safety climate survey questions

Safety behaviors

(Neal, Griffin, & Hart, 2000)

1. Safety Compliance (SC) adhering to safety procedures and carrying out work in a safe manner

Please circle the number to best rate the frequency of each statement	**Never**	**Rarely**	**Sometimes**	**Fairly Often**	**Very Often**	**Always**
6. I use all the necessary safety equipment to do my job	0	1	2	3	4	5
2. I use the correct safety procedures for carrying out my job	0	1	2	3	4	5
3. I ensure the highest levels of safety when I carry out my job	0	1	2	3	4	5

2. Safety Participation (SP): Helping coworkers, promoting the safety program within the workplace, demonstrating initiative, and putting effort into improving safety in the workplace

Please circle the number to best rate the frequency of each statement	**Never**	**Rarely**	**Sometimes**	**Fairly Often**	**Very Often**	**Always**
4. I promote the safety program within the organization	0	1	2	3	4	5
5. I put in extra effort to improve the safety of the workplace	0	1	2	3	4	5
1. I voluntarily carry out tasks or activities that help to improve workplace safety	0	1	2	3	4	5

Safety climate

(Kines et al. 2011)

Management Level Factors:

1. Management safety priority, commitment and competence (9 questions): Workers' perceptions of management: prioritizing safety, being active in promoting safety and reacting to unsafe behavior, showing competence in handling safety, and communicating safety issues

Please circle the number to best rate the frequency of each statement	**Never**	**Rarely**	**Some-times**	**Fairly Often**	**Very Often**	**Always**
Top management (TMP):						
7. *Top management* places safety before production	0	1	2	3	4	5
15. We who work here have confidence in *top management's* ability to deal with safety	0	1	2	3	4	5
14. *Top management* ensures that safety problems discovered during safety rounds/evaluations are corrected immediately	0	1	2	3	4	5
16. *Top management* ensures that everyone receives the necessary information on safety	0	1	2	3	4	5
Supervisor (SUPP):						
17. *My current, immediate supervisor* looks the other way when someone is careless with safety	0	1	2	3	4	5
28. *My current, immediate supervisor* encourages employees here to work in accordance with safety rules - even when the work schedule is tight	0	1	2	3	4	5
19. *My current, immediate supervisor* accepts employees here taking risks when the work schedule is tight	0	1	2	3	4	5
20. When a risk is detected, *my current, immediate supervisor* ignores it without action	0	1	2	3	4	5
21. *My current, immediate supervisor* does not deal with safety properly	0	1	2	3	4	5

2. Management safety empowerment (7 questions): Workers' perceptions of management empowering workers and supporting participation

Please circle the number to best rate the frequency of each statement	**Never**	**Rarely**	**Some-times**	**Fairly Often**	**Very Often**	**Always**
		Top management (TME):				
10. *Top management* strives to design safety routines that are meaningful and actually work	0	1	2	3	4	5
9. *Top management* involves employees in decisions regarding safety	0	1	2	3	4	5
12. *Top management* strives for everybody at the worksite to achieve high competence concerning safety and risks	0	1	2	3	4	5
		Supervisor (SUPE):				
22. *My current, immediate supervisor* encourages employees here to participate in decisions which affect their safety	0	1	2	3	4	5
24. *My current, immediate supervisor* considers employees' suggestions regarding safety	0	1	2	3	4	5
26. *My current, immediate supervisor* asks employees for their opinions before making decisions regarding safety	0	1	2	3	4	5
25. *My current, immediate supervisor* makes sure that everyone can influence safety in their work environment	0	1	2	3	4	5

3. <u>Management safety justice (6 questions):</u> Workers' perceptions of management treating workers who are involved in accidents fairly

Please circle the number to best rate the frequency of each statement	**Never**	**Rarely**	**Some -times**	**Fairly Often**	**Very Often**	**Always**
			Top management (TMJ):			
13. *Top management* looks for causes, not guilty persons, when an accident occurs	0	1	2	3	4	5
11. *Top management* blames employees for accidents	0	1	2	3	4	5
8. *Top management* treats employees involved in an accident fairly	0	1	2	3	4	5
			Supervisor (SUPJ):			
23. *My current, immediate supervisor* collects accurate information in accident investigations	0	1	2	3	4	5
27. Fear of sanctions (negative consequences) from *my current, immediate supervisor* discourages employees here from reporting near-miss accidents	0	1	2	3	4	5
18. *My current, immediate supervisor* listens carefully to all who have been involved in an accident	0	1	2	3	4	5

Work crew level factor:

1. Workers' safety commitment (6 questions): Workers' perceptions of how they themselves relate to safety at work concerning if they generally: show commitment to safety and are active in promoting safety and care for each other's safety

Please circle the number to best rate the frequency of each statement	**Never**	**Rarely**	**Some-times**	**Fairly Often**	**Very Often**	**Always**
	Co-worker (CSC):					
29. My coworkers and I try hard together to achieve a high level of safety	0	1	2	3	4	5
30. My coworkers and I take joint responsibility to ensure that the workplace is kept tidy	0	1	2	3	4	5
31. My coworkers and I do not care about each others' safety	0	1	2	3	4	5
32. My coworkers and I avoid tackling risks that are discovered	0	1	2	3	4	5
33. My coworkers and I help each other to work safely	0	1	2	3	4	5
34. My coworkers and I take responsibility for each others' safety	0	1	2	3	4	5

Appendix 4.II

Safety climate and safety behavior: Confirmatory factor analysis results

Factor	**Item**	**Estimate**	**S.E.**	**P-Value**	**Inter-item reliability (α)**
SP	V1	0.686	0.051	P < 0.01	0.828
	V4	0.809	0.033	P < 0.01	
	V5	0.873	0.029	P < 0.01	
SC	V2	0.851	0.027	P < 0.01	0.840
	V3	0.848	0.031	P < 0.01	
	V6	0.714	0.042	P < 0.01	
TMP	V7	0.716	0.045	P < 0.01	0.844
	V14	0.715	0.038	P < 0.01	
	V15	0.860	0.024	P < 0.01	
	V16	0.814	0.028	P < 0.01	
TME	V9	0.755	0.034	P < 0.01	0.812
	V10	0.817	0.036	P < 0.01	
	V12	0.772	0.036	P < 0.01	
TMJ	V8	0.784	0.039	P < 0.01	0.717
	V13	0.727	0.056	P < 0.01	
SUPP	V17	0.704	0.074	P < 0.01	0.846
	V19	0.823	0.043	P < 0.01	
	V20	0.752	0.078	P < 0.01	
	V21	0.759	0.094	P < 0.01	
	V28	0.274	0.113	P < 0.01	
SUPE	V24	0.882	0.031	P < 0.01	0.801
	V25	0.805	0.035	P < 0.01	
	V26	0.574	0.060	P < 0.01	
	V28	0.503	0.098	P < 0.01	
SUPJ	V18	0.653	0.076	P < 0.01	0.679
	V23	0.779	0.062	P < 0.01	
CSC	V29	0.808	0.034	P < 0.01	0.850
	V30	0.731	0.037	P < 0.01	
	V33	0.702	0.081	P < 0.01	
	V34	0.683	0.064	P < 0.01	
HTM	TMP	0.927	0.032	P < 0.01	
	TME	0.979	0.023	P < 0.01	
	TMJ	0.920	0.039	P < 0.01	
HSUP	SUPP	0.625	0.075	P < 0.01	
	SUPE	0.974	0.034	P < 0.01	
	SUPJ	0.946	0.054	P < 0.01	

Note. Each of the items correspond to the numbered questions in Appendix 4.I. HTM (Higher order top management safety climate factor) and HSUP (Higher order supervisor safety climate factor)

PART V

Construction supervisors' safety performance: The impact of safety climate perceptions and safety climate knowledge on safety behaviors

Chapter 1

Introduction

In Gillen et al.'s (2004) interviews with 64 construction workers on what constituted good management safety practices, one worker said, "I think as a foreman you have to really…lead by example more than anything else…then the people that you see know that you're serious about it, then they're going to get serious about it" (pg. 249). This statement typifies the importance of supervisors in the construction industry. As is common in the construction industry, directing crews on job sites away from the primary organizational unit allows superintendents and supervisors to create their own safety climate and influence how the work is performed (i.e., safely or unsafely). Their safety specific words and deeds set the stage for how work is performed (Dingsdag, Biggs, & Sheahan, 2008; Törner & Pousette, 2009). Supervisors who place a low priority and value on safety are likely to negatively influence worker safety climate, and in turn unknowingly promote poor safety behaviors among their crews (Zohar, 2011). Ultimately, any effort to monitor and control occupational health and safety in the construction industry requires buy-in from supervisors such that they are not only leading by example, but also actively engaging their crews in safety practices (Zohar, 2002). However, an understanding of why and how supervisors come to perform these types of safety behaviors is unclear.

1.1. Safety behaviors and the factors that influence them

1.1.1. Types of safety behaviors

Safety behaviors are typically conceptualized as behaviors that are task related and behaviors that are contextually related to safety specific job-tasks. Task oriented safety behaviors involve behaviors that directly contribute to job site safety (e.g., following safety procedures) whereas contextual behaviors indirectly contribute to job site safety (e.g., promoting the safety program) (Borman & Motowidlo, 1997; Griffin & Neal, 2000). Meta-analyses have linked positive safety behaviors to fewer incidents and injuries on the job (Christian, Bradley, Wallace, & Burke, 2009; Clarke, 2006; 2010). Among construction supervisors, both types of safety behaviors are important not only for their personal safety, but also for the safety of their crews. Supervisors who follow all safety policies and procedures model safe behaviors for their crews. They demonstrate to their crews that following company safety policies and procedures is an important facet of job performance. Furthermore, supervisors who promote safe practices and put in extra effort to ensure a safe workplace convey a value and priority for safety on, as well as off, the job. Supervisors who perform both types of safety behaviors (task and contextual) on the job communicate that safety is valued and expected on the job, which ultimately influences crew safety climate perceptions and other important safety outcomes (S. E. Biggs, Banks, Davey, & Freeman, 2013; Gittleman et al., 2010; Kines et al., 2010).

1.1.2. Safety climate perceptions

A work environment where safety is talked about, planned for, and ultimately valued regardless of production schedules is an environment conducive to positive safety climate perceptions. Prior research has linked positive worker safety climate perceptions to positive safety outcomes (e.g., safety knowledge and behaviors) (Christian et al., 2009; Clarke, 2006; 2010), and in some cases longitudinal research designs found support for a causal relationship between safety climate and safety outcomes (Pousette, Larsson, & Törner, 2008). Alternatively, a lack of attention to safety issues and behaviors that reflect other priorities may have negative effects on job site safety climate. This is often fueled by workers' perceptions that management clearly values adhering to production schedules rather than to safety practices. Thus, supervisors may be more unlikely to behave safely if they feel under pressure to meet production demands, and unsupported by their contractor (Conchie, Moon, & Duncan, 2013).

1.1.3. Safety climate knowledge

Based on prior safety climate research, there is evidence that safety knowledge mediates the relationship between safety climate perceptions and personal safety behaviors (Christian et al., 2009; Griffin & Neal, 2000; Neal, Griffin, & Hart, 2000). An indirect effect in this case asserts that the link between safety climate perceptions and personal safety behaviors occurs because workers have adequate knowledge of methods to be safe. This relationship is based on Campbell's theory of performance that includes the antecedents (e.g., climate) and determinants (i.e., knowledge, skill, and motivation) of performance (Neal et al., 2000). Work environments with a positive safety climate are more likely to have workers who are trained in methods of how to be safe, and workers who understand how to be safe will perform safe behaviors more frequently. This area of research within the construction industry, however, has only investigated general safety knowledge (e.g., "I understand the health and safety regulations relating to my work" (Griffin & Neal, 2000) and did not stratify by job position (e.g., journeymen, foremen, superintendents) to understand their relative influence on workers safety perceptions.

Among construction supervisors (foremen, superintendents, project managers), knowledge specific to safety climate may be an important determinate of their safety related behaviors. Supervisors who understand their own role in worker's perception of safety climate may be more likely to frequently promote safety among their crews. In the present study, the domain of supervisor specific safety climate knowledge includes two components. First, supervisors should have a general notion of what safety climate is. Supervisors should understand that their crew's safety climate perceptions reflect a supervisor's pattern of prioritizing and valuing safety over time (Zohar, 2011). Supervisors should understand that safety climate is most often measured through perception surveys that ask workers questions related to company safety policies, procedures, and practices, and is considered to be a leading (i.e., proactive) indicator of occupational health and safety. Since safety climate measurements often tap into management's safety practices (Flin, Mearns, O'Connor, & Bryden, 2000; Kines et al., 2011; Zohar & Luria, 2005), supervisors should understand they are important indicators of safety climate perceptions. Second, supervisors should understand the safety leadership behaviors that influence safety climate perceptions. Specifically, supervisors should know how to involve and empower their workers in job site safety (Gillen et al., 2004; Törner & Pousette, 2009). They should also be aware of how to give their workers feedback on their safe and unsafe behaviors (Hofmann & Morgeson, 2004; Kines et al., 2010). Finally, when safety-specific problems arise, supervisors should know to proactively address them as part of their work routine (Zohar, 2007).

The present study tested the hypothesized following relationships in Figure 5 among a sample of construction industry supervisors. First, there would be significant, direct relationships among all study variables. Second, the relationship between safety climate and both types of safety behaviors would be partially mediated by safety climate knowledge.

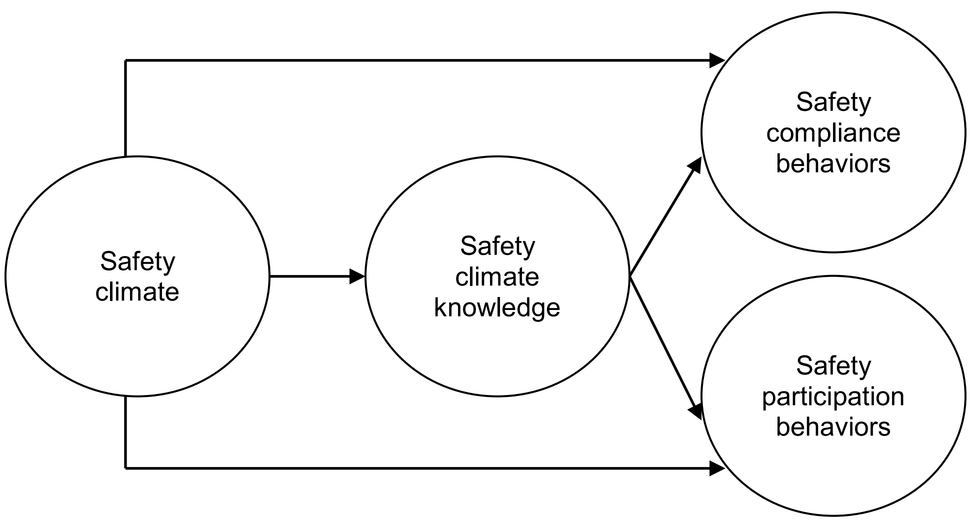

Figure 5. Hypothesized relationship between safety climate, safety climate knowledge, and safety behaviors

Chapter 2

Methods

2.1. Participants

The present study utilized a sub-set of the data reported in a previous study (Schwatka & Rosecrance, 2014). Ninety-one supervisors from three medium sized contractors in the United States participated in the study. The supervisors were foremen (53%), general foremen (20%), field foremen (10%), project managers (9%), superintendents (7%), and project coordinators (1%). The majority of them were from the sheet metal trade (44%); others were pipefitters (33%), plumbers (7%), steamfitters (6%), plumbers and pipefitters (3%) or unspecified (7%). The average age of the supervisors was 44 years (SD = 8.5) and 95% of them were male. They had worked for their company an average of 5.42 years (SD = 5.33).

2.2. Measures

Safety climate: Safety climate perceptions were measured with an adapted version of the Nordic safety climate questionnaire (Kines et al., 2011) tested in a previous study by Schwatka and Rosecrance (2014). A global safety climate score was created based on responses to questions related to top management, supervisor, and co-worker safety response (24 items). Top management and supervisor safety response represented safety commitment, empowerment, and justice questions. For example, “Top management places safety before production” and “My current, immediate supervisor encourages employees to participate in decisions which affect their safety.” Co-worker safety response represented safety commitment questions. For example, “My co-workers and I help each other to work safely.” Responses to questionnaire items were scored on a Likert scale ranging from 0-6, never to always. See Appendix 4.I and Appendix 4.II for a description of each factor and their respective questions.

Safety climate knowledge: Supervisors were asked to complete multiple choice, true/false, and open-ended questions relating to safety climate knowledge that was developed by the researchers. The questionnaire items employed in the present study are outlined in Appendix 5.I. Each of two research team members graded the open-ended questions, and the question's score was derived from the average score given by the two raters. A total safety climate knowledge score was then given for each supervisor (out of 14 points), where higher scores indicate greater knowledge.

Safety behaviors: Safety behaviors were measured with Neal et al.'s (2000) measure of safety performance that includes two factors, safety compliance (3 items) and safety participation (3 items). Sample items include, "I use the correct safety procedures for carrying out my job" and "I voluntarily carry out tasks or activities that help to improve workplace safety." Responses were scored on a Likert scale ranging from 0-6, never to always. See Appendix 4.I and Appendix 4.II for a description of each factor and their respective questions. The University Institutional Review Board approved all methods.

2.3. Statistical analyses

Internal consistency reliability (chronbach's alpha) was computed to justify the use of mean scores as study variables. Given that all alpha values were greater than 0.70, there was adequate justification to create mean scores (see Table 13). Mean scores were computed and descriptive statistics were generated in SPSS version 21. The conceptual model presented in Figure 1 was specified as a path analysis in Mplus, Version 7 (L. K. Muthen & Muthen, 2012). A full information maximum likelihood estimator that appropriately accounts for missing data was used (Kline, 2011). Model fit was not assessed because the hypothesized path model fit the data perfectly (i.e., it was a completely saturated model).

Chapter 3

Results

Descriptive statistics of the safety climate, safety climate knowledge, and safety behavior variables are outlined in Table 13. Safety climate was significantly and positively correlated with safety compliance behaviors, but not safety participation behaviors. Safety compliance and safety participation behaviors were significantly and positively correlated with each other. Safety climate knowledge was not statistically correlated with safety climate or both types of safety behaviors.

Table 13. Descriptive statistics of all study variables

	Mean	SD	1	2	3	4
1. Safety climate	4.31	0.48	0.89	-0.00	0.14	0.32*
2. Safety climate knowledge	6.14	2.22		-	0.00	0.06
3. Safety participation	4.17	0.70			0.72	0.54*
4. Safety compliance	4.54	0.49				0.81

* $p < 0.001$

Note. Correlations are reported above the diagonal. Reliabilities are reported on the diagonal.

The path analysis did not demonstrate that safety climate knowledge mediates the relationship between safety climate and both types of safety behaviors (see

Figure 6). The direct paths to and from safety climate knowledge were not significant. Nor was the indirect path from safety climate, safety climate knowledge, and safety compliance ($\beta = 0.00$, $p = 0.98$) and safety participation ($\beta = 0.00$, $p = 0.98$) significant. However, there was a significant direct path between safety climate and safety compliance behaviors, and a marginally significant path between safety climate and safety participation behaviors.

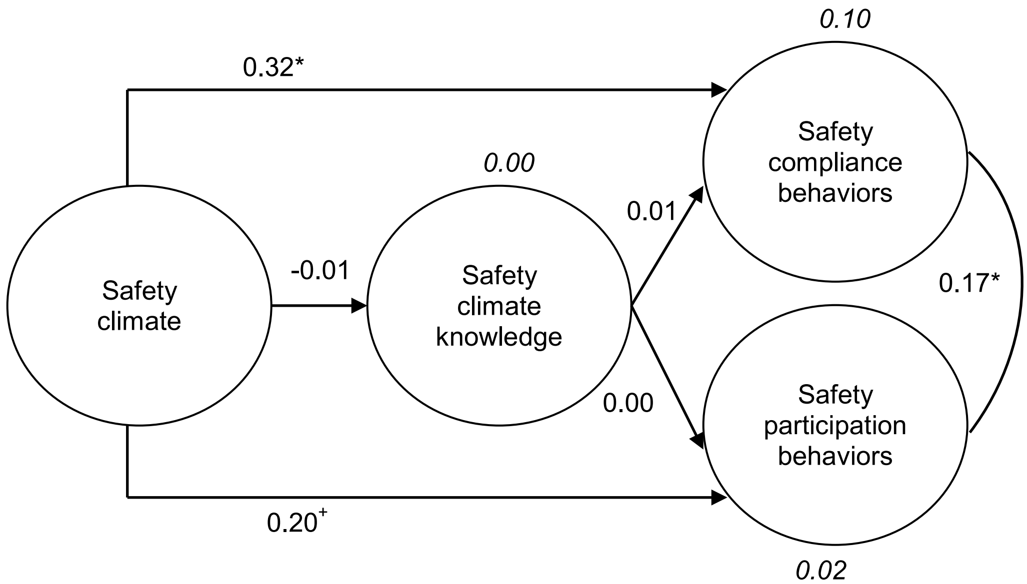

Figure 6. Final path model for relationships between safety climate, safety climate knowledge, and safety behaviors

*$p < 0.001$, $^{+}p = 0.17$
Note. Values in italics represent variance explained

Chapter 4

Discussion

The purpose of the present study was to determine if construction supervisor's knowledge of safety climate mediated the relationship between their perceptions of safety climate and their personal safety behaviors. Contrary to the study's hypothesis, safety climate knowledge was not related to the study variables. Supervisors' perceptions of safety climate was associated with their personal safety behaviors, but this relationship was not mediated by safety climate knowledge. Although these results did not support the initial study hypothesis, they indicate that construction supervisors do comply with safety rules and procedures, and actively promote their contractor's safety program if they perceive that their top management, supervisor, and co-workers are committed to safety. While the study results suggest that it may not be necessary for construction industry supervisors to understand safety climate concepts, it may be more likely that supervisor safety climate knowledge is more related to safety climate-specific improvement behaviors (e.g., involving crews in safety program) or to their style of safety leadership (i.e., safety-specific transformational leadership).

Supervisors mean safety climate knowledge score was relatively low (6.14 out of 14 total possible points, SD = 2.22). Thus, the construction supervisors in our sample were relatively unaware of what safety climate was and they did not know what safety leadership actions they should undertake to influence safety climate. However, our results suggest that it may not matter how much knowledge of safety climate that supervisors have in terms of their safety behaviors. Supervisors can perform positive safety behaviors as a result of their own positive safety climate perceptions regardless of how much they know about safety climate.

The present study provides inconclusive evidence for the hypothesized relationship between safety climate knowledge and safety climate and safety behaviors. The extremely small coefficients combined with the high non-significance levels relating safety climate knowledge to the other study variables indicates that there is no relationship. However, these results may be due to either the way safety climate knowledge was measured or indicative of safety climate knowledge's relationship with other variables not measured.

The questions generated to measure safety climate knowledge were based on safety climate and safety-specific leadership theories, but the wording and structure of some items may have impacted our results. A combination of true/false, multiple choice and open-ended questions were chosen to ascertain supervisor's knowledge. The answers to the open-ended questions were challenging to assess, as there was considerable variation in responses. Multiple graders were utilized in order to overcome a grading bias, however some error may have occurred. Additionally, the closed-ended questions may have been confusing, thus reducing the sensitivity of the knowledge test to detect accurate safety climate knowledge. Lastly, the safety climate knowledge variable in the present study was considered to be a "grade." Prior attempts to measure safety knowledge relied on question responses that were Likert in nature (Griffin & Neal, 2000). Perhaps the results would have been different if safety climate knowledge questions were phrased in a different manner (e.g., "I know how to involve my crews in workplace safety")?

Safety climate knowledge may be more related to variables not included in this study. Prior research that linked safety climate, safety knowledge, and safety behaviors was based on a safety behavior variable that was measured in a general manner (Christian et al., 2009; Griffin & Neal, 2000; Neal et al., 2000). Safety behaviors reflected overarching actions to keep oneself and the work site safe (e.g., "I use the correct safety procedures for carrying out my job") (Neal et al., 2000). Safety climate knowledge may be more related to specific safety climate improvement behaviors (e.g., "I involve my work crew in the safety program").

Additionally, safety climate knowledge may be related to safety specific transformational leadership (SSTL). SSTL is measured by asking workers to rate their manager on four aspects of safety specific transformational leader behaviors (e.g. "My supervisor encourages me to express my ideas and opinions about safety at work"). Prior research linked SSTL to higher safety climate perceptions and other safety outcomes (Barling, Loughlin, & Kelloway, 2002; Kelloway, Mullen, & Francis, 2006; Mullen, Kelloway, & Teed, 2011). Thus, leaders who adopt a transformational style of leadership are likely to positively influence worker safety climate perceptions and other safety outcomes. Furthermore, leaders who understand the concept of safety climate may be more likely to display a safety leadership style with transformational qualities or vice versa. Future research should investigate this potential causal or reciprocal relationship as it has implications for safety leadership training for supervisors. For example, in Mullen and Kelloway's (2009) SSTL intervention, they found that SSTL training for supervisors increased their worker's safety climate perceptions. It would be interesting to determine if the addition of safety climate concepts in such training would impact safety outcomes above and beyond a more limited SSTL intervention. Supervisors who understand safety climate concepts may be more motivated to adopt SSTL qualities, as they will understand how their actions influence the safety climate of their job sites and ultimately their worker's safety outcomes.

The present study's results are similar to findings from our previous study, which tested the safety climate and safety behavior model without the inclusion of safety climate knowledge and with a more diverse construction sample (i.e., crews and supervisors) (Schwatka & Rosecrance, 2014). Despite differences in the way safety climate was represented (i.e., globally or by multiple factors), the direct relationships between safety climate and both types of safety behaviors were similar. The present study's sample size limited our ability to accurately test for measurement equivalence across company position. However, the similarity in findings provides preliminary evidence for a model of safety climate and safety behaviors that is consistent across company position. There is some evidence for measurement equivalence of safety climate measurements across construction trades and worker ethnicities (Cigularov, Adams, Gittleman, Haile, & Chen, 2013a; Cigularov, Lancaster, Chen, Gittleman, & Haile, 2013b), but no studies known to the researchers have tested for similarities between company position. Since it is common to compare responses between company position within the construction industry (Gilkey et al., 2012; Gittleman et al., 2010), measurement equivalence testing will provide the necessary justification to continue to compare mean scores across company positions.

4.1. Limitations

While the present study provided some interesting preliminary answers to questions regarding supervisor safety climate knowledge, the study's limitations should be kept in mind. First, the study design was cross sectional, and thus causal assumptions cannot be made. Because of this, we can only determine if the models are consistent or inconsistent with mediation, and not that mediation actually exists. Second, the study had a relatively small sample, and may not be generalizable to a larger population of construction supervisors. Additionally, the small sample size hindered our ability to analyze our data in a more sophisticated manner that accounts for the latent structure of our study variables (i.e., structural equation modeling). Other potential omitted variables may affect the hypothesized relationships in this study (e.g., motivation to improve safety climate perceptions). Lastly, the relationships studied may differ for different sized contractors, trades, geographical regions, etc., but our study was not able to account for them.

4.2. Conclusion

The present study reaffirms prior research that suggests the relationship between safety climate and safety behaviors is significant (Christian et al., 2009; Clarke, 2010). The results extend previous research by demonstrating that this relationship is significant among site-supervisors. Namely, supervisors with positive safety climate perceptions are likely to behave in a safe manner. The importance of their participation in job site safety practices cannot be understated. When supervisors model safe behaviors and engage their crews in safety practices, they inform their crews that safety is important and valued. Crews who perceive that safety is important and valued have positive safety climate perceptions. Thus, supervisors must build and utilize safety leadership skills in order to improve the safety of their job sites. However, methods to develop these skills are not well understood. The present study hypothesized that supervisor safety climate knowledge was a critical link between their safety climate perceptions and safety behaviors. The study's findings suggest that future research should refine safety climate knowledge measures and test it against measures of supervisor safety climate improvement behaviors and safety-specific transformational leadership qualities.

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Appendix 5.I

Safety climate knowledge questions

(Developed by researchers)

1. **True / False** (Circle one) As a company develops a mature safety culture, crews work safer and the quality of their work increases.

2. **Open ended** Give two examples of ways that crews are empowered to take on safety on the jobsite.
   E.g., ability to stop work if unsafe and asking questions about safety

3. **True / False** (Circle one) OSHA recordables are a lagging indicator of occupational health and safety performance while measures of safety culture are a leading indicator.

4. A leader who rejects their safety leadership role and only addresses safety when it becomes a problem is what kind of safety leader (circle one)?
   a. Absent safety leader
   b. Transformational safety leader
   c. Active safety leader
   d. Passive safety leader

5. **True / False** (Circle one) Safety is the result of an individual's behavior more than company leadership.

6. **Open ended** A foreman approached a work area and found that one of the journeymen did not adequately plan for safety in the pre-task plan, but their work seems to be going smoothly and on track for completion. Briefly describe what the foreman should do.
   Must mention 1) Stop work, 2) Discuss/talk/coach PTP, and 3) Redo PTP

7. Safety culture develops from ___________ company safety policies, procedures and practices (circle one).
   a. "…perceptions of…"
   b. "…well documented…"
   c. "…shared perceptions of…"
   d. "…well developed and implemented…"

8. **Open ended** Give two examples of how a foreman can support the crew's involvement in safety.
   E.g., giving feedback on safety behaviors and giving workers time to complete a job

9. Which of the following are components of effective feedback (circle all that apply)?
    a. Discuss what specific behavior should be changed or repeated in the future
    b. Record all observations and discuss them at the next tool-box talk
    c. Describe what ideal or poor behavior was observed
    d. Discuss observations when there is a break in work (unless there is immediate danger)
    e. Discuss the impact and consequences of the behavior

10. **True / False** (Circle one) A company that has a great safety culture knows that prioritizing safety just as much as other organizational goals is more important than frequently communicating the value of safety to crews.

PART VI

Safety climate and safety leadership training for construction supervisors

Chapter 1

Introduction

Every construction company has its own unique safety culture that dictates “tacit ways of perceiving, thinking, and reacting” towards safety, indeed it is “one of the most powerful and stable forces operating in organizations” (Schein, 1996 pg. 231). Many contractors in the construction industry use the term safety culture to describe their value for safety. It is also commonly referred to as the way safety is treated when no one is looking. Research suggests that building and sustaining a positive safety culture can result in safer and healthier working conditions for construction workers (Guldenmund, 2000).

Safety climate, on the other hand, is a subset or snapshot of safety culture that may be more easily measured and influenced (Denison, 1996). It is a subset of safety culture stemming from the underlying organizational assumptions regarding safety and safety practices in the workplace. Safety climate can be considered an “artifact” of culture, which can be tangibly measured (Schein, 1990; 2010) by administering questionnaires that query workers about their perceptions relating to company safety policies, procedures and practices. These perceptions are often in reference to management’s safety actions (Flin, Mearns, O'Connor, & Bryden, 2000). Measures of safety climate can reflect the disparity between what management says about safety and what they do in practice (Gittleman et al., 2010). Thus, best practices aimed at improving safety climate should focus on management’s safety actions that are not only endorsed, but also performed.

Although enforcement agencies such as OSHA (Occupational Safety and Health Administration) require written safety policies and procedures, it is just as important for management to actively demonstrate the practice of such policies. Construction workers often describe this practice as “walk the talk.” This phrase goes back as far as Shakespeare’s play Richard III when the evil Richard hires a man to murder his brother. The murder assures

Richard that he will back up his word with a deed, “Fear not, my lord, we will not stand to prate; Talkers are no good doers: be assured. We come to use our hands and not our tongues” (Shakespeare, I.iii.557-559).

1.1. Leader-focused safety climate intervention strategies

Safety climate perceptions are largely shaped by management’s words and actions. Although top-level management may emphasize safety in written company policies, jobsite foremen may focus their attention on production. Thus, their informal words and actions on site (e.g., increasing accident risk to finish a job quickly) indicate to crews that safety is not the priority. On construction job sites, the power of supervisors’ words and actions is illustrated in Kosney et al.’s (2013) interview study with 35 workers. They found that reducing costs and working faster was often emphasized as opposed to reinforcing safety. One worker even recalled being laughed at after following procedures to report an injury saying,

> “So, I ended up cutting my hand on a stud, when I…was [a] second year apprentice. So, I went to my foreman he started laughing at me you know, come on you’re a big baby. I am like I am not a big baby, you told me I have to report all accidents so I am doing what I am supposed to do. Are you going to fill out the report or you’re not going to fill out the report? Oh, you’re a big baby, so I am kind of, I am left there - what do I do right?” (pg., 446).

After experiencing multiple events like these with their supervisors, crewmembers develop perceptions of “how things are done around here.” These perceptions represent a company’s safety climate, and are powerful enough to influence crew safety outcomes such as knowledge, motivation, behavior, and injuries and illnesses (Christian, Bradley, Wallace, & Burke, 2009; Clarke, 2006; 2010; Goldenhar, Williams, & Swanson, 2003; Kines et al., 2011; Nahrgang, Morgeson, & Hofmann, 2011; Pousette, Larsson, & Törner, 2008; Probst & Estrada, 2010; Probst, Brubaker, & Barsotti, 2008). Despite the empirical evidence regarding the positive effects of a high safety climate, little has been done to actively influence safety climate perceptions on construction job sites.

Based on prior research, there are three leader-based avenues to influence safety climate perceptions. First, at the most basic level, safety specific communication between management and employees is likely to positively influence safety climate perceptions (Zohar, 2002a). This is because, at its core, safety climate reflects perceptions of the priority of safety over competing organizational goals (e.g., productivity). This inference is based on what management says and does in practice, rather than what is promoted by the company. For example, supervisors who talk about safety just as much as getting the job done on time are more likely to promote a positive safety climate than those who do not. A climate for safety, good or bad, ultimately forms from *shared* worker perceptions of this pattern of management practices (Zohar, 2011). Second, leaders who go beyond simply communicating about safety with employees to developing quality relationships marked by open communication (i.e., leader member exchange) are also likely to have a positive impact on worker's safety climate perceptions (Hofmann, Morgeson, & Gerras, 2003). Third, and perhaps as an exemplar, leaders who develop a leadership style with transformational qualities can positively influence safety climate perceptions (Barling, Loughlin, & Kelloway, 2002; Kelloway, Mullen, & Francis, 2006; Zohar, 2002b). These qualities include being role models, inspiring workers to be safe for the sake of the group, challenge worker's perceptions about safety to encourage them to develop innovative and improved safety methods, and lastly conveying an active interest in worker's safety that goes beyond company or government requirements (Barling et al., 2002).

Of the studies that attempted to enhance safety climate perceptions by translating this knowledge into practice, only one study was within the construction industry. A few studies have addressed methods to increase leader's safety specific communication with workers (Zohar, 2002a; Zohar & Luria, 2003; Zohar & Polachek, 2013); one study was within the Dutch construction industry (Kines et al., 2010). No studies investigated methods to improve safety-specific leader member exchanges. Finally, only one study attempted to enhance safety specific transformational leader behaviors through leadership training workshops (Mullen &

Kelloway, 2009). All of these studies found promising results and provide evidence for leader-focused interventions to improve safety climate perceptions. Yet, none have explored methods of training supervisors on the principles of safety climate and the role they play in the development and maintenance of climate. This type of training could be a supplement to typical occupational health and safety (OHS) training such that leaders will not only understand how to be safe but also how to influence the safety of their crew members. Formal training on safety climate for supervisors could provide a structured approach to alert them to the importance of their safety specific actions, and learn what is expected of them (Hale & Borys, 2013).

The importance of safety climate is understood among many construction industry stakeholders (Laboers' Health and Safety Fund of North America, n.d.). It was also the sole topic of a joint National Institutional Occupational Safety and Health (NIOSH), Center for Construction Research and Training (CPWR), and National Occupational Research Agenda (NORA) one-day workshop with participants from industry, academia, and governmental agencies (CPWR, 2013). Furthermore, studies aimed at improving safety culture were identified as one of the top ten priorities identified by the Construction Section of the National Occupational Research Agenda (2008). Thus, validated safety climate training may be well received among numerous construction industry stakeholders.

1.2. Present study

The purpose of the present study was to develop and evaluate a safety climate intervention for site supervisors (site superintendents, foremen, engineering managers) in the construction industry using a pre-post, control group design. The first aspect of the intervention was a workshop to teach supervisors about safety climate and safety leadership. The objectives of the training were to educate supervisors on safety climate, the effects of a positive and negative climate, how their style of leadership impacts safety climate, and the specific steps they can take to improve safety climate among their crews. The second aspect of the intervention was two progress checks designed to assess their progress towards meeting goals set during the training, and to engage the supervisor's manager in the process. The intervention was not designed to be a leadership-training program nor did it include traditional OHS training concepts (e.g., personal protective equipment, safety management plans, OSHA regulations). Additionally, the training was not designed for crewmembers (i.e., pre-apprentices, apprentices, journeymen), but intervention effects were expected to trickle down from supervisors to their crews (Zohar, 2011). The theoretical background and specifics of the intervention is described in the methods section.

The study was designed to answer two primary research questions: 1.) Can an intervention composed of a workshop plus progress checks result in positive safety outcomes, and 2.) Can the addition of progress checks to the workshop enhance the treatment effect? The safety outcomes addressed in this study were three safety climate indicators (top management, supervisor, and co-worker), safety behaviors (safety participation and safety compliance), safety climate knowledge, and training transfer behaviors. It was hypothesized that an intervention with both the workshop and the progress checks would enhance the training transfer environment, and thus greater improvements in safety outcomes would be observed as opposed to the workshop alone. Furthermore, regardless of intervention type, it was hypothesized that positive, significant trends would be observed among all study variables except the top management safety climate outcome. This was because the intervention was focused on supervisors, and supervisors who improve their safety leadership behaviors are likely to influence worker's supervisor safety climate perceptions. Furthermore, supervisors are likely to influence worker involvement in safety and thus an equal rise in worker's co-worker safety climate perceptions and personal safety behaviors was expected.

Chapter 2

Methods

2.1. Study design & participants

The effectiveness of the two intervention components, workshop and progress checks, was evaluated with a pre-post, quasi-experimental design. Three companies were recruited to participate. Two of these companies participated in the workshop only and one company participated in both the workshop plus progress checks. There was no treatment control group. See Figure 1 for detailed information on study design.

The three contractors participating in the study were mechanical contractors in the Pacific Northwest region of the United States. All companies worked in the same geographical region, were active in a local construction safety group, employed similar trades, worked on similar jobsites, and were medium sized construction firms (60-300 employees). All front-line supervisors (i.e., foreman, general foremen and superintendents) were asked to participate in the intervention components and evaluation surveys. If appropriate, project managers and project engineers participated as well. All crewmembers of the supervisors (i.e., pre-apprentices, apprentices, and journeymen) were asked to participate in all surveys except for the 2nd baseline and immediate follow-up surveys, which occurred the same day as the supervisor workshops. The University Institutional Review Board approved all methods.

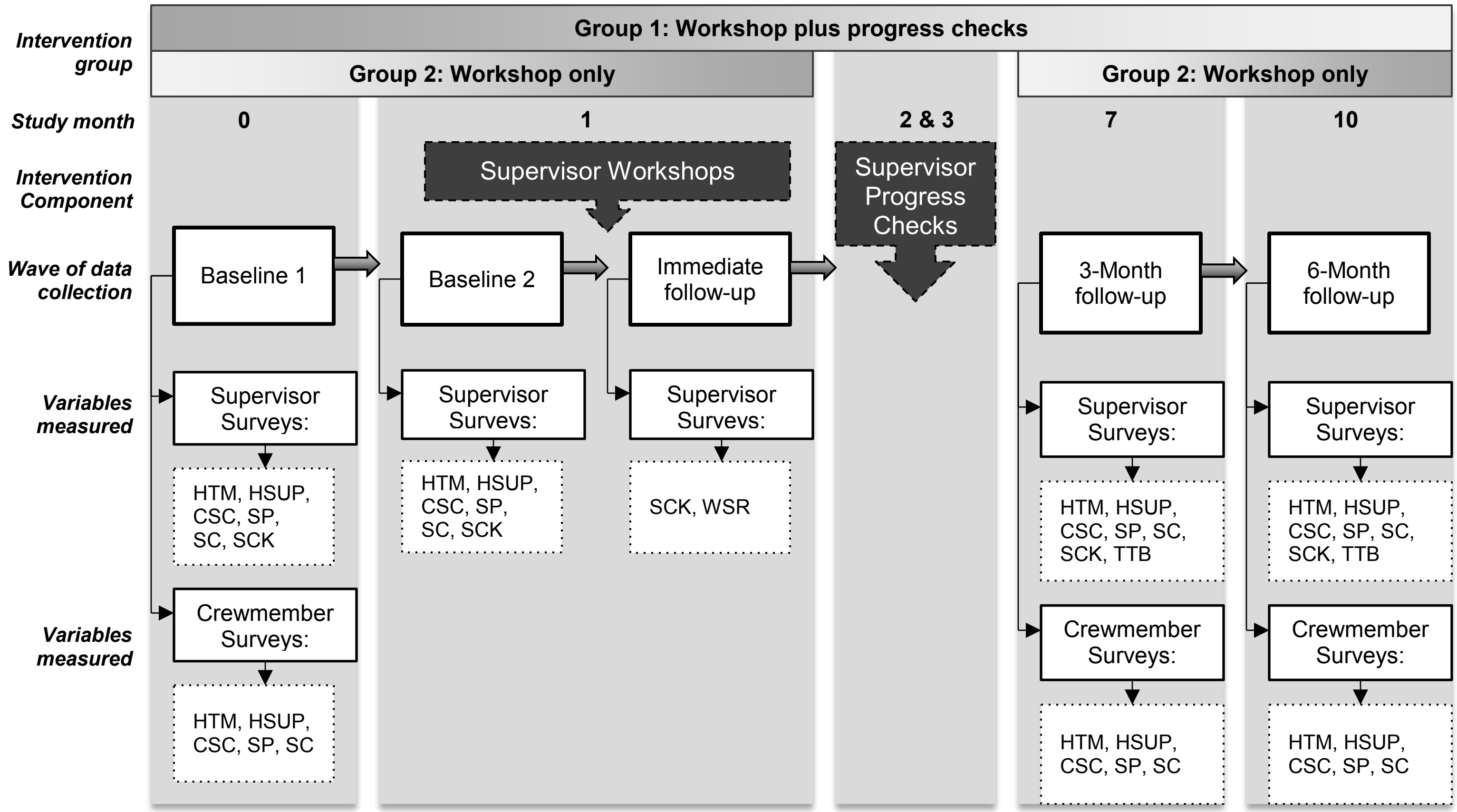

Figure 7. Study design

Note. HTM = Top management safety climate, HSUP = Supervisor safety climate, CSC = Co-worker safety climate, SP = Safety participation, SC = Safety compliance, SCK = Safety climate knowledge, WSR = Workshop reaction, TTB = Training transfer behaviors

Workshops were delivered in a series of small groups of approximately 12-15 supervisors. They took place in company offices or union halls, and each lasted four hours. For supervisors that were part of the workshop plus progress check condition, the manager's of supervisors participating in the intervention were asked to schedule short on-on-one meetings (approximately 15 minutes in length) with each of the supervisors in the intervention that they are in charge of. The meetings occurred one time per month for the following two months. The managers did not receive training on the progress check methods; rather each supervisor-manager pair followed a progress check guide with discussion questions and spaces to record answers (see Appendix 6.I.). All progress checks were collected immediately after each meeting, content analyzed by the researchers, and results were reported back to the company's existing safety committee during their monthly committee meeting.

As per requests from the participating companies, crewmembers were not matched to their respective supervisor due to concerns of anonymity. Participants' surveys were tracked based on a unique identifier that the participant wrote on the top of their survey (i.e., 2 digits of day of birth, last 2 digits of phone number, last 2 digits of social security number).

2.2. Intervention components

2.2.1. Workshop

A needs assessment identified the requisite safety climate and safety leadership knowledge that construction supervisors should possess (see Appendix 6.II for the workshop outline). The content was designed around the five specific components of ACTIVE safety leadership:

	<u>A</u>lways	
1	<u>C</u>ommunicate	your value of safety to your crew frequently,
2	<u>T</u>reat	safety with the same priority as other organizational goals,
3	<u>I</u>nvolve	crews in safety analyses and pre-task planning,
4	<u>V</u>oice	your feedback when you see *safe and unsafe* behaviors,
5	<u>E</u>mpower	crews to actively take on safety on the job.

The training was designed to include an appropriate balance between information given, discussion and practice. This included a consideration of what construction workers typically prefer in terms of training: engagement, based on reality, and the use of adult learning principles (Burke et al., 2011; Kaskutas et al., 2010; Lipscomb, Dale, Kaskutas, Sherman-Voellinger, & Evanoff, 2008). All content was applicable to the regional construction industry and trades in which the participating companies operate. Video vignettes facilitated learning and elicited discussion on the key concepts addressed in the workshop. Other interactive aspects included a leadership self-assessment exercise and a feedback themed role-play exercise. Each trainee received a training workbook that contained all the information discussed in the training.

Supervisors' motivation to learn was addressed by appealing to their personal stake in the development and maintenance of safety climate perceptions of their crews. This was addressed throughout the workshop by educating them on safety climate principles, but also engaging them in a discussion about their personal safety specific experiences with previous supervisors and as a supervisor themselves.

2.2.2. Progress checks

Strategies to help supervisors transfer learned concepts to their jobs included goal setting and employing the support of the supervisor's managers in the progress checks. At the end of the workshop, trainees were given time to write down four specific goals that they wanted to work towards over the next few months in their workbook. They were asked to refer back to material discussed during the training and to write down SMART goals (i.e., specific, measureable, actionable, relevant, and time oriented). Setting specific goals helps trainees to purposefully direct their actions, regulate their effort, and ensure persistence. Their commitment to them depends on their ability to believe that it is possible (self-efficacy) and important. Supervisor's acknowledgement and encouragement of training can aid in goal attainment (Al-Eisa, Furayyan, & Alhemoud, 2009; Latham & Locke, 1991). Thus, the progress checks were conducted in house between supervisors and their manager to help foster the communication and support that is necessary for goal attainment.

2.3. Intervention evaluation

2.3.1. Process evaluation

A process evaluation was used to account for how the intervention was implemented and the processes that either helped or hindered its implementation. The process evaluation components followed those outlined in Saunders (2005): fidelity, dose delivered (completeness), dose received (exposure), reach, and context.

2.3.2. Outcome evaluation

Training content and design. Members of the construction industry evaluated the workshop and progress check materials developed by the research team to ensure that the content was understandable and applicable to the construction industry. This occurred during one of the participating contractor's safety committee meetings. Following each workshop, participants were asked to complete workshop reaction questionnaires. The reaction questions were used to evaluate the workshop materials, content and delivery (see Appendix 6.III.). Sample items include, "I consider the training highly relevant to my job" and "The training materials are too simple and basic; they do not challenge trainees with anything new." Responses were scored on a Likert scale ranging from 0-6, strongly disagree to strongly agree. These evaluations also serve as process evaluation indicators.

Changes in learners. Supervisors were asked safety climate knowledge questions to determine how effective the workshop was in conveying the concepts of safety climate and active safety leadership (see Appendix 5.I). The specific true/false, multiple-choice, and open-ended questions were developed based on the content of the workshop. Safety climate knowledge questions had a total possible score of 14 points. The open-ended questions were graded by two separate individuals who were blinded to when the questions were answered (i.e., before or after the intervention), and the average of their score was the amount of points given. Sample questions include, “As a company develops a mature safety culture, crews work safer and the quality of their work increases” and “Give two examples of how a foreman can support the crew’s involvement in safety.” Additionally, supervisors were asked to fill out questions relating to training transfer behaviors during both follow-up surveys (Al-Eisa et al., 2009; Machin & Fogarty, 2004) (see Appendix 6.II). A sample question is, “I have discussed with my supervisor ways to apply the material that I learned in the leaders create culture training program.” Responses were scored on a Likert scale ranging from 0-6, strongly disagree to strongly agree.

Organizational payoffs. Even though the training was focused on leaders, positive changes were expected among crews. Thus, an assessment of safety climate perceptions and personal safety behaviors were completed among supervisors and their crews. Safety climate was measured with a modified version of the Nordic safety climate questionnaire (Kines et al., 2011). The measure reflects the safety responses of top management, supervisors, and co-workers. Sample items include, “Top management ensures that everyone receives the necessary information on safety,” “My current, immediate supervisor looks the other way when someone is careless with safety,” and “My co-workers and I try hard together to achieve a high level of safety.” Responses were scored on a Likert scale ranging from 0-6, never to always. Safety behaviors were measured with Neal et al.’s (2000) measure of safety performance that includes two factors, safety participation and safety compliance. Safety compliance measures behaviors intended to comply with safety rules, whereas safety participation refers to behaviors that go above and beyond complying to helping and promoting safety. Sample items include, “I use the correct safety procedures for carrying out my job” and “I voluntarily carry out tasks or activities that help to improve workplace safety.” Responses were scored on a Likert scale ranging from 0-6, never to always. See Appendix 4.I and Appendix 4.II for a description of the variables and their questions.

2.3.3. Statistical analysis

2.3.3.1. Data collection

The surveys were distributed and collected during normal business hours during pre-scheduled meetings such as toolbox talks or safety meetings. The researchers distributed and collected the majority of the surveys, but members of the company's safety team distributed surveys to workers that were not present when the researchers were on the jobsite. All surveys were collected upon completion and placed into a sealed envelope, in which the researchers collected and maintained at the university.

2.3.3.2. Data preparation

Within each wave of data, all questions for each respective outcome were averaged in SPSS version 21. A safety climate knowledge score was given to each supervisor as previously described. Surveys from all waves of data collection were then merged into one file by the worker's unique identifier they wrote on the top of their survey. Thus, only surveys with unique identifiers were retained for data analysis Crewmembers unique identifiers were missing from all three waves of data collection at 10%, 19%, and 16%. Supervisor's unique identifiers were missing from all five waves of data collection at 8%, 7%, 0%, 6%, and 9%. Four additional crewmembers were removed from the dataset because they moved from one company to another in the study at follow-up. One supervisor was removed for the same reasons as well. See Table 1 for the study's sample size at each wave of data collection after removing surveys without unique identifiers and participants who changed companies during the study. See Table 14 for the study's sample size at each wave of data collection after removing surveys without unique identifiers and participants who changed companies during the study. Typical of the construction industry, participating companies fluctuated in the number of employees throughout the study. Thus, the number of employees participating in each wave of the surveys varied.

Supervisors and crewmembers' data were analyzed separately because they played different roles in the intervention. It is of note that supervisors were defined as individuals who took the workshop and completed a 2nd baseline questionnaire. Supervisors who did not attend the workshop but took surveys at other time points were included in the study, but coded as crewmembers. This is because it is common for construction workers to move from journey (crew) level positions to foremen (supervisor) level, and vice versa, from project to project.

Table 14. Sample size by data collection wave, job position, and intervention group

Supervisors				**Crewmembers**			
Intervention group				**Intervention group**			
Workshop + Progress Checks		**Workshop**		**Workshop + Progress Checks**		**Workshop**	
Wave	N	Wave	N	Wave	N	Wave	N
1	26	1	14	1	94	1	119
2	61	2	46				
3	47	3	40				
4	24	4	16	4	132	4	192
5	8	5	13	5	82	5	155

Note. Waves of data collection = 1 (baseline 1), 2 (baseline 2), 3 (immediate follow-up), 4 (3-month follow-up), and 5 (6-month follow-up).

See Table 15 for the response pattern of supervisors and crewmembers in each intervention group. Among crewmembers, the final dataset containing all three waves of data on the five outcomes contained a total of 608 uniquely identified workers with varying patterns of missing data. For example, in the workshop plus progress check intervention group, 10 (4.2%) crewmembers had complete data from all three waves of data collection. Within this same intervention group, there were many uniquely identified individuals that only had information from one wave of data (e.g., n = 82 at 3-month follow-up), but at least 25% of the uniquely identified crewmembers had responses from at least two waves of data. Among supervisors, the final dataset on all their outcomes contained 107 uniquely identified workers with varying patterns of missing data. For example, in the workshop plus progress check intervention group, only 6 (10%) supervisors had information on variables from all four waves of data. Within this same intervention group, at least 57% of the uniquely identified supervisors from this intervention group had responses from at least two waves of data.

Upon inspection, there was a significant missing data pattern for the variables top management safety climate and supervisor safety climate among all workers. Namely, missing data within these variables was more prevalent among workers in the workshop only intervention group, as compared to workers in the workshop plus progress checks intervention group and among crewmembers, as compared to supervisors. It was determined that the missing data pattern between the workshop plus progress check and workshop only intervention groups could in part be explained by tenure and time spent with current supervisor in the analyses. Workers in the workshop plus progress checks intervention group worked for their company and their current supervisor significantly longer than workers in the workshop only intervention group, thus, these variable were included as covariates in the subsequent analysis models. Correlations between intervention group and tenure and time spent with supervisor ranged from 0.16 to 0.30 ($p < 0.05$) at each point in time. Workers in the full intervention group might have felt like they had more time to judge questions relating to top management safety climate and supervisor safety climate, and thus would not have left the question blank. Since supervisors' and crewmembers' data were analyzed separately, the difference between missing data was not controlled for.

Table 15. Pattern of study participation by data wave combination, job position, intervention group and variable studied

Supervisors								**Crewmembers**			
Workshop + Progress checks				**Workshop**				**Workshop + Progress checks**		**Workshop**	
***Variables*: HTM, HSUP, CSC, SP, & SC**		***Variable:* SCK**		***Variables*: HTM, HSUP, CSC, SP, & SC**		***Variable:* SCK**		***Variables*: HTM, HSUP, CSC, SP, & SC**		***Variables*: HTM, HSUP, CSC, SP, & SC**	
Wave(s)	N	Wave(s)	N	Wave(s)	N	Wave(s)	N	Wave(s)	N	Wave(s)	N
2	26	2	10	2	21	2	5	1	61	1	81
1 & 2	10	1 & 2	1	1 & 2	3	2 & 3	16	4	82	4	118
2 & 4	7	2 & 3	16	2 & 4	7	2 & 5	1	5	37	5	100
2 & 5	1	1, 2 & 3	9	2 & 5	3	1, 2 & 3	3	1 & 4	14	1 & 4	16
1, 2 & 4	10	1, 2 & 4	2	1, 2 & 4	2	2, 3 & 4	7	1 & 5	9	1 & 5	7
2, 4 & 5	1	2, 3 & 4	7	1, 2 & 5	3	2, 3 & 5	2	4 & 5	26	4 & 5	37
1, 2, 4 & 5	6	2, 3 & 5	1	2, 4 & 5	1	1, 2, 3 & 4	2	1, 4 & 5	10	1, 4 & 5	10
Total	*61*	1, 2, 3 & 4	8	1, 2, 4 & 5	6	1, 2, 3 & 5	3	*Total*	*239*	*Total*	*369*
		1, 2, 4 & 5	1	*Total*	*46*	2, 3, 4 & 5	1				
		2, 3, 4 & 5	1			1, 2, 3, 4 & 5	6				
		1, 2, 3, 4 & 5	5			*Total*	*46*				
		Total	*61*								

Note. Waves of data collection = 1 (baseline 1), 2 (baseline 2), 3 (immediate follow-up), 4 (3-month follow-up), and 5 (6-month follow-up). The sample size at each combination of data wave(s) represents the number of participants with information from that data wave(s).

2.3.3.3. Latent growth modeling

Latent growth modeling (LGM) in Mplus version 7 was utilized to determine if the intervention influenced change among the safety climate, safety behavior and safety climate knowledge variables. LGM's for supervisor's scores on the safety climate (HTM, HSUP and CSC) and safety behavior (SP and SC) variables were assessed at 4 time points (baseline 1, baseline 2, 3-month follow-up, and 6-month follow-up). LGM's for crewmember's scores were assessed at 3 time points (baseline 1, 3-month follow-up, and 6-month follow-up). The LGM for supervisor's SCK scores was assessed at 5 time points (baseline 1, baseline 2, immediate follow-up, 3-month follow-up, and 6-month follow-up).

Unlike repeated measures ANOVA, LGM in Mplus allows researchers to determine within and between individual differences in development over time, rather than just within individual change over time. LGM is similar to multi-level modeling (MLM) in that the intercept and slope can be modeled randomly, time is treated as a continuous variable, contextual effects can be time variant or invariant, variance and covariance of observations overtime do not need to be assumed to be equal, and missing data is handled well (Jackson, 2010; Kwok et al., 2008). In LGM, however, the intercept and slope are treated as latent factors. LGM results can be evaluated based on not only the significance of parameter estimates, but also the model fit statistics (i.e., how does the hypothesized growth model fit the study's data). Maximum likelihood estimation (ML) was used, which appropriately handles missing data when the missing data are missing at random, or the mechanism for missingness is available and included in the model.

The trend and coding of time chosen for each outcome was initially set in a linear fashion with time scores representing study month. In all LGMs in this study, baseline 1 was the intercept and reference point for all change overtime. If a linear growth model did not fit the data well, parameters (i.e., time scores) were freely estimated to allow for the determination of a non-linear growth model (e.g., curved) (McArdle & D, 1987). Additionally, in some cases the slope growth factor or the residual variance of one of the loadings had a non-significant zero or very small negative variance, and was set to zero to allow for adequate model estimation (L. Muthen & Muthen, 2008). The LGMs for each growth model were assessed via the chi-square test, RMSEA, CFI/TLI, and SRMR. A non-significant chi-square test indicates that the hypothesized model fits the data well. Smaller AIC, RMSEA (< 0.08) and SRMR (<0.08) values and larger CFI (> 0.95) and TLI (> 0.95) values are indicative of good fitting models. Once the trend and coding of time was determined for each LGM and the hypothesized LGM model was determine to provide adequate fit to the data, the indicator of intervention type (i.e., workshop only (coded as a 1), or workshop plus progress checks (coded as a 2)) was entered into the model. As previously mentioned, tenure was included as a time varying covariate (e.g., tenure reported at baseline 1 loaded onto top management safety climate at baseline 1) in the top management safety climate conditional model and time with supervisor was included in the supervisor safety climate conditional model to account for the missing data pattern. Since the unconditional and conditional growth models were non-hierarchical, the final model was chosen by examining the Akaike AIC values. If no appreciable change in fit was seen, the more parsimonious model was kept (i.e., the unconditional growth model without the covariate).

The latent growth intercept, slope and estimated parameters in the present study can be interpreted as follows. In a linear model,

Intercept growth factor = Mean outcome score at baseline 1

Slope growth factor = Mean growth per 1 month increase in time.

Model estimated mean at time point *i* = Intercept growth factor + (slope growth factor*study month).

In a non-linear model,

Intercept growth factor = Mean outcome score at baseline 1

Slope growth factor = Mean growth from baseline 1 to data wave set to one

Estimated loadings = Latent time estimated by model

Model estimated mean at time point *i* = Intercept growth factor + (slope growth factor*estimated loading).

Furthermore, comparisons between waves of data can be made not only by observing the significance of the parameters but also the magnitude of change between mean scores. Such comparisons determine at which time point the greatest "velocity" of change occurred (McArdle & D, 1987).

Chapter 3

Results

3.1. Process evaluation

Fidelity and dose delivered. Overall, the workshop portion of the intervention was implemented as planned and in accordance with theory. This was possible because the workshop was outlined and scripted such that all workshops were consistent with each other, and the same trainers were present at all workshops. Among the majority of the workshops, however, it was often the case that more time was spent on earlier sections, leaving minimal time for the concluding sections. The progress checks were guided by a worksheet in hopes that the content of the checks would be consistent among all trainees. However, it was not possible to track how much time was spent discussing progress and on some occasions progress checks occurred among work groups rather than one-on-one as planned. This was because some of the trainee's supervisors either did not have enough time to schedule separate progress checks or thought that a group discussion was best for their work group.

Dose received. All scheduled workshops (N=12) occurred as planned, but the progress checks did not occur at both time points for all workshop participants in the full intervention group (see Table 1). Just over half of those that participated in the workshop also participated in the first progress check, and just over one quarter participated in the second round.

Reach. The majority of all supervisors at each company participated in the intervention, resulting in 96% of all eligible supervisors the full intervention group and 100% in the partial intervention group participating. Additionally, the majority of supervisors that participated in the intervention continued to work at their respective company at the time of the final 6-month follow-up survey, resulting in 93% of supervisors in the full intervention group and 91% of supervisors in the partial intervention group.

Context. An important aspect of the study's sample is the context in which many participants worked. The geographical region in which the contractors work is known for an above average safety record. This is in part due to a construction job site that has been in constant construction for a couple of decades and the general contractor's and local union's focus on safety.

3.1. Outcome evaluation

3.1.1. Supervisors

After the workshop, trainees were asked to answer questions related to the training content and design. On a scale of 1-6, from completely disagree to completely agree, the majority of trainees: 1) Rated the relevance of the training to their job at a 5 or above (95%), 2) Rated the simplicity and challenging nature of the training at a 2 or below (73%), 3) Rated the engagement of the training at a 5 or above (92%), 4) Rated the opportunity to demonstrate their knowledge during training at a 5 or above (90%), 5) Rated the inability to apply training knowledge to their job at a 2 or below (89%), 6) Rated the video's helpfulness in understanding training concepts at a 5 or above (90%), and 7) Rated their intent to strongly recommend the training to other leaders in the industry at a 5 or above (84%).

During the 3 and 6-month follow-up surveys, trainees were asked questions related to training transfer and to rate their level of agreement on a scale of 0-5 with the statement from strongly disagree to strongly agree. At both 3 and 6-month follow-up, the majority of trainees rated the transfer questions at a 4 and above. At 3-month follow-up, the majority of trainees discussed with their supervisor and co-workers ways to apply the material (78% and 75%, respectively), used the knowledge and skills learned (70%), found them to be useful (64%), and found that it helped improve their job performance (68%). At 6-month follow-up, they discussed with their supervisor and co-workers ways to apply the material (74% and 77%, respectively), used the knowledge and skills learned (71%), found them to be useful (63%), and found that it helped improve their job performance (69%). The intervention groups did not differ significantly on their average training transfer behaviors score at 3-months (t = -0.64(114), p = .52) and 6-months follow-up (t = 0.52(86), p = .60).

Supervisor safety climate knowledge was assessed via LGM among five separate waves of data (baseline 1, baseline 2, immediate follow-up, 3-month follow-up, and 6-month follow-up). Since baseline 2 and immediate follow-up were collected on the same day as the workshops, their residuals were allowed to correlate. The linear LGM fit the data very poorly (AIC = 1218, χ^2 = 47 (10), p < 0.01, RMSEA = 0.18, CFI = 0.59, TLI = 0.59, SRMR = 0.25), so a non-linear model with free time scores was estimated (i.e., baseline 1 was set to 0 and 6-month follow-up was set to 1, and all scores in between were freely estimated). The slope's variance was negative and non-significant, and thus was set to zero to allow for adequate model estimation (L. Muthen & Muthen, 2008). The resulting model fit the data well (see Table 16). After including the intervention group covariate in the model, the fit of the model was not improved (AIC = 1187, χ^2 = 14 (12), p = 0.26), so the unconditional growth model was retained. Thus, the growth pattern of the safety climate knowledge was positive and did not depend on which intervention group the supervisor was in. The greatest amount of growth, however, occurred between baseline 2 and immediate follow-up. At baseline average knowledge scores were at 5.91 points, and immediately after the workshop it increased to 7.70 (i.e., intercept + (slope*loading estimate), 7.70 = 5.91+(1.25*1.44)). This means that supervisors gained the most knowledge immediately after the workshop, and their knowledge gain did not decrease to baseline 1 levels at 6-months post intervention. Model estimated mean scores plotted by time point are presented in Figure 8.

Table 16. Supervisors univariate latent growth models for each study outcome

	HTM			HSUP			CSC		
	Parameter estimate	S.E.	P-value	Parameter estimate	S.E.	P-value	Parameter estimate	S.E.	P-value
Intercept	4.36	0.05	0.00	4.45	0.05	0.00	4.57	0.04	0.00
Slope	0.00	0.01	0.89	-0.01	0.01	0.44	-0.02	0.01	0.02
Estimated loadings									
Baseline 1							0.00		
Baseline 2							1.00		
Immediate follow-up	+			+			+		
3-month follow-up							7.00		
6-month follow-up							2.47	1.22	0.04
Intercept variance	0.14	0.03	0.00	0.16	0.03	0.00	0.17	0.04	0.00
Slope variance	*	*	*	*	*	*	*	*	*
Model fit									
AIC	264.00			282			222		
X^2 (df)	16.5 (7)		0.02	6.07 (7)		0.53	3.32 (4)		0.0501
RMSEA (95%CI)	0.11 (0.04-0.18)			0.00 (0.00-0.11)			0.00 (0.00-0.13)		
CFI/TLI	0.83/0.86			1.00/1.00			1.0/1.0		
SRMR	0.43			0.37			0.07		

+Variable was not measured at this time point *Parameter was fixed to zero due to a non-significant zero or negative variance
Note. LGMs for HTM, HSUP & SC were linear (0 1 7 10) and LGMS for HSUP (0 * * 1), CSC (0 1 7 *) and SP (0 * * 1) were non-linear. HTM (top management safety climate), HSUP (supervisor safety climate), CSC (co-worker safety climate), SP (safety participation behaviors), SC (safety compliance behaviors), SCK (safety climate knowledge)

Table 16. Continued

	SP			SC			SCK		
	Parameter estimate	S.E.	P-value	Parameter estimate	S.E.	P-value	Parameter estimate	S.E.	P-value
Intercept	4.07	0.12	0.00	4.54	0.05	0.00	5.91	0.27	0.00
Slope	0.15	0.10	0.16	0.00	0.01	0.99	1.25	0.34	0.00
Estimated loadings									
Baseline 1	0.00						0.00		
Baseline 2	1.09	0.26	0.00				0.51	0.19	0.01
Immediate follow-up	+			+			1.44	0.35	0.00
3-month follow-up	1.50	0.55	0.01				1.00	0.26	0.00
6-month follow-up	1.00						1.00		
Intercept variance	0.72	0.32	0.02	0.15	0.04	0.00	2.36	0.45	0.00
Slope variance	0.18	0.25	0.46	0.00	0.00	0.47	*	*	*
Model fit									
AIC	379			238			1187		
X^2 (df)	4.65 (3)		0.20	1.98 (5)		0.85	14.18 (9)		0.11
RMSEA (95% CI)	.07 (0.00-0.19)			0.00 (0.00-0.07)			0.07 (0.00-0.14)		
CFI/TLI	.97/.94			1.0/1.0			0.94/0.94		
SRMR	0.09			0.21			0.11		

+Variable was not measured at this time point *Parameter was fixed to zero due to a non-significant zero or negative variance
Note. LGMs for HTM, HSUP & SC were linear (0 1 7 10) and LGMS for HSUP (0 * * 1), CSC (0 1 7 *) and SP (0 * * 1) were non-linear. HTM (top management safety climate), HSUP (supervisor safety climate), CSC (co-worker safety climate), SP (safety participation behaviors), SC (safety compliance behaviors), SCK (safety climate knowledge)

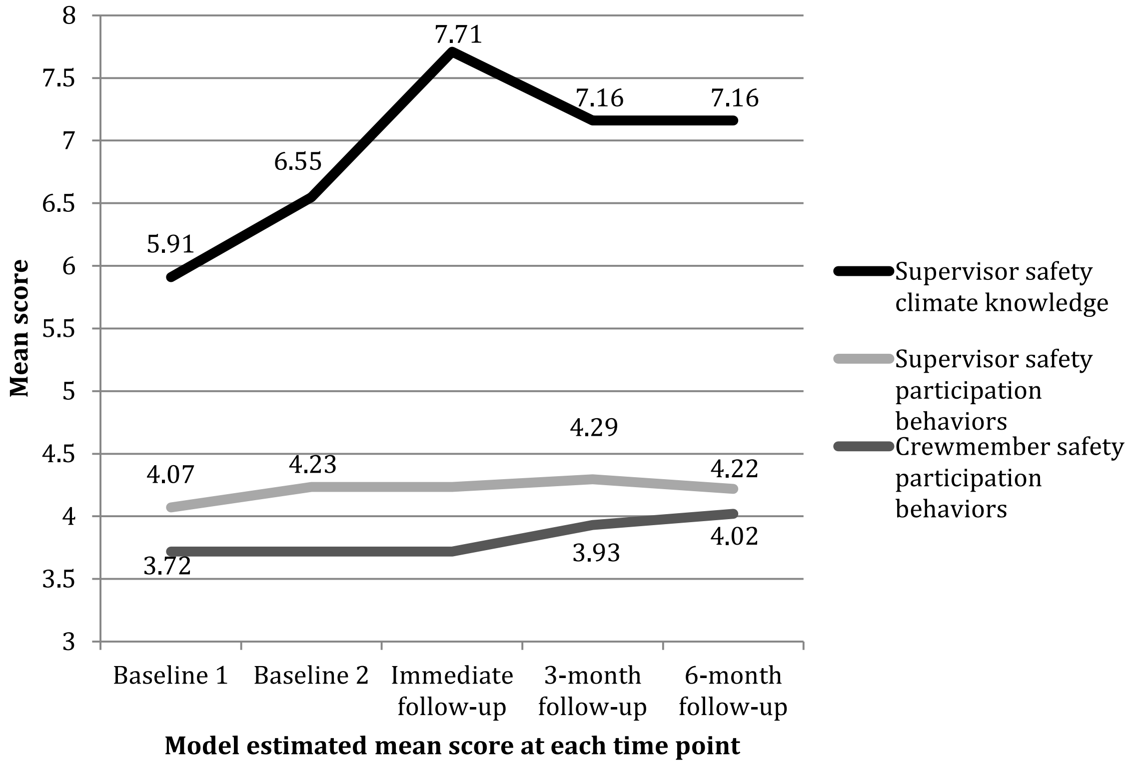

Figure 8. Significant supervisor and crewmember model estimated mean scores

Note. Supervisor SCK scores were on a scale from 0-16. Supervisor SP and crewmember SP were on a scale from 0-5.

Linear LGMs for top management safety climate, supervisor safety climate and safety compliance behaviors had good model fit. However, linear models for co-worker safety climate (AIC = 230, χ^2 = 16.2 (5), $p < 0.01$, RMSEA = 0.15, CFI = 0.83, TLI = 0.80, SRMR = 0.25) and safety participation behaviors (AIC = 378, χ^2 = 12 (7), p = 0.10, RMSEA = 0.08, CFI = 0.92, TLI = 0.93, SRMR = 0.41) fit the data poorly. For co-worker safety climate, the scores at 6-month follow-up were freely estimated, but the non-linear model fit the data poorly (AIC = 299, χ^2 = 13.3 (5), p = 0.03, RMSEA = 0.12, CFI = 0.89, TLI = 0.87, SRMR = 0.22). Modification indices suggested that the residuals of the baseline 1 and 6-month follow-up scores be allowed to correlate. This improved the fit of the model (see Table 16 for the final results). It should be noted that, in order for this analysis to run in Mplus, the residual variance of the 3-month follow-up co-worker safety climate score had to be set to zero. However, setting it to zero significantly changed the coefficient of the freely estimated time score ($\beta = 1.99$, $p = 0.15$ to $\beta = 2.47$, $p = 0.04$). For safety participation behaviors, the scores at baseline 2 and 3-month follow-up were freely estimated (see Table 16). It should be noted that the linear LGM for top management safety climate fit the data poorly; however, a non-linear model did not fit the data better (AIC = 267, $\chi^2 = 15$ (5), $p < 0.01$, RMSEA = 0.14, CFI = 0.82, TLI = 0.78, SRMR = 0.43). Thus, the LGM for top management safety climate should be interpreted with caution. Once adequate model fit was established, the intervention group covariate was added to each of the models in Table 16. Among all outcomes, the inclusion of the intervention group covariate in the LGMs did not improve the fit of the models. Compared to the AIC values in the unconditional growth models in Table 16, the AIC values of the conditional growth models were either equal or larger (top management safety climate AIC = 1346, supervisor safety climate AIC = 1379, co-worker safety climate AIC = 224, safety participation AIC = 382, and safety compliance AIC = 239).

As can be seen in Table 16, there were significant growth trends among the co-worker safety climate and safety participation behavior variables. Supervisor's co-worker safety climate declined significantly from baseline 1 to 3-month follow-up, but increased at 6-month follow-up back to baseline 1 scores. However, since the coefficient of the freely estimated time score changed significantly after setting one of the residual variances to zero, these results should be interpreted with caution. Supervisor's safety participation behaviors increased significantly over time up until 3-months follow-up. However, their mean score at 6-months follow-up was not significantly different from baseline 1. Supervisor's top management safety climate, supervisor safety climate and safety compliance behaviors did not change overtime. Model estimated mean scores of safety participation behaviors plotted by time point can be seen in Figure 8.

3.1.2. Crewmembers

Linear LGMs for supervisor safety climate, co-worker safety climate, safety participation behaviors, and safety compliance behaviors had good model fit (see Table 17). However, a linear model for top management safety climate fit the data very poorly. Non-linear models with freely estimated time scores would not converge, so the linear model with poor fit was retained. Thus, top management safety climate results should be interpreted with caution. Once adequate model fit was established, the intervention group covariate was added to each of the models in Table 17. Among all outcomes, the inclusion of the intervention group covariate in the LGMs did not improve the fit of the models. Compared to the AIC values in the unconditional growth models in Table 4, the AIC values of the conditional growth models were either equal or larger (top management safety climate AIC = 5414, supervisor safety climate AIC = 4104, co-worker safety climate AIC = 1474, safety participation AIC = 1825, and safety compliance AIC = 1293).

As can be seen in Table 17, there were significant linear growth trends in the safety participation behavior variable. Crew's safety participation behaviors increased from 3.72 at baseline 1 to 3.93 at 3-months follow-up and to 4.02 at 6-months follow-up. Crew's top management safety climate, supervisor safety climate, co-worker safety climate and safety compliance behaviors did not change overtime. Model estimated mean scores of safety participation behaviors plotted by time point can be seen in Figure 8.

Table 17. Crewmember univariate latent growth models for each study outcome

	HTM			HSUP			CSC		
	Parameter estimate	**S.E.**	**P-value**	**Parameter estimate**	**S.E.**	**P-value**	**Parameter estimate**	**S.E.**	**P-value**
Intercept	4.10	0.05	0.00	4.31	0.04	0.00	4.30	0.05	0.00
Slope	0.00	0.01	0.75	0.00	0.01	0.94	0.01	0.01	0.34
Estimated loadings									
Baseline 1									
3-month follow-up									
6-month follow-up									
Intercept variance	0.44	0.04	0.00	0.32	0.03	0.00	0.52	0.05	0.00
Slope variance	*	*	*	*	*	*	0.01	0.00	0.00
Model fit									
AIC	1610			1495			1472		
X^2 (df)	16 (3)		0.38	5.1 (3)		0.16	0.09 (2)		0.67
RMSEA (95% CI)	0.08 (0.05-0.13)			0.3 (0.00-0.08)			0.00 (0.00-0.06)		
CFI/TLI	0.88/0.88			0.98/0.98			1.0/1.0		
SRMR	0.10			0.07			0.01		

*Parameter was fixed to zero due to a non-significant zero or negative variance

Note. LGMS for HSUP, CSC, SP & SC were linear (0 7 10) and the LGM for HTM (0 1 *) was non-linear. HTM (top management safety climate), HSUP (supervisor safety climate), CSC (co-worker safety climate), SP (safety participation behaviors), SC (safety compliance behaviors)

Table 17. Continued

	SP			SC		
	Parameter estimate	S.E.	P-value	Parameter estimate	S.E.	P-value
Intercept	3.72	0.06	0.00	4.38	0.04	0.00
Slope	0.03	0.01	0.00	0.01	0.01	0.24
Estimated loadings						
Baseline 1						
3-month follow-up						
6-month follow-up						
Intercept variance	0.46	0.04	0.00	0.18	0.02	0.00
Slope variance	*	*	*	0.00	0.00	0.31
Model fit						
AIC	1824			1292		
Chi-square (df)	1.71 (3)		0.64	3.14 (2)		0.37
RMSEA (95% CI)	0.00 (0.00-0.06)			0.01 (0.00-0.07)		
CFI/TLI	1.0/1.0			0.99/0.99		
SRMR	0.02			0.09		

*Parameter was fixed to zero due to a non-significant zero or negative variance

Note. LGMS for HSUP, CSC, SP & SC were linear (0 7 10) and the LGM for HTM (0 1 *) was non-linear. HTM (top management safety climate), HSUP (supervisor safety climate), CSC (co-worker safety climate), SP (safety participation behaviors), SC (safety compliance behaviors)

Chapter 4

Discussion

The present study was one of the first to develop and test a safety climate intervention in the construction industry. This intervention focused on both safety climate and safety leadership concepts. In addition to teaching these concepts in a workshop, a reinforcement method (i.e., progress checks) was hypothesized to facilitate the transfer of workshop concepts to the job. However, the results suggest that a workshop results in the same outcomes as an intervention composed of the workshop and progress checks. Generally, the present study suggests that a safety climate and safety leadership workshop results in increased supervisor knowledge of safety climate and safety leadership, supervisor training transfer behaviors, and positive safety participation behaviors for both supervisors, and their crewmembers. However, the workshop did not facilitate any changes in safety climate outcomes for both supervisors and their crewmembers. This result may be due in part to high baseline safety climate perceptions, which indicates that workers already felt that their top management, supervisors, and co-workers valued and prioritized safety.

Contrary to what was hypothesized, the additional intervention component (i.e., progress checks) did not improve all study outcomes after the intervention. There may be a couple of reasons for this null finding. First, the way the progress checks were designed may have influenced its implementation fidelity. When designing the intervention, the researchers considered conducting the progress checks themselves instead of relying on the managers of supervisors to organize and conduct them. While this method would offer better control over the implementation of the intervention, it was not a logistically feasible or sustainable method. The researchers believed that initiating a discussion between supervisors and their managers would spark an on-going conversation about safety culture and safety leadership. It would also foster critical support for the supervisor (Al-Eisa et al., 2009; Conchie, Moon, & Duncan, 2013).

However, only half of supervisors in the workshop participated in the first progress check and participation dropped to one-quarter at the second progress check. Thus, not all of the supervisors received the full amount of training. Second, of those that did receive the full amount of training, the researchers could not fully control the conversation that was had between the supervisors and their managers. Each supervisor/manager pair was required to fill out a progress check guide, and return it to the researchers. Thus, there was some structure to their progress checks, but since the researchers were not present it was difficult to determine how the conversation unfolded. Also, in some cases, the conversation was not one-on-one as planned, but rather amongst a group (i.e., multiple supervisors and their common manager). A one-on-one environment would allow for a more open conversation, but the supervisor's manager argued that a group conversation was best for them since they all know each other well. The null findings may be due to implementation fidelity and dose delivered rather than inadequate intervention design.

Among all participants, there were some positive trends post-intervention. Post-intervention, supervisors better understood what safety climate is and the specific things they should do to improve safety climate perceptions among their crews. Supervisors also indicated that they were transferring concepts learned in the workshop to their job by talking with others about the learned concepts and using the concepts during the course of their work. Positive changes were also observed in safety participation behaviors. Supervisors reported performing more behaviors that actively promote the safety program, and putting in extra effort to ensure a safe job site post-intervention. Furthermore, their crewmembers reported performing more of these behaviors too. However, safety behaviors related to complying with rules and procedures did not increase post-intervention. The relationship between safety climate and leadership style and safety participation behaviors, compared to safety compliance behaviors, has been noted in prior research (Clarke, 2006; Griffin & Neal, 2000; Hoffmeister et al., 2014; Martínez-Córcoles, Schöbel, Gracia, Tomás, & Peiró, 2012). The present study supports and extends these findings. It demonstrates that supervisors' knowledge gained during the training and subsequent efforts to transfer this knowledge to their job, results in more safety participation behaviors. Furthermore, the effect trickled down to crewmembers that did not participate in the intervention.

The present study's safety climate results are comparable to other construction industry leader focused interventions that measured safety climate. Previous non-construction studies resulted in improved supervisor specific safety climate perceptions (Zohar, 2002a; Zohar & Luria, 2003; Zohar & Polachek, 2013), but a change was not observed in the construction specific study (Kines et al., 2010). The present study also did not observe any practical changes in safety climate perceptions. The lack of change in the present study, however, may be due to high baseline scores. This indicates that workers already felt that people at their company valued and prioritized safety. The present study also found that safety behaviors related to contextual performance (e.g., promoting the safety program) positively increased post-intervention for both supervisors and their crewmembers. No prior studies measured contextual safety behaviors. It is interesting that both the present study and the leader focused intervention study in construction (Kines et al., 2010) did not improve safety climate perceptions related to supervisor safety response. Kines et al. (2010) notes that the lack of change may be representative of the difficultly of changing climate and the time it may take to change climate. This change may be especially difficult in the construction industry due to several unique industry characteristics. For a detailed description of the nature of the construction industry see Loushine et al. (2006).

4.1. Future directions

Changing safety climate perceptions in the construction industry may take time as supervisors work to modify how they approach safety on the job. As supervisors start to actively promote safety amongst their crews, crewmember safety climate perceptions may evolve. These new, positive efforts made by supervisors, however, may take time to significantly influence crewmember perceptions. Indeed, worker safety climate perceptions are rooted in "procedures as pattern" (Zohar, 2010). Supervisors who consistently work to promote safety amongst their crewmembers remove the disparity between what the company espouses in theory, and what is actually done in practice. Thus, supervisor safety participation behaviors may be a critical link in the development of safety climate perceptions. The present study measured safety climate at two time-points post-intervention (3 and 6 months post-intervention). Had the present study continued to measure safety climate past 6-months post intervention, significant changes may have been revealed. Furthermore, the short term positive changes in supervisor's contextual safety behaviors observed in the present study may influence safety climate perceptions down the line. This relationship, however, has yet to be studied.

The present study's findings offer several avenues for future research. As previously mentioned, the intervention should be evaluated amongst other types of construction contractors. This includes contractors with poor baseline safety climate scores, but also among different sized contractors, types of work (e.g., carpentry), and industry segments (e.g., residential). The nature of construction also presents several potential challenges to improving safety climate. First, the construction workforce is always in transition. Unless contractors have a steady flow of work, workers will move between contractors as projects arise. So, even if a company consciously strives to improve safety climate amongst their workforce, it may be difficult to sustain due to a transient workforce. It will be especially important for supervisors to set the stage for safety up front and to consistently promote safety through out the project. Future research should study this intervention while accounting for the flow of employees between contractors and projects.

Additionally, it is unclear how the multi-level nature of construction work might affect safety climate development. The construction industry is segmented into general contractor and sub-contractor relationships, trade, union status, and within one contractor, there are differences by project and work group unit. For example, while contractors may each have their own unique safety climate on one job site (Probst et al., 2008), a general contractor's safety climate may significantly influence a sub-contractor's safety climate (Lingard, Cooke, & Blismas, 2010). Thus, one contractor's safety climate may be susceptible to outside influences. It may be possible to target safety climate perceptions by employing a triangulating method whereby general contractors, sub-contractors, and unions work together to improve safety climate perceptions among a common workforce.

4.2. Strengths and limitations

The present study drew upon participatory action research to engage and empower study participants. Throughout the study, the researchers consulted with members of the construction industry on the study content, design, and implementation. While the researchers heavily controlled the implementation of the workshop intervention component, supervisory participants had a significant amount of control over the intervention progress checks. As with any field research in the construction industry, the researchers had no control of workplace factors that may have influenced the results. While actively engaging participants in the research process is beneficial, it shifts some control away from the researchers.

A primary study's strength is the pre-post, quasi-control group design evaluated within a latent growth-modeling framework. However, the selection of participating contractors and assignment to intervention group was non-random, and the present study could not compare the two intervention types to a zero-intervention group. Thus, our findings may not be generalizable to other contractors. Another strength is the almost perfect participation rate of all eligible supervisors during the workshops and their continued employment with their respective contractor at 6-months follow-up.

The main limitation of the present study was an inability to account for the nested nature of the data. Thus, safety climate could not be evaluated as a shared phenomenon. It also means that differences between work groups could not be accounted for. For example, it could not be determined if there was an interaction between supervisor knowledge and crewmember safety participation.

Only supervisors who attended the workshop were considered “supervisors” in this study; however, other supervisors who did not attend the workshop may have contributed to the results seen in this study. However, this effect may be minimal for a few reasons. First, most supervisors who were employed at the time of the workshop attended the workshop, and were still employed at the time of follow-up. Second, from what can be estimated based on the matched surveys, few participants switched roles (supervisor - crewmember) throughout the course of the study (n = 3). Third, there were some new supervisors that joined the company after the intervention started, but not many (about 10%). However, since this study had a hard time following people over time, it cannot be determined how many workers switched roles after the intervention began.

There are some limitations to the measurement of the study variables. Given the large amount of missing data within each wave of data, the present study had a difficult time tracking individuals overtime. This could be due to a variety of factors including workers entering their unique identifier during some data waves but not all, individuals forgetting their unique identifier and entering a new code in subsequent data waves, workers leaving a participating contractor for another non-participating contractor, and workers not being present during scheduled survey times. Common method bias was also a limitation of the study since all study variables were self-report questionnaires. Future research should include objective measures of safety performance to evaluate the effectiveness of the intervention. Finally, the present study did not account for the measurement invariance of the measures overtime.

4.3. Conclusions

Safety culture in the construction industry can be represented by two components of workplace health and safety: the internal and environmental factors (H. C. Biggs & Biggs, 2013; H. C. Biggs, Dingsdad, & Roos, 2008; Choudhry, Fang, & Mohamed, 2007; Zou, 2011).

Environmental factors include safety management systems, behavior based safety, life cycle safety management, and safety knowledge management. Internal factors, on the other hand, represent employee empowerment, leadership, safety knowledge, safety motivation, safety behaviors and safety climate. Zou (2011) appropriately distinguished between them by calling it the "art" and "science" of safety management. Guldenmund (2000) notes that addressing safety culture is an "ambitious and time consuming" endeavor, which requires someone with detailed knowledge of the company to pin point the company's basic assumptions regarding safety. Contractor's can use safety climate measurements to understand their safety culture. As they measure it overtime, it can become a leading measure of their safety performance.

The present study found that a workshop for construction site-supervisors focused on safety climate and safety leadership principles significantly increased supervisor safety climate knowledge, training transfer behaviors, and safety participation behaviors. Crewmember safety participation behaviors also increased. Thus, a safety intervention targeted at supervisors can be used to foster critical employee involvement in job site health and safety efforts. Since crewmember involvement in safety programs is a critical element of any occupational health and safety intervention, this safety climate intervention could be a useful tool to foster the crewmember participation needed to increase the effectiveness of any OSH effort (Nielsen, Randall, Holten, & Gonzalez, 2010).

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Appendix 6.I.

Progress check guide

ACTIVE Safety Leadership Development Progress Check

Goal: Set aside time to discuss employee progress towards development of ACTIVE safety leadership skills.

Objectives:

1. Determine if employee has met goals or took action after the workshop to become more of an ACTIVE safety leader.
2. Discuss enablers and barriers to becoming more of an ACTIVE safety leader.
3. Discuss ways to continue becoming more of an ACTIVE safety leader and ways to overcome barriers to doing so.
4. Set new ACTIVE safety leadership goals.

Instructions:

During the ACTIVE safety leadership workshop, all trainees were asked to write down four goals in their workbook. These were specific goals that they were asked to work on achieving over the next few months. The purpose of the meeting with your employee(s) is to determine their progress towards meeting these goals and to discuss ways to achieve the goals. *If goals were forgotten*, discuss actions taken after workshop to become more of an ACTIVE safety leader.

Frequency: Meet with employees that you supervise 1 time per month for 2 months.

Location: The meeting can be before or after a pre-planned meeting. It can also be scheduled separately to take place during lunch or a coffee break.

Duration: Take at least 15 minutes to discuss your employee's progress. If you have more time, feel free to take longer.

Content: Use the progress check guide to guide your discussion. Fill out the questions.

Turn in progress check guide ASAP to ______ when done.

Progress Check Number (Circle One): 1st 2nd Employee Name: ____________ DATE: ____

ACTIVE Safety Leadership Development Progress Check

Always
Communicate your value of safety to your crew frequently,
Treat safety with the same priority as other organizational goals,
Involve crews in safety analyses and pre-task planning,
Voice your feedback when you see **safe and unsafe** behaviors,
Empower crews to actively take on safety on the job.

Step 1: Determine if employee has met goals or took action after the workshop to become more of an ACTIVE safety leader.

1. What were their goals? If goals were forgotten discuss actions taken after workshop.
(Provide a summary)

____
____
____
____
____
____
____

Step 2: Discuss enablers and barriers to becoming more of an ACTIVE safety leader.

2. Did the training help them become more of an ACTIVE safety leader? (Circle one) Yes No Why or why not?

____
____
____

3. If becoming more of an ACTIVE safety leader has been challenging, what were the specific issues or barriers they faced?
   (Provide a summary)

4. If no challenges or barriers occurred, what enabled them to apply what they learned in the workshop?

Step 3: Discuss ways to continue becoming more of an ACTIVE safety leader and ways to overcome barriers to doing so.

5. What suggestions or solutions can be employed to continue to become more of an ACTIVE safety leader? How can you help your employee?

Step 4: Set new ACTIVE safety leadership goals.

6. Modify goals or create new goals based on your discussion.
    1. ____
       ____
    2. ____
       ____
    3. ____
       ____
    4. ____
       ____

Appendix 6.II

Workshop and progress check organization and content

Workshop **Hour**	**Section and description**	**Reference**
0.0 – 1.0	*Safety culture/climate overview* 1. Safety culture and climate defined and differentiated 2. Role of supervisors in crew perceptions of safety climate on the job 3. Las Vegas City Center case study – Impact of safety climate perception differences between management and crews 3.a. Video: City Center project overview 4. Consequences of a poor safety climate	(Christian et al., 2009; Clarke, 2010; Gittleman et al., 2010; Las Vegas Sun, 2013; Nahrgang et al., 2011; Wiegmann et al., 2002; Zohar, 2011; 2000; Zohar and Luria, 2005)
1.0 – 2.0	*Safety leadership characteristics* 5. Range of leadership styles from passive to active 5a. Video: What is it like to be a leader in the construction industry? 5b. Exercise: What kind of safety leader are you?	(Bass, 1985; Kelloway et al., 2006; Mullen et al., 2011; Mullen and Kelloway, 2009)
2.0 – 4.0	*ACTIVE safety leadership* 6. Communication about your value for safety 7. Treating safety with the same priority as other organizational goals 7a. Video: Safety is a priority 7b. Video: Safety is more than just a priority, it is a value 8. Multi-causal nature of organizational accidents 9. Balancing organizational goals: Production, efficiency, quality, safety 9a. Video: How do others balance organizational goals? 10. Importance of walking the talk when it comes to safety 10a. Video: How are others walking the talk? 11. Voicing feedback when safe and unsafe behaviors are seen 11a. Video: How do others give feedback? 11b. Role play: Practicing feedback when an unsafe behavior is seen 12. Empower crews to take on safety 12a. Video: How do others empower their crews? 13. Ways to involve crews in safety 14. Goal setting: List 4 SMART goals to work on becoming a more active safety leader	(Dedobbeleer and Beland, 1991; Gillen et al., 2004; Hofmann and Morgeson, 2004; Kines et al., 2010; Latham and Locke, 1991; Mohamed, 2002; Reason, 1997; Shannon et al., 1997; Stajkovic and Luthans, 1997; Törner and Pousette, 2009; Zohar, 2007; 2002; Zohar and Luria, 2010; 2003)

Progress Checks	**Description**	**Reference**
~0.15	1. Discussion of goal attainment, factors that helped or hindered goal attainment, methods to overcome barriers, setting new or revised goals.	(Al-Eisa et al., 2009; Latham and Locke, 1991)

Appendix 6.III.

Workshop reaction and training transfer behaviors survey questions

Workshop reaction survey

(Kirkpatrick & Kirkpatrick 2008)

Please rate the following statements by your level agreement	**Completely disagree**	**Somewhat disagree**	**Slightly disagree**	**Slightly agree**	**Somewhat agree**	**Completely agree**
1. I consider the training highly relevant to my job.	1	2	3	4	5	6
2. The training materials are too simple and basic; they do not challenge trainees with anything new.	1	2	3	4	5	6
3. The training materials kept me interested and engaged throughout the training.	1	2	3	4	5	6
4. During the training I had many opportunities to demonstrate my knowledge.	1	2	3	4	5	6
5. I will not be able to apply anything that I learned on the job.	1	2	3	4	5	6
6. The videos were very helpful for understanding the concepts being taught.	1	2	3	4	5	6
7. I will strongly recommend this training to other leaders in the construction industry.	1	2	3	4	5	6

Training transfer behaviors

(Al-Eisa et al, 2009; Machin & Fogarty, 2004)

Please circle the number to best indicate your level of agreement with each statement.	**Strongly Disagree**	**Disagree**	**Somewhat Disagree**	**Somewhat Agree**	**Agree**	**Strongly Agree**
1. I have discussed with my supervisor ways to apply the material that I have learned in the Leaders Create Culture workshop.	0	1	2	3	4	5
2. I have discussed with my co-workers ways to apply the material that I have learned in the Leaders Create Culture workshop.	0	1	2	3	4	5
3. I have used the knowledge and skills I learned in the Leaders Create Culture workshop on the job.	0	1	2	3	4	5
4. The knowledge and skills I learned in the Leaders Create Culture workshop are useful to me in my current role.	0	1	2	3	4	5
5. The knowledge and skills I learned in the Leaders Create Culture workshop have helped me improve my job performance.	0	1	2	3	4	5