Improving Health and Safety in Construction: The Intersection of Programs and Policies, Work Organization, and Safety Climate

IMPROVING HEALTH AND SAFETY IN CONSTRUCTION: THE INTERSECTION OF PROGRAMS AND POLICIES, WORK ORGANIZATION, AND SAFETY CLIMATE

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A Dissertation Submitted to the Faculty of

The Harvard T.H. Chan School of Public Health

in Partial Fulfillment of the Requirements

for the Degree of Doctor of Science

in the Department of Environmental Health

Harvard University

Boston, Massachusetts

May, 2015

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Abstract

Statement of Problem: Despite significant advancements in occupational health and safety in recent decades, injury rates in commercial construction remain high. New programs that address the complexity of the construction work environment are needed to keep workers healthy and safe.

Methods: The first step of this dissertation was to explore associations between organizational programs and policies, as measured by a Contractor Safety Assessment Program (CSAP) score, and worker safety climate scores. Next, a safety communication and recognition program was developed and piloted. It was evaluated through a mixed methods approach in a randomized controlled trial. Primary outcome measures included safety climate, awareness, communication, and teambuilding. Additionally, the dynamic nature of the construction site was quantified through an analysis of the determinants of length of stay of construction workers on the worksite.

Results: Correlations between CSAP scores and safety climate scores were weak at best, thus highlighting a gap in communication between management and workers. The program was a safety communication and recognition program developed to meet this gap. It used data from safety inspection scores to provide feedback to workers on hazards and controls, and provided a reward when the site met a pre-determined safety inspection threshold (a measure that was fair, consistent, attainable and fair). In the final program design, the whole site was treated as the unit of analysis. The program led to many positive changes, including a statistically significant increase in safety climate scores of 2.29 points (p-value=0.012), when adjusting for time-varying parameters and worker characteristics. Workers at the study sites noted increased levels of safety awareness, communication, and teamwork, when compared to control sites. The composition of workers on-site at any given month changed by approximately 50%, and the length of stay on-site was associated with race/ethnicity, union status, title, trade, and musculoskeletal pain (p-values<0.05).

Conclusions: The construction work environment is dynamic, with over half of the population on-site changing each month. This makes applying and evaluating traditional worksite based interventions challenging. Interventions like this program that are developed to address the complexities can have a positive impact on site safety measures.

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ACKNOWLEDGEMENTS

The work presented in this dissertation would not have been possible without the love, support, and guidance from my wonderful family, friends, colleagues, and mentors. I am forever indebted to you.

First and foremost, I’d like to thank my advisor, Dr. Jack Dennerlein. Jack, on that bus ride so many years ago, you asked what may have seemed like a simple question at the time “What are you doing this summer?” The answer to this ended up changing my life in such a huge and wonderful way. I am forever grateful to you for all of your mentorship over the years. I only hope that someday I can give back to a student everything that you have given to me. I very much look forward to continued collaboration in the future.

I want to also thank Dr. Robert Herrick being an excellent teacher and committee member. Bob, you helped show me the world through the industrial hygiene lens--a viewpoint that I take with me in all aspects of my work. I am extremely grateful for your encouragement, guidance, and thoughtful questions these past few years and I know the work is stronger because of it.

The third member of my committee, Dr. Paul Catalano, also deserves special thanks. Paul, you provided invaluable guidance on many aspects of my dissertation, but especially the biostatistics. Be it in the classroom, a committee meeting, or an individual meeting, you helped me sort through my data to tell my story in a way that was interesting, meaningful, and exciting.

I’d also like to some of the people that helped with individual chapters. My co-authors of Chapter 1: Lauren Murphy and Katie Taylor. This chapter laid the groundwork (both theoretically on the topic of safety climate and literally through all of the site visits) for my dissertation and I am very grateful for your help. My co-authors in Chapter 5: Dr. Jeffrey Katz, Dr. Cassandra Okechukwu, and Dr. Justin Manjourides. You helped me with one of the most challenging and exciting chapters in my dissertation and I am extremely appreciative of your advice and assistance.

Thanks also to David Lombardi for your time, guidance, and support through my oral exam. During the preparation and exam, you asked engaging questions that helped improve the work presented here.

In addition, I'd like to thank the following organizations for the financial support throughout my graduate school education: The National Institute for Occupational Health and Safety's Education and Research Center at Harvard (T42OH008416), and the Clinical Orthopedic and Musculoskeletal Education and Training (COMET) Program at Brigham and Women's Hospital funded by National Institute of Arthritis And Musculoskeletal And Skin Diseases of the National Institutes of Health (T32AR055885). Thank you!

I'd also like to thank the members of the HOBEL and NOBEL groups: Jenny, Matt, Oscar, Mike, Michael, Alberto, Lauren, Ana, Ashley, Luz and all the others that have come through the lab over the years. You all made it fun to come into the office every day. I learned a ton from each of you and am so grateful for the time we spent together.

The Building Safety for Everyone crew also deserves special recognition. Annie, Kincaid, Mia, Dana, Kristen, and Andrea – you breathed life into this project, and helped to make those 7am start times so much more tolerable. There is no way this study would have been completed without you – not only because of the time you put into data collection, but also for your positive energy and support you gave to me during the project.

My friends and family have been truly amazing throughout this process. To my friends, both near and far: You are a wonderful group that I am so thankful and proud to have in my life. To Luke, for more than these words can ever fully capture. Thank you for the smiles, the support, and the love.

To my family, Mom, Dad, Maddie: You have always been my biggest fans, and I am forever grateful. You've provided me with the encouragement and the determination to reach my goals, continually inspiring me to be the best person I can be. Thank you for everything. It means the world to me. And to my grandmother: Granny, your have been an inspiration to me since I was a little girl. I will carry your words and energy with me throughout my life, as I try (just like you did) to make the world a better place in ways both big and small.

And finally, to all the construction workers in Boston that made this work possible. I would be nowhere without your willingness to open up to me and share your thoughts on health and safety. My

hope is that the information contained in this dissertation will somehow make your work and life a bit healthier and a bit safer. This work is dedicated to you.

Thank you.

Emily Sparer

Boston, Massachusetts

April 20, 2015

INTRODUCTION

The health and safety conditions on construction sites have greatly improved in recent decades, yet hazardous working conditions remain on most sites, and as a result, workers are at still at high risk for injury and illness. Each year, the number of workers fatally injured in the construction industry tops all other industries (BLS 2014). In 2013 for example, construction worker fatalities made up 18.1% of all work-related deaths in the United States, more than any other industry. That same year, the rate of days away from work for construction workers was 154.7 per 10,000 FTEs, which was 54.9% higher than that of all private industry (99.9 per 10,000 FTEs)(BLS 2014).

In order to reduce these high numbers, many researchers and practitioners have been searching for new methods of injury prevention that go beyond traditional health and safety programs and policies to address the unique aspects of the construction worksite. Construction, often described as a "mélange of order and chaos" (Carlan, Kramer et al. 2012) is a dynamic work environment that is constantly changing. As building structures are constructed, demolished, and renovated, the tasks at hand change, and so too do the workers (Ringen and Stafford 1996, Carlan, Kramer et al. 2012). This makes applying traditional methods of occupational injury prevention to the construction industry challenging and often ineffective. A goal of many of the newer efforts, such as stretch-and-flex, pre-task planning, and safety incentive programs, is to address the complexities of the construction site and improve safety communication and awareness.

The construction site is a combination of many different groups of people working together to tear down, build, or repair structures (Gillen, Faucett et al. 1997). To understand the work organization of this environment, one must first start with the hierarchical structure of the work of the worksite. Often, a property owner hires a general contractor (GC) or construction management (CM) company to oversee construction. The GC/CM team will typically include a mixture of project managers, engineers, and site supervisors, and often a safety manager. The GC/CM team will then hire subcontractors in specialty trades and general laborers to complete the work (Wilson and Koehn 2000). Within each of the subcontractors, there is usually an on-site foreman (someone with more experience and responsibility in managing his or her on-site crew), a group of journeymen (workers who have gone through the apprenticeship training for their specific trade), and a group of apprentices (workers who are in training). In Massachusetts, over 60% of commercial construction workers are unionized (Figueroa and Grabelsky 2010), meaning that some level of safety training and information comes from the unions. The GC/CM, subcontractor, and union may all have different levels of safety requirements that go above or beyond the OSHA standards. The different entities may also have varying levels of implementation and enforcement of their health and safety.

As a result of the unique construction work organization, workers receive messages related to safety (and productivity) from multiple sources that can differ quite substantially. There can be a wide variety of importance placed on safety, both between and within companies by management. This can be manifested through rewarding or punishing, either implicitly or explicitly, messages about safety priorities (Zohar 2010, Zohar and Polachek 2014). Thus, given the multiple ways that workers can and do receive safety information on the construction site; interventions that aim to improve the communication infrastructure on the worksite are extremely important (Gallagher 2003, OSHA 2012).

Organizational programs and policies can also affect injury-related outcomes though safety climate. Safety climate is defined as a measure of shared employees perceptions about the extent to which an organization values and rewards safety in comparison to other competing priorities (Zohar 1980, Zohar and Polachek 2014). The link between safety climate and injury-related outcomes is well established and has been investigated in many different industries (Flin, Mearns et al. 2000, Christian, Bradley et al. 2009, Beus, Payne et al. 2010). However, the link between organizational programs and policies and safety climate is less clear, especially in dynamic work environments such as construction. Most of the research on safety climate has been conducted in industries other than construction, specifically, in more stable work environments like manufacturing.

Dissertation goal

The goal of this dissertation was to better understand how worksite-level programs and policies and work organization impact site safety and ultimately work related injury (Figure 0.1). Organizational programs and policies can play a direct role in improving health and safety outcomes and work-related injury (Amick, Habeck et al. 2000). For example, OSHA's Injury and Illness Prevention Programs (I2P2) contain six key elements that have been found to greatly impact health and safety. These elements include the following: 1) management leadership; 2) worker participation; 3) hazard identification and assessment; 4) hazard prevention and control; 5) education and training; and, 6) program evaluation and improvement (OSHA 2012).

To address the dissertation goal, the first step was to examine existing measures of worksite programs and policies and their perceptions by workers (Chapter 1). Then, in an effort to enhance the communication infrastructure on the worksite (in order to better connect what was written in the programs and policies and what was actually perceived by workers), a safety program focused on safety communication improvements was designed, implemented, and evaluated (Chapters 2-5). The dissertation does not investigate the direct role OPPs have on working conditions, rather, it uses safety climate as a reflection of these working conditions (hence the dotted lines in Figure 0.1).

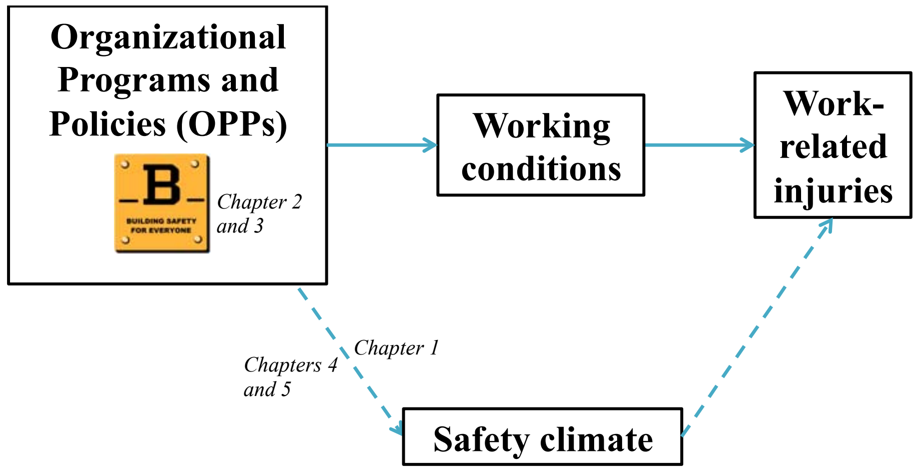

Figure 0.1: Dissertation overview. Chapter 1 examines a measure of organizational programs and policies, CSAP, and the association with safety climate. Chapter 2 and 3 describe the development and testing of the Building Safety for Everyone program components. Chapter 4 examines the efficacy of the Building Safety for Everyone program on site safety measures. Chapter 5 quantifies patterns of worker movement on and off site and the associated worker characteristics in order to better evaluate the impact of the intervention.

Chapter overview

The first chapter of this dissertation, Chapter 1, examines and compares metrics of construction safety taken at the company level, the contractor safety assessment program (CSAP), and at the worker level, safety climate. The CSAP score is a measure used widely in industry hiring practices that assesses a company's formally written policies and procedures and combines this information with other lagging indicator information (e.g. experience modification rates, OSHA inspection history). However, the relationship of the CSAP score and future injury outcomes is unknown. As a first step in understanding this possible association, the relationship of the CSAP score to safety climate , a measure of workplace safety that has been found in many studies to be associated with and predictive of injury outcomes (Huang, Ho et al. 2006, Wallace, Popp et al. 2006, Christian, Bradley et al. 2009) was examined . In this chapter, the associations between these metrics are examined, with the goal of determining if a CSAP score provides any reflection of safety climate on a worksite.

Chapter 2 is a discussion of the safety performance threshold value to be used in a leading-indicator based safety incentive program. Leading indicator-based safety incentive programs are quite novel, and while they are used in practice, a detailed description of their components is absent from the literature. In this chapter, the different ways in which safety inspection data can be analyzed and grouped to best determine a threshold for reward in an incentive program are investigated. This chapter represents the first step in the development of a leading indicator-based safety incentive program for commercial construction.

In Chapter 3, the work described in the previous chapter is expanded to develop the remaining components of the leading indicator-based safety incentive program, now referred to as a safety communication and recognition program. The goals of this chapter are to qualitatively document the development and feasibility of the safety communication and recognition program on a construction worksite and to document the final program design.

Chapter 4 uses a mixed methods approach to evaluate the effectiveness of a safety communication and recognition program for commercial construction sites. Measures of safety examined include safety climate (assessed quantitatively through worker surveys), and safety awareness, communication, collaborative competition, and teambuilding (assessed qualitatively through focus groups).

The final chapter, Chapter 5, uses data collected during the intervention evaluation of the safety communication and recognition program to better understand the complexities of the dynamic work environment. This chapter first describes the patterns surrounding the length of time commercial construction workers spend on worksites in the Boston area. It then investigates the association of individual worker characteristics, including trade, job title, and a measure of health status (musculoskeletal pain) with the length of time individual workers remain on the construction site. This chapter highlights some of the challenges of completing intervention evaluation research on construction sites and offers insight into some of the resulting biases.

It is my hope that that data and methods presented in this dissertation will provide other researchers and practitioners with information on how to better prevent future worksite injuries. I also hope that this information will help others better design and evaluate worksite-based intervention programs. Despite the complexities of the dynamic work environment that is a construction site, we can do a better job at keeping all workers safe and healthy.

CHAPTER 1

Correlation between Safety Climate and Contractor Safety Assessment Programs in Construction

American Journal of Industrial Medicine. 2013. 56: 1463-1472.

ABSTRACT

Background: Contractor safety assessment programs (CSAPs) measure safety performance by integrating multiple data sources together; however, the relationship between these measures of safety performance and safety climate within the construction industry is unknown.

Methods: Four hundred and one construction workers employed by 68 companies on 26 sites and 11 safety managers employed by 11 companies completed brief surveys containing a nine-item safety climate scale developed for the construction industry. CSAP scores from ConstructSecure, Inc., an online CSAP database, classified these 68 companies as high or low scorers, with the median score of the sample population as the threshold. Spearman rank correlations evaluated the association between the CSAP score and the safety climate score at the individual level, as well as with various grouping methodologies. In addition, Spearman correlations evaluated the comparison between manager-assessed safety climate and worker-assessed safety climate.

Results: There were no statistically significant differences between safety climate scores reported by workers in the high and low CSAP groups. There were, at best, weak correlations between workers' safety climate scores and the company CSAP scores, with marginal statistical significance with two groupings of the data. There were also no significant differences between the manager-assessed safety climate and the worker assessed safety climate scores.

Conclusions: A CSAP safety performance score does not appear to capture safety climate, as measured in this study. The nature of safety climate in construction is complex, which may be reflective of the challenges in measuring safety climate within this industry.

INTRODUCTION

A recent approach within the construction industry to increase safety on worksites has been evaluating contractors' performance during the bidding process; however, measuring the safety performance of a company (such as a general contractor or a subcontractor) in the construction industry can be challenging. Traditional safety performance metrics rely on lagging indicators of safety, such as lost workdays; restricted work activity injuries; OSHA recordable injuries; and the Experience Modification Rate (EMR), which is a measure of a company's past loss experience used by insurance companies to set premiums (Hinze and Godfrey 2003, Siu, Phillips et al. 2004, Hoonakker, Loushine et al. 2005). However, these traditional, injury-based metrics may present a skewed picture of safety performance, as they do not account for leading indicators (e.g., organizational programs and policies) that are important determinants of worksite safety (Flin, Mearns et al. 2000, Christian, Bradley et al. 2009, Beus, Payne et al. 2010).

With the goal of improving safety, a group of construction safety professionals developed a contractor safety assessment program (CSAP) called ConstructSecure, Inc. that integrates these traditional injury-based measures with leading indicators of safety. ConstructSecure, Inc., a commercial product, generates a CSAP score on a 100-point scale that allows for easy interpretation. The final score is based in part on the EMR, lost time and OSHA recordable injury rate, and OSHA experience (number of citations, the severity, the regulation, and the penalty assessed). Points are also added to the final score based on an assessment of the company's safety management system through a series of questions on management commitment, employee involvement, hazard inspection and identification, worker training, and program evaluation, all of which are components of what OSHA defines as an Injury and Illness Prevention Program (I2P2) (OSHA 2012). Additionally, the quality and comprehensiveness of the company's safety program is assessed and added to the score. The company's written safety programs are uploaded to ConstructSecure's website, and the text is read and assessed for certain elements related to workplace hazards and safety practices.

All CSAP data are entered by one individual, typically an environmental health and safety manager. Many general contractors and owners (e.g., Harvard University, Skanska) now require all companies bidding on projects to be registered within a CSAP, allowing project managers to evaluate subcontractors and general contractors before beginning work.

A CSAP metric is thought to be a balanced scorecard; it combines many different safety performance metrics and allows for an assessment of contractor safety. As proposed by Kaplan and Norton (1992), a balanced scorecard approach to measuring performance (safety or otherwise) is the most efficient way to compare companies. This measurement tool brings together disparate elements of a company in order to complement one another and provide a more accurate reflection of the safety performance. While a CSAP score may reflect certain aspects of a company's safety performance, its ability to reflect the safety climate of a company is unknown. Furthermore, as a CSAP is based on written safety plans and incident history, it is unable to capture the dissemination or communication of the formal safety policies and procedures to workers.

Safety climate measures workers' perception of the safety culture of their organization at one point in time, and has been found to predict safety-related outcomes(Huang, Ho et al. 2006, Wallace, Popp et al. 2006), such as injury frequency (Johnson 2007) and levels of under-reporting(Probst, Brubaker et al. 2008). Safety culture represents the set of attitudes, beliefs, values, and priorities held by managers and employees that directly influences the development, implementation, performance, oversight, and enforcement of health and safety in the work environment (Guldenmund 2000, NORA 2008).

Therefore, the objective of this exploratory study was to test if a CSAP safety performance score provided any reflection of safety climate on a worksite. The central hypothesis was that safety culture, as measured through the safety climate of an organization, was associated with the level of an organization's health safety management programs and policies, as measured through a CSAP performance metric.

MATERIALS AND METHODS

Study Design and Participant Eligibility

A cross-sectional survey in English was administered to construction workers throughout eastern Massachusetts on commercial construction sites through non-probability convenience sampling methods between January and July of 2012. All workers on the visited construction sites aged 18–65 were eligible to complete the survey, provided they had not previously taken part in the study at another site. Surveys collected from workers employed by companies not registered in ConstructSecure, Inc., the CSAP database, were excluded from analyses.

As perceptions of safety climate often differ between managers and workers (Gittleman, Gardner et al. 2010), environmental health and safety managers from the companies with three or more employees surveyed were contacted separately and asked to complete a manager survey. The individual identified in the CSAP database as the person who completed the most recent ConstructSecure, Inc. application was approached.

Study Measures

The worker survey was developed based on a conceptual model (Figure 1.1) that described the framework of safety climate and its relation to other organizational factors. The survey contained Dedobbeleer and Béland’s nine-item safety climate scale for construction (Dedobbeleer and Béland 1991), as well as potential demographic covariates such as age, gender, race/ethnicity, education, trade, and job title. Each of the nine questions was assigned a point value from 0 to 10 based on the item response, and then summed together to determine the total construct score for each respondent. The safety climate scores had the potential range of 0–90.

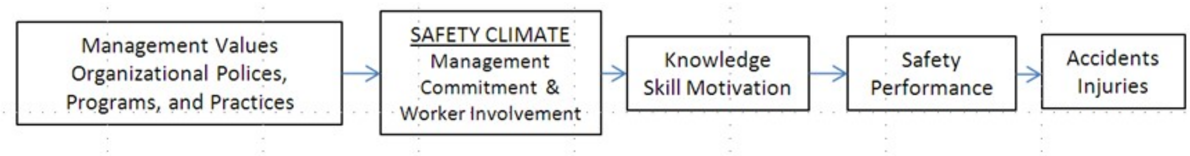

Figure 1.1 Theoretical model of safety climate and its relationship to other organizational factors (Neal, Griffin et al. 2000).We hypothesize that the CSAP captures many of these organizational factors and based on these models should be related to the safety climate metrics.

Each worker was assigned a CSAP score that corresponded to the score of his/her self-identified company (either a general contractor or a subcontractor). Company CSAP scores were obtained from the ConstructSecure, Inc. online database on the day the survey was completed. The scores had the potential range of 0–100.

The manager survey was completed online through Qualtrics (https://harvard.qualtrics.com/). It contained the same Dedobbeleer and Béland (1991) nine-item safety climate scale as the worker survey, with an additional self safety climate assessment scale developed by the investigators based on ten questions from the Laborers' Health and Safety Fund of North America (Schneider 2011).

Analysis

The workers who completed the survey were first categorized into either low or high CSAP groups based on a threshold of 86.1, the sample median CSAP score of the companies represented by the workers surveyed. The value selected as the high/low cutoff point in this study, while numerically high, closely matched the median value in the full CSAP database (87.4).

Differences in demographics, job-related factors, and worker safety climate scores between the high and low CSAP groups were then evaluated through two-sample t-tests and Fisher's exact test.

Workers were assigned their company's CSAP score and correlations between their company's CSAP score and safety climate were assessed using Spearman's correlation coefficient. The correlations were initially evaluated for all workers. In addition, since safety climate is a group-level construct, the correlations were also evaluated for all workers with at least four other co-workers from the same company surveyed (≥5 workers) and for all workers with at least nine other co-workers from the same company surveyed (≥10 workers).

Correlations were also evaluated at the company level, where each company was assigned a safety climate score—the average of all workers surveyed from the company. Separate correlation analyses were also performed for companies with five or more workers and ten or more workers.

Additionally, as a site's general contractor is often responsible for managing the health and safety of a worksite, correlations were also evaluated at the general contractor level, where each general contractor was assigned a safety climate score calculated as the average of all workers surveyed on their sites.

In order to aggregate individual responses to the group level, within-group agreement indices were calculated. Values of intraclass correlation coefficients, specifically ICC(1) and ICC(2), were calculated for groupings of participants by company and by general contractor. Additionally, ICC(1) and ICC(2) were calculated for companies with five or more employees surveyed and for companies with 10 or more employees surveyed. While there is no standard guideline on an acceptable ICC(1) value, the most widely accepted criterion is >0.10 to denote a medium effect size (Murphy and Myors, 1998). There is also no definitive guideline on an acceptable ICC(2) value, but the most widely accepted criterion for ICC(2) is >0.70 (Ostroff and Schmitt, 1993; LeBreton and Senter, 2008). The results for ICC(1) and ICC(2) for all of the company groupings were 0.11 and 0.44, and for the general contractor groupings were 0.046 and 0.59, respectively. ICC(1) and ICC(2) for companies with five or more employees were 0.13 and 0.70, and for companies with 10 or more employees were 0.13 and 0.77, respectively. As ICC(1) values are lower and ICC(2) values are higher, these results indicate that individual responses can be aggregated to these group levels. Confirmatory factor analysis was completed on the nine-item safety climate scale and resulted in two factors, worker involvement and management commitment, which was consistent with previous studies (Dedobbeleer and Béland 1991).

Finally, correlations between manager-assessed safety climate, worker-assessed safety climate, and the CSAP score were also evaluated using the Spearman coefficient.

All data analyses were completed in SAS version 9.2 (SAS Institute, Inc., Cary, NC) and were considered significant at $P<0.05$. Data collection methods used in this study were reviewed and approved by the Harvard School of Public Health's Office of Regulatory Affairs and Research Compliance. The approved methods included a protocol in which construction workers were approached and invited to participate in the survey. Participants were informed verbally that by completing the survey, they indicated consent. As the survey was a one-time occurrence, in which individual identifiers were not required, written consent was waived in order to maintain anonymity.

RESULTS

Study Population

Completed surveys were obtained from 401 workers across 26 sites under 14 different general contractors (Table 1.1).

Table 1.1: A breakdown of the number of companies (workers) surveyed base on different grouping factors with and without Contractor Safety Assessment Performance (CSAP) scores

Company	With CSAP scores	Without CSAP Scores
Number of sites	26	N/A
Total Companies*	56 (358)	12 (22)
With greater than 5 workers	19 (268)	2
With greater than 10 workers	9 (201)	1
Number of GC's	14 (401)	0

*There were 22 workers whose company was unknown.

These workers were employed by 68 different companies, of which 58 were registered with the CSAP database. The respondents were primarily male (97%), with a mean age of 42 years (Table 1.2).

Table 1.2: Distribution of demographic variables and job history characteristics of employees at companies scoring high (>86.1) or low (≤86.1) on the Contractor Safety Assessment Performance (CSAP) Questionnaire

Variables	Construction Workers Surveyed			
	Total	Low CSAP Scored Companies	High CSAP Scored Companies	P-Value[1]
Age (mean years ± SD)	**338**	43 ± 10 (n=193)	42± 10 (n=145)	0.85
Gender	345			
Male	335 (97%)	190 (96%)	145 (98%)	0.525
Female	10 (3%)	7 (4%)	3 (2%)	
Missing	58 (14%)			
Race	333			0.34
Native	10 (3%)	8 (4%)	2 (1%)	
Asian	2 (0.6%)	1 (0.5%)	1 (0.7%)	
Black	27 (8%)	14 (7%)	13 (9%)	
White	264 (80%)	151 (77%)	113 (82%)	
Other / Multi-race	30 (9%)	21 (11%)	9 (7%)	
Missing	70 (17%)			
Ethnicity	327			0.10
Hispanic	30 (9%)	22 (11%)	8 (6%)	
Not Hispanic	297 (91%)	172 (89%)	125 (94%)	
Missing	76 (19%)			
Union Member	352			0.33
Yes	325 (92%)	188 (94%)	137 (91%)	
No	27 (8%)	13 (6%)	14 (9%)	
Missing	51 (13%)			
Job Title	342			0.86
Foreman	35 (10%)	21 (11%)	14 (10%)	
Not Foreman	307 (90%)	174 (89%)	133 (90%)	
Missing	31 (15%)			
Trade				<0.001
Management and Site Engineers	14 (6%)	3 (3%)	11 (10%)	
Carpentry and Masonry	51 (23%)	46 (40%)	5 (5%)	
Drywall, tile installers, tapers, glazers, painters	7 (3%)	6 (5%)	1 (1%)	
Laborers	46 (21%)	15 (13%)	31 (28%)	
Equipment operators	18 (8%)	1 (1%)	17 (16%)	
Electricians	30 (13%)	8 (7%)	22 (20%)	
Plumbers and Pipefitters	26 (12%)	18 (16%)	8 (7%)	
Structural Steel and Iron Workers	11 (5%)	5 (4%)	6 (6%)	
Other	20 (9%)	12 (11%)	8 (7%)	

[1] Bivariate analysis of high and low scoring companies.

(Table 1.2 Continued)

Missing	180 (45%)			
Education	340			0.022
High School or GED	149 (44%)	97 (50%)	52 (36%)	
Some College or trade school	135 (40%)	66 (34%)	69 (47%)	
Associate's degree or higher	56 (16%)	31 (16%)	25 (17%)	
Missing	63 (16%)			

The majority of the respondents were non-Hispanic (91%) white (80%). Most respondents were union members (92%) and had an average tenure with their current company of 7 years (ranging from 1 day to 33 years). Individuals from 25 different trades were surveyed, with the carpentry and masonry trades being sampled more so than any other trades (23%). There were 180 workers who did not indicate a trade or left the question blank. Of all the respondents, 44% had a high school education or GED, and 40% had some college or trade school education. With the exception of trade, there were no significant differences in the demographic characteristics of the workers from the high and low CSAP categories.

Of the 27 companies contacted for the manager survey, 14 companies returned completed surveys. Only 11 of these surveys included a company name, causing three surveys to be excluded from the study. These 11 individuals were all safety managers and ranged in age from 26 to 54 years. Their tenure with their company ranged from 1 to 44 years, and all but two individuals were male. Approximately 78% of the respondents had at least a bachelor's degree, and all were white, non-Hispanic.

Correlations

There were no statistically significant differences in the safety climate scores between workers from high and low CSAP scoring companies (Table 1.3). This result was true across all companies with CSAP scores (n=56) at the individual level (n=336).

Table 1.3: Distribution of worker safety climate among employees at companies scoring high (>86.1) or low (≤86.1) in ConstructSecure Inc's CSAP database.							
Variables	**Range**	**Individuals**			**Contractor averages**		
		High (n=151)	**Low (n=185)**	**p-value**	**High (n=29)**	**Low (n=27)**	**p-value**
Safety climate	0-90	71.0 ± 11.6	70.6 ± 11.4	0.73	70.7 ± 7.9	70.4 ± 7.8	0.91
Worker involvement	0-40	28.1 ± 5.8	27.4 ± 6.3	0.30	27.9 ± 3.7	26.7 ± 3.8	0.27
Management commitment	0-50	42.9 ± 7.2	43.2 ± 7.1	0.73	42.1 ± 4.5	43.2 ± 5.1	0.37

Most Spearman correlations of worker safety climate and the sub-scale (worker involvement and management commitment) scores with company's CSAP score were very weak and not significant (Table 1.4).

Table 1.4: Spearman correlations (and p-values) of overall safety climate and sub-factors to Company CSAP Score from the Construct Secure database.						
Construct	**Individuals (correlation coefficient)** *(p-value)*			**Contractor averages (correlation coefficient)** *(p-value)*		
	All (n=336)	**5+** (n=258)	**10+** (n=192)	**All** (n=56)	**5+** (n=19)	**10+** (n=9)
Safety climate (9 questions)	0.085 (0.12)	**0.16 (0.012)**	**0.16 (0.02)**	0.037 (0.79)	0.20 (0.41)	0.15 (0.70)
Worker involvement (4 questions)	0.11 (0.038)	**0.12 (0.047)**	**0.15 (0.033)**	0.19 (0.17)	0.39 (0.10)	0.29 (0.44)
Management commitment (5 questions)	0.035 (0.52)	**0.16 (0.012)**	0.13 (0.067)	-0.11 (0.40)	0.21 (0.40)	-0.084 (0.83)

There was a small positive correlation (r=0.11) between the CSAP score and the worker involvement score (P=0.038) at the individual level for all workers. There were also small positive correlations of r=0.16, r=0.12, and r=0.16 between the CSAP score and safety climate score (*P*=0.012), worker involvement score (*P*=0.047), and the management commitment score (P=0.012), respectively, at the individual level for companies who had five or more surveys. Additionally, there were small positive correlations between the CSAP score and the individual safety climate score (r=0.16, *P*=0.02) and the worker involvement score (r=0.15, *P*=0.033), when including only workers from companies with 10 or more surveys. These correlations seem to be mainly driven by a large number of higher scoring companies and a small number of low scoring companies (Figures 1.2 and 1.3), and the association disappeared when at all other levels of grouping.

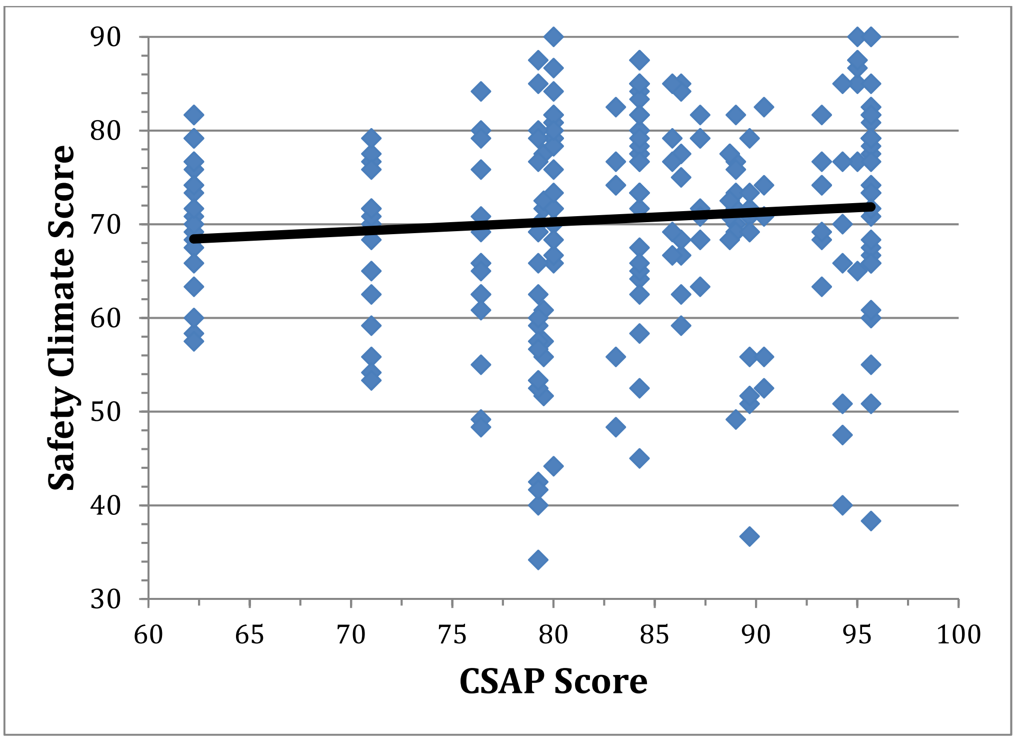

Figure 1.2 Scatter plot analyzing the linear relationship between safety climate score and CSAP score for each company at the individual level with companies who had >5 surveys.

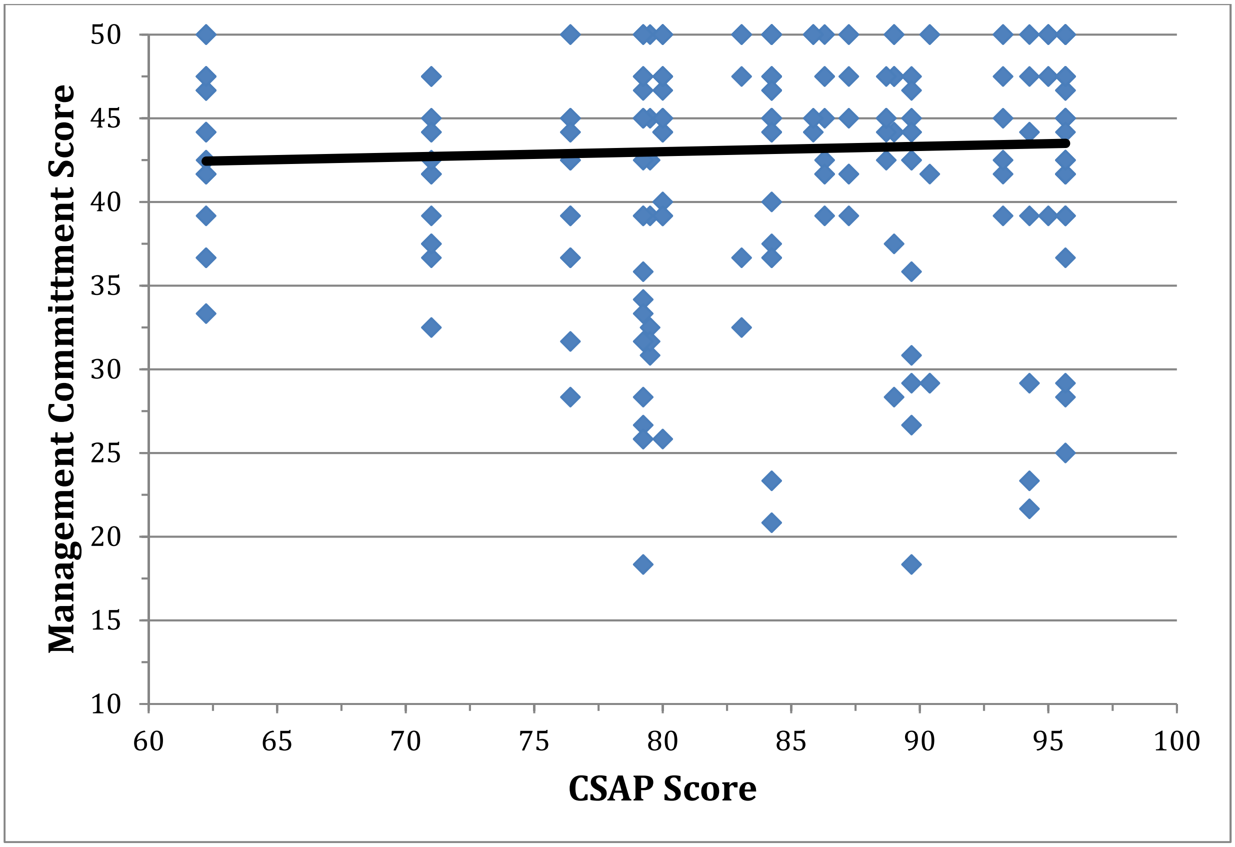

Figure 1.3 Scatter plot analyzing the linear relationship between management commitment and CSAP score for each company at the individual level with companies who had >5 surveys.

Some correlations did increase when examined at the company level (Figure 1.4); however, the small number of companies reduced the power, and hence the correlations were not statistically significant.

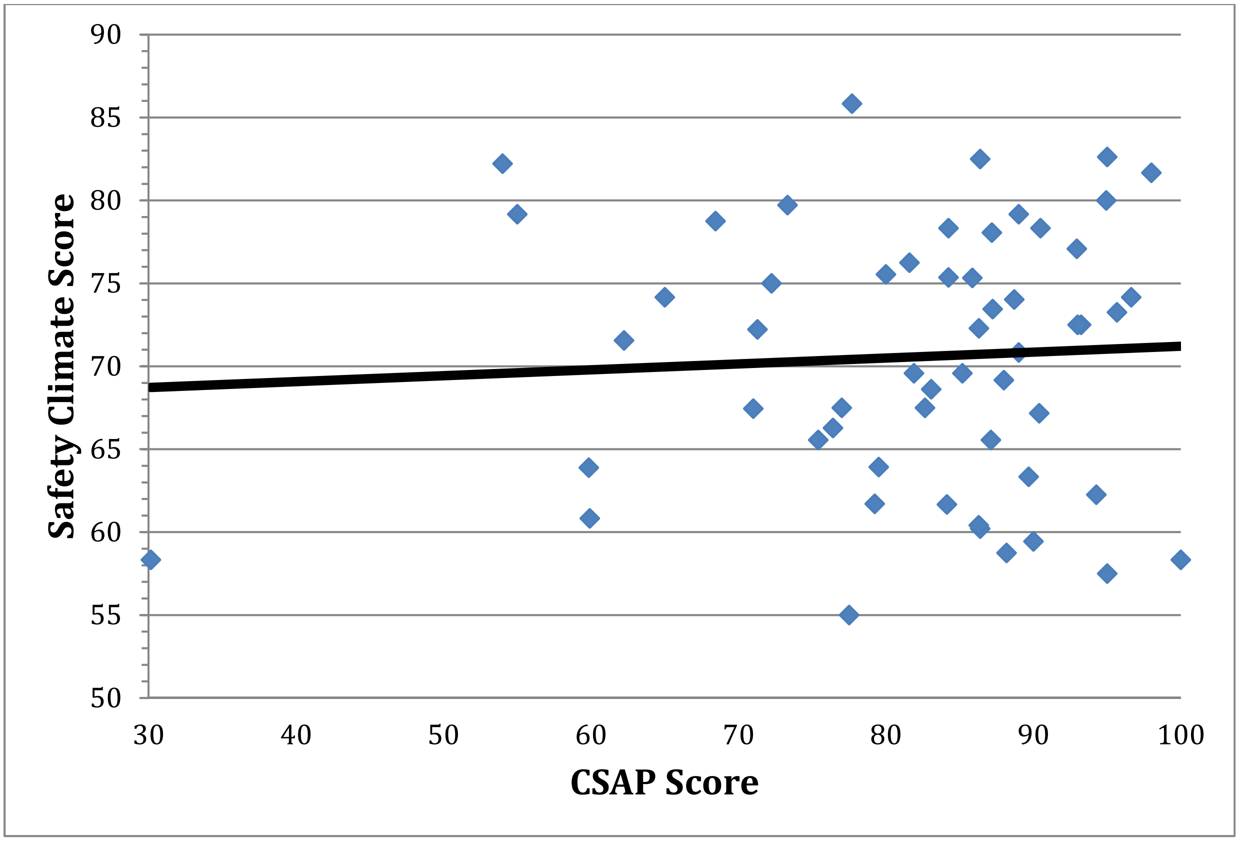

Figure 1.4 Scatter plot analyzing the linear relationship between safety climate and CSAP scores, at the company level

Similarly, some correlations did increase when examined at the general contractor level. The correlation between the general contractor CSAP score and the general contractor average safety climate score was 0.11 (P=0.71). The correlations between the general contractor CSAP score and the general contractor average worker involvement score and management commitment score were -0.050 (P=0.87) and 0.048 (P=0.87), respectively. Again, the low number (n=14) reduced the power; none were statistically significant.

Spearman correlations conducted between the manager-assessed safety climate scale and the average climate score from their workers was moderate (r=-0.26), but not statistically significant (P=0.44) (Figure 1.5). The correlation between the manager-assessed safety climate score and the company's CSAP score was weak and not statistically significant (r=-0.023, P=0.95). The modified LHSFNA scale had weak correlations with both worker safety climate and the CSAP score (r=-0.41, P=0.22 and r=-0.0046, P=0.99, respectively).

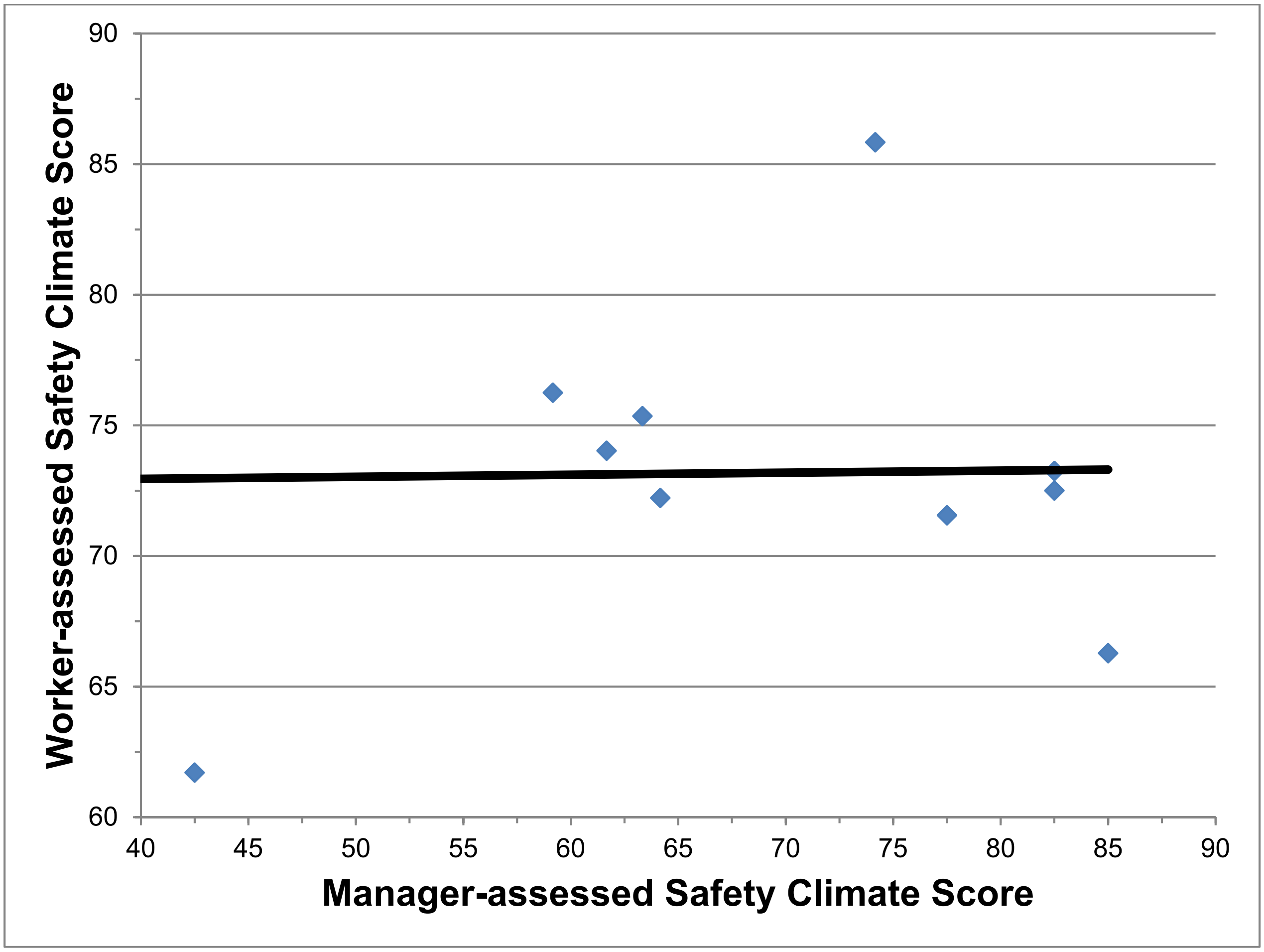

Figure 1.5 Scatter plot of the relationship between manager-assessed and worker-assessed safety climate scores.

DISCUSSION

The goal of this exploratory study was to examine the association between workers' safety climate scores and a score of their respective company's (their direct employer, either a subcontractor or a general contractor) health and safety management systems, a Contractor Safety Assessment Program (CSAP) performance metric. Overall, the results presented here suggest that workers' safety climate scores from a given company were largely independent of that company's assessment of its health and safety management systems (as measured by a CSAP). There were, at best, weak, non-significant correlations between workers' safety climate scores and the CSAP score for either their immediate employer (the subcontractor) or the general contractor for the worksite. The independence of the worker safety climate score and the CSAP performance metric can exist for many reasons, including some of the basic assumptions about safety climate in the construction industry and potential limitations of the data collection.

The lack of correlation may be due to a difference in what CSAP measures compared to what safety climate captures. CSAP scores are calculated through a computer algorithm that scans and scores formally written company policies and procedures and then combines that score with other leading and lagging safety performance indicators. A CSAP does not capture the dissemination or communication of these formal safety policies and procedures to workers. Safety climate, on the other hand, pertains to the communication of safety as a priority from top management and direct supervisors to workers (Zohar and Luria 2003). A company may have formal policies and procedures that present safety as a top priority, but just because those policies and procedures exist does not mean that they are implemented accordingly (Zohar 2008). For example, site supervisors and foremen who do not value safety themselves may not enact their company's formal safety policies and procedures as they are written. This in turn can prevent employees from receiving the message that safety is a priority, thus negatively impacting employees' perception of safety climate (Zohar and Luria 2003). Conversely, the formal policies and procedures of a company may not consider safety extensively, but the supervisors of that company may act and communicate in a way that shows employees that their safety is valued, which increases employees' safety climate perception. These two scenarios highlight the potential disconnect between the written programs and policies of a company and what is enacted at the worksite and reflected in the safety climate measurements.

The lack of association may also be due to the complex nature of climate in the construction industry and the fact that most measures of climate are based on more stable workforces. Measuring safety climate in the construction industry differs from most climate research (Guldenmund 2000). Unlike a stable cohort of workers in a manufacturing plant, as one example, workers on construction projects vary day to day with different social interactions and networks. Most safety climate research has been conceptualized and conducted in industries that have relatively stable and traditional organizational structures (e.g., Zohar, 1980; Fleming et al., 1998; Zohar and Luria, 2005). For example, within one organization in manufacturing, employees are trained to complete jobs in specific departments, and within those departments they report to assigned line supervisors. Line supervisors, who directly manage those front-line employees, are overseen by higher-level managers. Typically, in an organization in the manufacturing industry, employees work in the same teams or departments and report to the same supervisors. This allows for social interactions among coworkers and communication between supervisors and their employees that are mechanisms through which safety climate perceptions form. Social interactions help employees to gather and interpret information regarding the true priority of safety in their organization (Schneider and Reichers 1983).

Communication with supervisors also demonstrates to employees the true priority of safety through the ways supervisors enact formal safety policies and procedures and handle competing demands between safety and productivity or profit.

A potential limitation in our study was the choice of our climate metric. In order to capture employees' safety climate perceptions, the proper psychological measure is needed. The Dedobbeleer and Béland (1991) measure was chosen because it is the only measure, to the authors' knowledge, of safety climate specific to the construction industry. It is important to have industry-specific measures, as the nature of safety climate in each industry may differ. Unfortunately, the Dedobbeleer and Béland (1991) measure was constructed in a way that may not accurately evaluate employees' true safety climate perceptions. It is important that safety climate questions be specific to different reference groups in an organization. In traditional organizations, employees form safety climate perceptions using information about their direct supervisors and their organization separately (Zohar 2010). For example, an employee may believe his supervisor cares about his safety while the organization, as a whole, does not. To determine the overall safety climate perception that an employee has for his company, all aspects of his organization have to be taken into consideration. This is more complicated in the construction industry, but in the Dedobbeleer and Béland (1991) measure, there are a limited number of questions and the referent category changes between the job itself, the worksite, and the company. Different referents are important, but it must be done in a systematic and comprehensive way and it must also be clear to the workers who they should be thinking of when answering questions. For example, as each referent is not defined in the Dedobbeleer and Béland (1991) measure, one employee may be thinking of the "company" as the general contractor while another employee is thinking about his direct employer.

An additional issue is the limited number of questions and factors used by Dedobbeleer and Béland (1991) to measure safety climate. While more research is needed to determine the overall factor structure of safety climate, which may differ in different industries, Zohar (1980) found eight factors and so examining only two may limit results.

Furthermore, selection bias of both the worksites visited and the workers surveyed could have impacted the findings. Companies with either very high or very low CSAP scores may have been more willing to allow surveying on-site. This could have occurred for two reasons. Companies with high CSAP scores may have felt confident in having researchers survey their employees about safety or companies with low CSAP scores may have wanted to prove their safety climate scores were higher than their CSAP scores. It is unlikely, however, that individual workers would know their company CSAP scores; thus, any resulting biases are assumed to be non-differential.

There may also be some selection bias in the contractors included in the study, as they must be registered in the CSAP database. The contractors must have, at a minimum, some value of safety and safety management in their organizations to simply register for the CSAP. However, as seen in Table 1.5, the distribution in this study sample mirrors the distribution of companies in the full dataset. As more owners and general contractors require that subcontractors register with CSAP, the scores are less skewed by companies with more robust safety programs and represent a less biased picture of commercial construction.

Table 1.5: Distribution of CSAP scores in ConstructSecure full database and in sample database		
Percentile	**ConstructSecure full database (n=1183) Score (%)**	**Sample database (n= 58) Score (%)**
90th	96.8	95.0
75th	94.0	89.9
50th	87.4	86.1
25th	76.3	77.1
10th	64.5	64.2

The contractors included in this study were limited to commercial contractors working in the greater Boston area. As a result, the findings may not be generalizable to industrial or residential construction, or to small commercial companies, outside of the northeast. However, the data obtained in this study can be used to shape future studies that expand the study radius and scope.

Finally, the power of this study to examine the association between managers' perception and employees' perception was limited due to the small sample size of managers surveyed (n=11).

The transitory nature of construction raises questions about how construction workers form their safety climate perceptions. Do they bring the safety perceptions they have formed from their company to each job? Do they form new perceptions for each worksite? Is it the union, subcontractor, site, or other subgroup that most influences workers' perception of safety climate? Most of the available safety climate literature in the construction industry has included theoretical and organizational models that have been used to develop fundamental safety climate in classical work-organizational industries. Most studies have used abbreviated climate scales with origins in health care or manufacturing or with few validation studies conducted in the construction industry (Jorgensen, Sokas et al. 2007, Kines, Andersen et al. 2010).

Measuring safety climate in the construction industry is complex and has not received much conceptual attention in the safety climate literature. Up to this point, most studies that address safety climate have treated the organizational layers on the construction site as similar to any other industry.

It is important to determine the ways in which construction workers would group themselves in terms of safety climate groups. For example, it may be a general contractor on a worksite or a union that is influencing construction workers' safety perception more so than any other reference group. It is not for researchers to decide what makes the most sense; however, researchers can understand how safety climate works in the construction industry from the workers themselves. This study highlights the need for safety climate research in construction to recognize and address the numerous dimensions of the construction site.

Conclusions and Contributions

This exploratory study is one of the first to evaluate whether a newly developed and widely used measure of contractor safety performance is associated with safety climate measures. CSAP programs are used with increasing frequency in contractor hiring decisions, yet the question of their relationship with safety climate remains. With 401 workers surveyed, from 26 different worksites of varying scope and size, this study provides the important first step in understanding the correlation between a CSAP measure and safety climate. Workers' safety climate scores, as measured in this study, were independent of an overall measure of their company's health and safety management systems, a CSAP safety performance score. Safety climate in construction is a complex construct, which is reflected in the challenges encountered in its measurement.

CHAPTER 2

Determining Safety Inspection Thresholds for Employee Incentives Programs on Construction Sites

Safety Science. 2013. 51: 77-84

ABSTRACT

The goal of this project was to evaluate approaches of determining the numerical value of a safety inspection score that would activate a reward in an employee safety incentive program. Safety inspections are a reflection of the physical working conditions at a construction site and provide a safety score that can be used in incentive programs to reward workers. Yet it is unclear what level of safety should be used when implementing this kind of program.

This study explored five ways of grouping safety inspection data collected during 19 months at Harvard University-owned construction projects. Each approach grouped the data by one of the following: owner, general contractor, project, trade, or subcontractor. The median value for each grouping provided the threshold score. These five approaches were then applied to data from a completed project in order to calculate the frequency and distribution of rewards in a monthly safety incentive program. The application of each approach was evaluated qualitatively for consistency, competitiveness, attainability, and fairness.

The owner-specific approach resulted in a threshold score of 96.3% and met all of the qualitative evaluation goals. It had the most competitive reward distribution (only 1/3 of the project duration) yet it was also attainable. By treating all workers equally and maintaining the same value throughout the project duration, this approach was fair and consistent. The owner-based approach for threshold determination can be used by owners or general contractors when creating leading indicator incentives programs and by researchers in future studies on incentive program effectiveness.

INTRODUCTION

Worksite approaches to address the high morbidity and mortality rates in the construction sector (CPWR 2008) include a variety of programs and policies ranging from requiring specific worker safety training to sophisticated pre-task safety planning. One approach, employee safety incentive programs, addresses worksite safety by improving feedback to the employees about the worksite's safety performance and thus provides workers with additional motivation to create a safer work environment (Cooper and Phillips 1994, Gilkey, Hautaluoma et al. 2003). With the goal of changing safety culture, the mechanics of employee safety incentive programs use a given safety performance threshold to reward workers when a certain performance criterion is achieved (Figure 2.1). If the workers exceed this predetermined threshold level of safety at the end of a reward period (i.e. one month, one quarter), they receive a reward (Fell-Carson 2004).

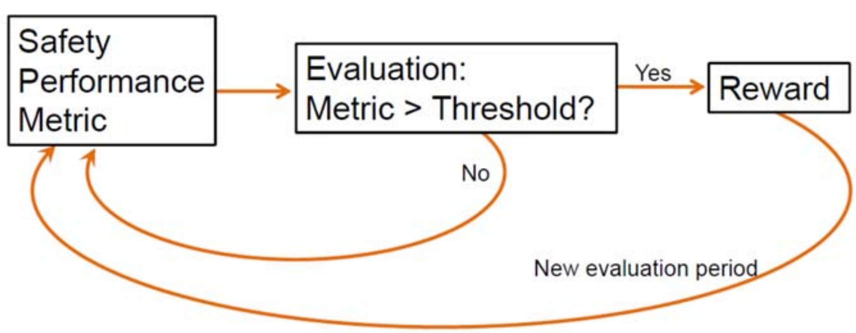

Figure 2.1 In any incentive program, workers are evaluated based on a safety performance metric. If the metric exceeds a pre-determined threshold at the end of the evaluation period (i.e., one month, one quarter), they receive a reward. The program restarts at the end of the evaluation period and the workers have a new chance to receive the reward at the end of the following evaluation period.

The typical safety performance metric and threshold for employee safety incentive programs is the number of lost time or recordable injuries; however, the lagging nature of this safety performance metric raises doubts about its effectiveness in truly reducing injuries and moreover changing the work environment (Mohamed 2003). Lagging indicator incentive programs may give only the illusion of lowering injury rates since the reward is based on an absence of reported injuries, which may incentivize underreporting of injuries (Duff, Robertson et al. 1994, Brown and Barab 2007, Michaels 2010). More specifically, workers may feel pressured not to report an incident to their supervisor, as it could cause the period without a recordable injury to be reset, and thus prevent the rest of the employees from receiving the reward (Fell-Carson 2004).

Novel proposed employee incentive programs use safety performance metrics that precede an incident, mainly the reduction of physical hazards on a worksite; however, identifying a threshold for a leading indicator reward system based on a systematic method to quantify the control of hazards on a worksite has not been described before (Haslam, Hide et al. 2005, Nelson 2008). Methods to quantify the control of hazards on a worksite involve some form of a safety audit, walkthrough, or safety inspection completed by a project or safety manager (Dyck and Roithmayr 2004, Dennerlein, Ronk et al. 2009, Mikkelsen, Spangenberg et al. 2010). These construction safety audit programs have been packaged into commercially available programs (e.g., Predictive Solutions). Data from these inspections, which include both safe and unsafe work practices, can generate a weighted safety score that reflects the number of safe observations out of the total observations (Cooper and Phillips 1994).

Current published studies focus only on one subgroup of workers or one type of work practice (Cooper and Phillips 1994, Duff, Robertson et al. 1994, Lingard and Rowlinson 1997, Wiscombe 2002). None have addressed the complexity associated with construction worksites. A typical construction project is comprised of an owner, a general contractor, and numerous subcontractors (of various trades), all of whom have different experiences and attitudes towards safety (Gittleman, Gardner et al. 2010). Hence, there is no standard published protocol for selecting an appropriate threshold value for an employee safety incentive program based on quantifiable safety inspections/walkthroughs.

As demonstrated in research in other industries and other incentive-based behavioral change programs, a reward threshold score should feel attainable by all workers on-site, yet it also should be competitive enough that it encourages improvement in safe work practices (Fell-Carson 2004). While a reward threshold of 100% might be ideal, it is unrealistic to implement such a standard. If workers never meet the threshold and never receive a reward, they may grow weary of the incentive program and stop trying to improve their safety behavior. At the same time, if the threshold is too low, and workers receive the reward each month, they may not see the point in trying to improve their safety behavior (Lingard and Rowlinson 1997).

The goal of this descriptive study was to evaluate various approaches to selecting a threshold value from inspection data for design of a leading indicator employee safety incentive program. All approaches use pre-existing safety inspection data (leading indicators), collected prior to the start of this study, from multiple projects from a 19-month period on a large university campus. The use of safety inspection data replicates a process that could be easily completed in a real-world health and safety program for construction.

Potential approaches to threshold calculation vary by different groupings of inspection data within large scale commercial construction work, either from a general contractor or owner perspective. Evaluation of the threshold consisted of calculating the frequency and distribution of a monthly reward program at a completed construction project. The evaluation criteria are qualitative in nature and require that the resulting score and its reward frequency and distribution are consistent, competitive, attainable, and fair.

METHODS

Inspection data

This study utilized data from inspections (walk-through safety audits) conducted by the Harvard Construction Safety Group (HCSG) at 65 Harvard projects between January 2009 and July 2010 (Table 2.1). Although safety performance scores were available from September 2007 on, this study only used data from January 2009 onward for threshold development, as by that time inspectors had become more familiar with the inspection process. This allowed for a more standardized, and thus more accurate, inspection process and data collection. This study was exempt from the Harvard School of Public Health Institutional Review Board as the data contained no human subjects identifying information.

Table 2.1: Summary of 65 Harvard University Construction Projects Between January 2009 and July 2010. The table includes information on the projects used in the threshold calculations. The projects ranged in size from small renovations of two or three rooms in an existing space to large demolitions and reconstruction of buildings. Information was not collected on the worker population at the individual sites, as the unit of analysis in this study was the worksite. All inspections were conducted by one of four expert inspectors.

	Minimum	Maximum	Average	Median
Project duration (weeks)	8	60	16.7	15.5
Individual workers	10	175	45	35
Subcontractors	1	17	8	7
Inspections per week	0	2	0.8	0.92

Inspections were conducted approximately once per week at each of the 65 construction projects, covered the same safety parameters (mainly physical working conditions), and were completed by the same four expert inspectors (HarvardConstructionSafetyGroup 2010). The inspectors then entered their detailed safety inspections into Predictive Solutions (Industrial Scientific, Oakdale, PA, http://www.predictivesolutions.com/solutions/SafetyNet/), an online data management program formerly known as Design Build, Own, and Operate (DBO2). Once in the system, the data were exported to statistical programs for further analysis. All inspections occurred prior to the start of this study, thus inspectors did not know that the data would be used to generate a safety incentives reward threshold.

The observations that were entered into the Predictive Solutions database by the inspectors included most of the variables used in this study: the name of the subcontractor responsible for the work practice observed; the project where the observation occurred; the general contractor of the project; the number and type of safe observations on a certain date; and the number and type of unsafe observations on a certain date. Two other variables, owner and trade, were also used in this study but not explicitly specified in the each observation. The owner of all projects the database was Harvard University, thus this was not denoted in observations. The first author assigned each subcontractor a construction trade based on discussions with HCSG inspectors and review of company webpage's. The system was not designed for observations at the worker level, thus information on individual workers at the sites was not collected and is not discussed here.

Threshold calculation approaches

This study explored five approaches to calculate a reward threshold for a leading indicator employee incentive program. Each approach grouped the individual safety inspections together in different ways based on different organizational structures of the construction worksite: by owner, general contractor, project, trade, or subcontractor (Table 2.2). Our rationale for selecting these five approaches was that safety perceptions vary among different groups on a worksite (Gittleman, Gardner et al. 2010), which could be reflected in the breakdown of safety

Table 2.2: Summary of threshold determination approaches and results at the completed project. Five different approaches to calculate a threshold for a leading indicator incentive program were explored. Each approach looked at a different subset of safety inspection data from construction sites. Thresholds were then applied to a completed 17-month project in order to calculate reward frequency and distribution in a leading indicator incentive program.

Approach	**What data was the threshold based on?**	**What time frame was used to calculate the threshold?**	**Is the threshold the same from month to month?**	**Was the threshold the same for everyone at a specific project?**	**Threshold value used in reward distribution and frequency calculation at the completed project.**
Owner	Median value of project monthly scores from all owner projects	All available University-wide data (19-months)	Yes, consistent	Yes	96.3%
General Contractor	Median value of a general contractor's monthly scores	All available University-wide data	Yes, consistent	Yes	93.0% (2 sites, 37 inspections)
Project	Project's previous month's safety performance score	A single month of data.	No, changes each month	Yes	Ranged from 78.8% to 99.6%
Subcontractor	Median value of compiled monthly scores for a given subcontractor	All available University-wide data	Yes, consistent	No, each subcontractor has a different threshold	Ranged from 55.6% to 100.0%
Trade	Median value of compiled monthly scores for all subcontractors within a certain trade	All available University-wide data	Yes, consistent	No, each trade has a different threshold	Ranged from 86.5% to 95.0%

scores. We selected the five approaches based on the availability of information in the inspection scores. As all data was collected before the study began, we were limited by the level of detail included by the inspectors and organization of the database.

The owner-based grouping approach provided a single threshold value for all projects at Harvard University. To calculate the threshold under the owner-based grouping, the safety scores for each project were compiled as the ratio of the weighted number of all safe observations in a given month divided by weighted number of all the safe and unsafe observations in that month. All unsafe observations were weighted by severity and all safe observations were weighted by category, thus attempting to account for the inherent risk differences experienced by all trades on a worksite.

The scores in the owner-based approach were not separated by subcontractor or trade, as the goal of this approach was to look at all projects under the same owner at the project level. The selected threshold was the median value of monthly scores from all 65 projects over the 19-month period, which consisted of 149 monthly scores (not all 65 projects ran for the full 19-months) (Figure 2.2). The median was selected as the threshold due to the highly skewed distribution of the safety performance scores.

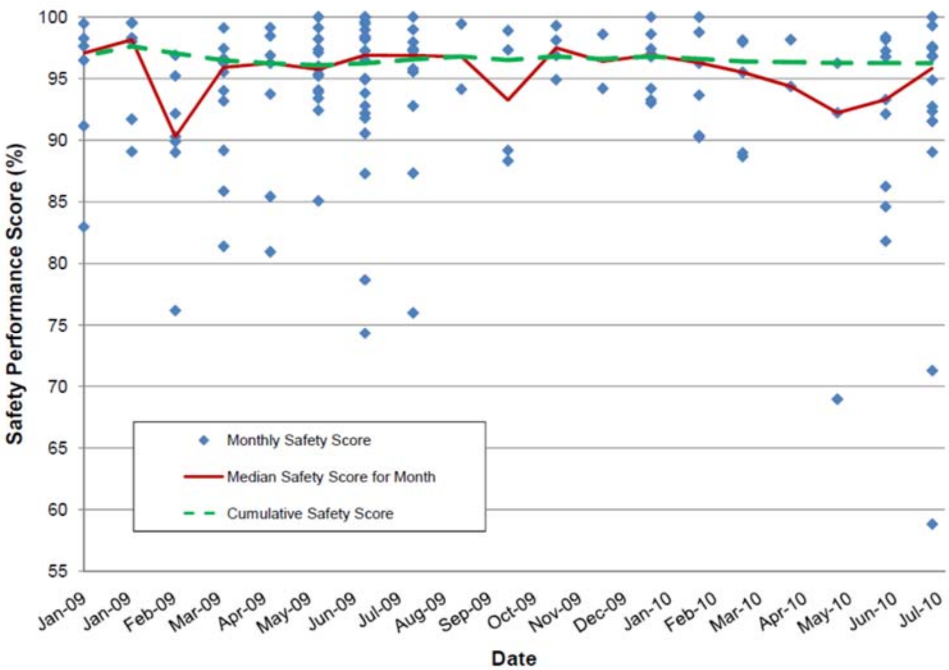

Figure 2.2 Distribution of the compiled monthly safety performance scores for each project at Harvard University between January 2009 and July 2010. Each dot represents the monthly overall safety score for a single project (n = 65).The red solid line represents the median safety performance score in a given month. The green dashed line represents the cumulative median safety score across all projects over the 19-month period.

The general contractor grouping approach provided a single threshold value for each general contractor that had completed work at Harvard during the 19-month period. The safety scores for each general contractor were compiled as the ratio of the weighted number of all safe observations in a given month divided by weighted number of all safe and unsafe observations in that month. For each contractor, the selected threshold was the median value of the monthly scores for the given general contractor observed during the 19-month period. There were 28 different thresholds, one for each of the general contractors.

The project-based approach provided multiple threshold values for a single project, where each month the new threshold at a given project was that project's safety performance score from the previous month. In other words, an incentive program that uses this approach gives the simple message to do better than last month. As the first month of a project has no data from the previous month to generate a threshold, the overall safety score from all projects was selected as the threshold. For example, the overall May 2010 score from all projects at the University would be used to determine whether or not the project would receive the reward for a project started in June 2010.

The subcontractor and trade-based approaches provided a single threshold value for each subcontractor and trade, respectively. The safety scores for each subcontractor and trade were compiled as the ratio of the weighted number of all safe observations in a given month divided by the weighted number of all safe and all unsafe observations in that month. For each subcontractor or trade, the selected threshold value was the median value of the compiled monthly score for the given subcontractor or trade, respectively. As a result, each subcontractor or trade had a unique threshold and would be evaluated separately and compared to its own threshold during reward distribution.

Evaluation through calculation of reward frequency and distribution at a completed project

Threshold values were calculated for each of the five approaches using 19-months worth of inspection data from the University and then applied to data from 48 inspections (4254 observations) of a 17-month long completed project on the Harvard University campus to calculate the reward frequency and distribution under each approach. The project involved construction of a new 43,500-square foot building intended for office and laboratory use. The project was completed between January 2009 and July 2010; hence, its inspection data were included in the calculation of the thresholds.

For each threshold approach, the number of months (frequency of reward) and the number of subcontractors (distribution of reward) that would have received the reward were calculated. In the discussion, these quantitative data will be evaluated qualitatively in terms of providing workers with a fair, consistent, attainable, and competitive incentive reward program. A fair reward program is defined as one that treats all workers on-site equally; that is, all workers are held to the same reward threshold and the program offers everyone the same opportunity for reward. A consistent program is defined as one that has the same eligibility and threshold requirements throughout the course of a project, either for a subcontractor or for the whole project. The definitions of attainable and competitive programs refer to the level of the threshold. The threshold value should be low enough that workers feel they can achieve the level of safety each month, but high enough that it still feels like a challenge.

RESULTS

There were 280 safety inspections recorded between January 2009 and July 2010 at 65 different projects across Harvard University. These inspections resulted in 22,586 observations, of which 1061 were unsafe and 21,525 were safe.

The compiled monthly safety scores at all Harvard projects ranged from 58.9% to 100%, with a mean of 92.7% and a median of 96.3% (Figure 2.2). Hence, the owner-based approach provided a threshold of 96.3%. When this threshold was applied to the calculated reward distribution and frequency at the 17-month completed project, all workers on that project would receive the reward 6 out of 17 months, or 35% of the project duration (Figure 2.3).

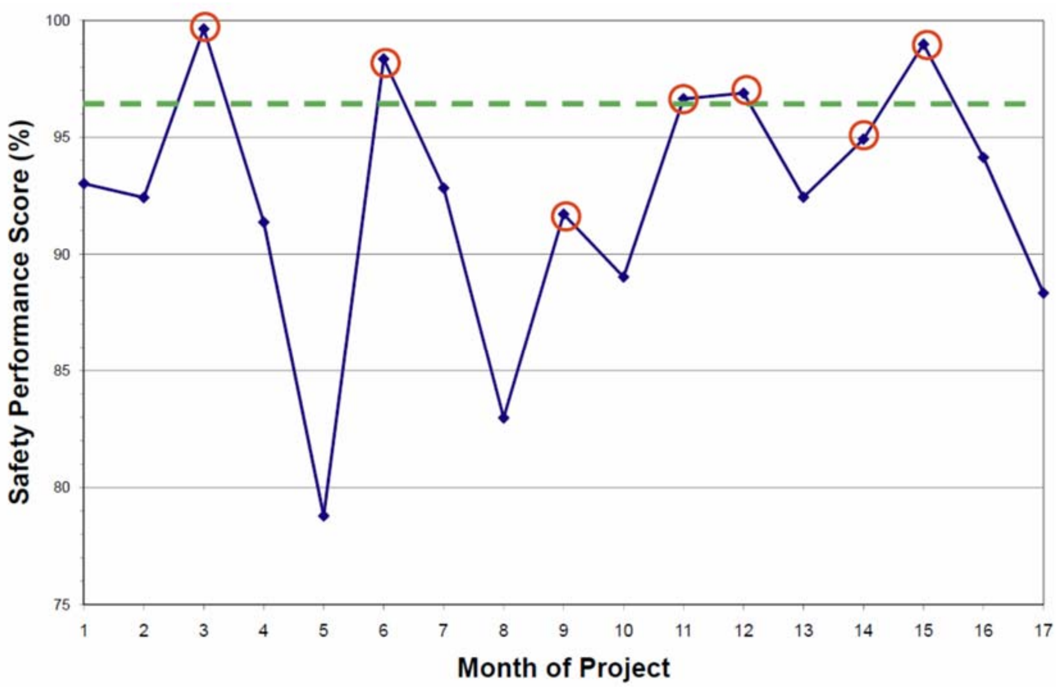

Figure 2.3 Safety performance of the owner-based and project threshold approaches score for the 17-month project during the reward distribution and frequency calculation. The dots represent the monthly scores at the completed project. The dashed line represents the owner-based approach threshold (96.3%). In this approach, rewards would have been distributed in all months in which the project scored above the green line. In the project-based approach, rewards would have been distributed each month that had a score higher than the previous month (red-circles).

The general contractor approach utilized data from two University-owned projects between January 2009 and July 2010 to select the threshold for the general contractor on the 17-month completed project. There were 37 inspections for these two projects. The monthly median and mean scores of these inspections were 93.0% and 92.1%, respectively. Using the median as the threshold in the reward distribution and frequency calculation, all workers on that project would receive the reward for 9 out of 17 months (52.9% of the project duration). Median scores for all other general contractors at Harvard from January 2009 to July 2010 ranged from 58.8% to 100% (Table 2.3).

Table 2.3: Summary of General Contractor Safety Scores. The data in this table show the median and mean monthly safety scores of the general contractors who worked at Harvard-owned projects between January 2009 and July 2010. These projects only account for the contractors who were identified as general contractors in the Predictive Solution database or through conversations with HCSG personnel.

General Contractor	Number of Projects	Number of Inspections	Median Safety Score	Mean Safety Score
A	2	6	97.2%	97.2%
B	6	19	97.9%	97.6%
C	1	1	93.8%	93.8%
D	2	8	99.0%	95.4%
E	2	10	82.5%	82.5%
F	1	1	90.0%	90.0%
G	2	37	93.0%	92.1%
H	1	6	97.8%	97.8%
I	1	12	92.2%	94.4%
J	20	68	98.7%	96.2%
K	2	18	99.5%	98.4%
L	3	8	98.8%	97.2%
M	2	4	95.6%	95.6%
N	1	9	95.8%	96.0%
O	5	33	98.1%	97.1%
P	1	1	58.8%	58.8%
Q	1	1	100.0%	100.0%
R	1	1	96.9%	96.9%
S	1	2	99.0%	99.0%
T	2	6	75.1%	75.1%

(Table 2.3 Continued)

U	1	1	71.3%	71.3%
V	1	2	93.3%	93.3%
W	1	1	93.8%	93.8%
X	1	1	100.0%	100.0%
Y	1	4	97.5%	97.5%
Z	1	1	100.0%	100.0%
AA	1	1	91.7%	91.7%
BB	1	1	76.2%	76.2%

The project-based approach to select a threshold for reward resulted in a value that changed from month to month. At the 17-month project use in the reward distribution and frequency calculation, the scores ranged from 78.8% to 99.6%, with a mean and median of 92.5% and 92.8%, respectively (see the red-circles in Figure 2.3). All workers on that project would receive the reward 8 out of 17 months, or 47% of the project duration (Figure 2.3).

The subcontractor and trade -based approaches resulted in different thresholds for each subcontractor and trade, respectively. The threshold scores for the individual subcontractors ranged from 55.6% to 100%. Under the calculated reward distribution, workers in each subcontractor would receive the reward from 0% to 100% of the time depending upon the subcontractor, with an across subcontractor average of 64% (Table 2.5). Hence workers of some subcontractors would never receive a reward where workers of others would always receive the reward. The subcontractor-based approach was dependent on the company's previous experience working for the owner. As a result, thresholds for some subcontractors were based on only a few inspections. Thresholds for the various trades ranged from 86.5% to 95.0%, with a mean of 92.1% and a median of 92.8%. Under the reward distribution calculation, workers for the trades received the reward 67% of the time they were on-site and were thus eligible for the reward (Table 2.4).

The five approaches were each evaluated qualitatively for fairness, consistency, attainability, and competitiveness (Table 2.6). The owner-based approach met all of the attribute definitions, whereas each of the other four approaches lacked at least one of the attributes.

Table 2.4: Summary of Threshold Scores Using the Trade-Based Approach at the Completed Project. In the calculation of reward distribution and frequency using the trade-based approach, individual subcontractors received the reward an average of 64% of the time, with a median distribution of 67%. Trade type for contractors in the "specialty" trade was unavailable for 5 subcontractors. They were thus not included in the calculation. The trade threshold was based on data collected throughout the University between January 2009 and July 2010.

Subcontractor Trade	Number of Subcontractors in Trade at University Construction Projects	Subcontractor ID	Number of Inspections Between January 2009 and July 2010	Trade Threshold	Number of Months Subcontractor Received Reward	Number of Months Subcontractor Worked on Project	Percent of Months that Subcontractor Received Reward out of Total Months Worked on Project
Construction	16	M	57	94.9%	6	10	60%
Construction of Buildings	10	J	100	94.8%	7	17	41%
Construction of Buildings	10	T	100	94.8%	4	9	44%
Electrical	29	E	156	94.6%	7	9	78%
Electrical	29	Q	156	94.6%	1	1	100%
Finishing	11	K	22	89.9%	0	1	0%
Finishing	11	W	22	89.9%	3	3	100%
Flooring	10	U	18	92.5%	2	3	67%
Glass	14	P	15	90.0%	2	3	67%
Heavy and Civil Engineering	5	B	25	94.3%	3	8	38%
Painting	12	D	26	95.0%	1	2	50%
Plumbing and HVAC	30	L	175	93.6%	8	11	73%
Poured Concrete	17	H	26	94.12 %	5	8	63%
Roofing	8	N	31	88.0%	5	7	71%
Roofing	8	R	31	88.0%	6	9	67%
Scaffolding	8	O	13	91.4%	4	4	100%
Specialty	40	A	73	93.4%	3	3	100%
Specialty	40	C	73	93.4%	0	2	0%
Specialty	40	G	73	93.4%	2	2	100%
Specialty	40	S	73	93.4%	2	3	67%
Specialty	40	V	73	93.4%	0	1	0%

(Table 2.4 Continued)

Steel	16	F	9	88.4%	4	5	80%
Steel	16	I	9	93.9%	2	4	50%
Average percentage of months reward was received out of total months on-site							61%
Median percentage of months reward was received out of total months on-site							67%

Table 2.5: Summary of Threshold Scores Using the Subcontractor-Based Approach at Completed Project. The data in the table above represents the overall safety score at the completed project. In the calculation of reward distribution and frequency using the subcontractor-based approach, reward distribution for individual subcontractors received the reward an average of 64% of the time, with a median distribution of 67%. The subcontractor threshold was based on data collected throughout the University between January 2009 and July 2010.

Subcontractor ID	Number of Subcontractor Inspections	Subcontractor Threshold	Number of Months Subcontractor Received Reward in Calculation	Number of Months Subcontractor Worked on Project in Calculation	Percent of Months that Subcontractor Received Reward out of Total Months Worked on Project
A	8	100.00%	3	3	100%
B	5	90.30%	3	8	38%
C	3	55.60%	1	2	50%
D	3	71.90%	1	2	50%
E	20	95.30%	7	9	78%
F	7	97.00%	4	5	80%
G	4	96.20%	2	2	100%
H	3	72.70%	5	8	75%
I	7	92.40%	2	4	50%
J	37	92.50%	8	17	59%
K	3	83.30%	0	1	0%
L	69	95.70%	8	11	73%
M	25	92.30%	6	10	60%
N	13	92.80%	4	7	57%
O	9	94.10%	4	4	100%
P	7	87.80%	2	3	67%
Q	1	100.00%	1	1	100%

(Table 2.5 Continued)

R	16	92.80%	5	9	56%
S	5	93.90%	2	3	67%
T	15	91.50%	6	9	67%
U	6	96.20%	2	3	33%
V	3	72.70%	0	1	0%
W	9	100.00%	3	3	100%
Average percentage of months reward was received out of total months on-site					63%
Median percentage of months reward was received out of total months on-site					67%

Table 2.6: Qualitative Review of Threshold Development Approaches. Each of the five approaches was reviewed qualitatively for fairness, consistency, attainability, and competitiveness. The results from this review are presented in the above table. Each "+" sign indicates that the approach met the attributes definition. The "–" sign means the approach did not meet the attribute definition. The "o" sign means the approach was neutral with respect to the attribute. As demonstrated in the table, the owner-based approach met the definition of the most attributes when compared to the other four approaches.

Attribute	**Approach**				
	Owner	**General Contractor**	**Project**	**Subcontractor**	**Trade**
Fair	+	+	+	–	–
Consistent	+	+	–	+	+
Attainable	+	+	o	o	o
Competitive	+	o	o	o	o
Sum of positives	4	3	1	1	1

DISCUSSION

The goal of this study was to create and evaluate different approaches of selecting a reward threshold from pre-existing inspection data for use in a future study on the effectiveness of leading indicator employee safety incentive programs. Of the five approaches evaluated, the owner-based approach was the most competitive yet it was also attainable and fair and maintained high standards of safety while accounting for inherent risk differences between trades (Table 2.6).

In the owner-based approach, a reward was achieved only about 1/3 of the time, making it the most competitive threshold. The threshold of 96.3% promoted the highest standard of safety across the whole worksite when compared to the other approaches. The program was consistent across the duration of the program and the single threshold for all workers on-site would make it easy for everyone to understand. This high threshold and low distribution rate (1/3 of the time) represent an achievable level of safety performance without compromising the integrity of the reward (Fell-Carson 2004). In addition, the threshold was fair, as it was the same for all workers on-site and did not leave anyone out of the reward distribution. All unsafe observations were weighted by severity and all safe observations by category, thus accounting for the inherent risk differences experienced by all groups on the worksite and allowing for direct comparison across groups (HarvardConstructionSafetyGroup 2010).

General contractors can also adapt the owner-based approach to determine a threshold for their own leading indicator employee safety incentives program by increasing the quantity of inspection data used in threshold determination. Instead of restricting the safety performance data used in threshold determination to projects under a single owner, as described above in the general contractor approach, general contractors can use data from any of their sites from multiple owners. The number of inspections used in the threshold determination will thus increase and be a much more representative reflection of the general contractor's safety performance. The range of threshold scores experienced by the general contractors is a reflection of the range in available inspection data for each of the general contractors.

General contractors with limited inspections tend to have much higher or much lower scores when compared to general contractors with more inspection data Table 2.3), which in turn can lead to a score that would not be both attainable and competitive. Furthermore, general contractors would only need about 4 months of inspection data in order to determine a threshold, as demonstrated from the stabilization of the cumulative monthly safety inspection score seen in Figure 2.1.

Given the high turnover rates and fluid work environment found in construction, worksite safety programs should have requirements that are consistent throughout the course of the program and are easy to understand by all workers. A threshold score that changes from month to month (like in the project-based approach) may be confusing to workers who do not fully understand the reasoning behind the changing value and thereby lead to resentment of the incentives program. Thresholds that change between groups should also be avoided, as they can be confusing and seem arbitrary to workers. This can in turn hinder the impact of a team approach towards safety and adversely affect the worksite dynamic. The owner-based approach led to a threshold value that was consistent over the course of the project duration, as it remained the same for everyone on the worksite for the entire project duration. The other approaches had much more variability, as they either varied across the duration of the project or between groups within the project.

The project, subcontractor, and trade-based approaches also have many logistical challenges related to implementation. The classification of subcontractors into trade categories can be problematic for companies that participate in more than one trade. It also can be very time consuming for the individual managing the safety scores to calculate multiple thresholds for all the different subcontractors that come through a project. Furthermore, the subcontractor approach was limited in the quantity of inspection data available for some subcontractors, meaning that some scores were based on data that may not have accurately represented the safety performance of the company.

The reward distribution and frequency calculation of each approach was performed at only one project because there was only one in the inspection database that was of average size and duration when compared to the rest of the Harvard projects (Table 2.1) and had consistent inspections throughout the entire project. Due to the lack of regularly conducted inspections at all Harvard projects, the thresholds used in the reward distribution and frequency calculations were based on projects with incomplete datasets. However, this irregularity was not likely to dramatically change the results of this study, as thousands of observations were still able to be used in the threshold determination.

The physical working conditions on a construction site can change drastically from one moment to the next (Kramer, Bigelow et al. 2009), which makes the inspection process quite difficult. The changing worksite tasks and the movement of trades on and off the site directly impact the level of safety on a worksite. A single inspection conducted by one inspector at a given moment in time may not accurately represent the level of safety at the worksite.

The selection of a threshold in a leading indicator incentive program must account for the uncertainty associated with the inspection process. The inspector should be part of the program process, and inspections should be frequent and site-wide. In the leading indicator-based safety incentive program described in this study, one individual (trained in the inspection process) conducted weekly inspections, during which the inspector referenced a manual that described in detail methods for observing, recording, and weighting observations (HarvardConstructionSafetyGroup 2010).

The data used in this study may be biased due to many reasons, including the inspector's previous experience with certain subcontractors or their views on certain work practices. However, a history in the safety field is needed to inspect a worksite as much of the hazard identification process comes from experience. The resulting bias would most likely overestimate the number of unsafe observations, as they are easier to identify than the safes, and lead to a lower final safety performance score. Any biases are expected to affect the inspection data at random. While this could lead to an overall lower threshold value, the conclusions should not be affected. This is another reason why general contractors and owners should use their own inspection data to generate a threshold value.

The reward distribution scheme presented here relied on multiple weekly inspections that were summed together to generate a single monthly safety performance score. In relying on multiple inspections to determine the reward status, the safety inspection score provided a more accurate representation of a project's safety conditions.

The methods described here rely on inspection data collected prior to the start of the study when inspectors had no knowledge that their inspections would be used in development of an incentives program. All data were collected from the same four inspectors over 1 year after the development and implementation of a standard inspection process. The type of data used prevented the testing of inter- or intra-assessor reliability among the inspectors in this study.

While the use of pre-existing inspection data collected by individuals who may hold some biases towards subcontractors does pose a limitation, it should not impact the study findings, as our goal was to replicate a real-world scenario that can be used by general contractors and owners.

In conclusion, the owner-based approach was competitive, attainable, fair, and consistent. As this approach met all of the evaluation criteria, it should be used to determine the threshold in a leading indicator employee safety incentive program. The goal of this study was not to evaluate the threshold's ability to impact safety performance; rather, it proposed an approach to using preexisting inspection data in order to develop a threshold that will be used in a future study on the effect of leading indicator employee safety incentive programs. The approaches described here for selecting such a reward threshold can help guide future research efforts, which can in turn provide assistance to general contractors and site owners in expanding their health and safety programs to include an incentive program.

While it is believed that leading indicator incentive programs, when part of comprehensive health and safety programs, have the potential to improve working conditions and reduce injury rates, this has yet to be proven. Until the effectiveness of such programs is studied in detail, the full impact of these programs is unknown.

CHAPTER 3

Development of a Safety Communication and Recognition Program for Construction

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ABSTRACT

Leading-indicator–based (e.g., hazard recognition) incentive programs provide an alternative to controversial lagging-indicator–based (e.g., injury rates) programs. We designed a leading-indicator–based safety communication and recognition program that incentivized safe working conditions. The program was piloted for two months on a commercial construction worksite, and then redesigned using qualitative interview and focus group data from management and workers. We then ran the redesigned program for six months on the same worksite. Foremen received detailed weekly feedback from safety inspections, and posters displayed worksite and subcontractor safety scores. In the final program design, the whole site, not individual subcontractors, was the unit of analysis and recognition. This received high levels of acceptance from workers, who noted increased levels of site unity and team-building. This pilot program showed that construction workers value solidarity with others on site, demonstrating the importance of health and safety programs that engage all workers through a reliable and consistent communication infrastructure.

INTRODUCTION

In an effort to control the high rates of injuries on construction sites (CPWR 2013), many general contractors and owners use a range of health and safety approaches, including safety incentive programs (Hinze 2002, GAO 2012, Lipscomb, Nolan et al. 2013). Incentive programs utilize a safety performance metric to reward workers and management when performance meets a specific criterion for a given period of time (Bower, Ashby et al. 2002, Hinze 2002, Molenaar, Park et al. 2009, GAO 2012). They aim to encourage increased hazard recognition and control by both workers and management in order to improve the physical working conditions of the worksite, thereby reducing the risk for injury (Winn, Seaman et al. 2004).

Traditionally, safety incentive programs have rewarded workers based on lagging indicators of workplace safety, that is, measures of safety collected after an incident occurs such as number of days without recordable injury. However, these lagging indicator programs, which are classified as “rate-based programs” by the U.S. Government Accountability Office (GAO) (2012), give only the illusion of lowering injury rates, as they can incentivize the underreporting of injuries rather than the actual reduction in injuries (Mohamed 2003). This type of incentive program is often used in commercially available behavior-based safety programs designed for implementation in various types of workplaces. These incentive programs stem from the theory that injuries result from the unsafe behavior of an individual worker (Geller 2005, Brown and Barab 2007) and are aimed at “correcting” workers’ behavior through positive or negative incentives(Geller 2005), rather than identifying and eliminating the hazard at the system or worksite level (Brown and Barab 2007, Lipscomb, Nolan et al. 2013). As a result, these incentive programs are the focus of much controversy (Duff, Robertson et al. 1994, Brown and Barab 2007), and have been criticized for “blaming the victim” and discriminating against injured workers (Pransky, Snyder et al. 1999, Fairfax 2012, Lipscomb, Nolan et al. 2013). Such systems often overlook the fact that unsafe conditions and job hazards (in addition to unsafe acts) are the result of organizational policies and programs.

In contrast, leading-indicator-based programs, which rely on measures of safety at the worksite level that precede an injury, such as unsafe working conditions or lack of safety management, provide an alternative safety performance metric for incentive programs (Mohamed 2003, Winn, Seaman et al. 2004). A leading indicator-based incentive program recognizes workers and management for participation in the safety improvement process through the recognition, reporting, anticipation, and control of unsafe working conditions (Lipscomb, Nolan et al. 2013). These programs increase safety communication between workers and management through regular safety performance feedback and an incentive structure that is not tied to incident reporting. Such communication systems augment safety management programs through demonstrating increased management commitment, employee involvement, hazard identification, and recognized hazard control, all important components of an effective health and safety program (OSHA 2012).

Leading indicators are often measured on construction sites through the industry practice of walk-through safety inspections (Becker, Fullen et al. 2001, Gilkey, Hautaluoma et al. 2003, American Industrial Hygiene 2005, Kaskutas, Dale et al. 2008, Dennerlein, Ronk et al. 2009, Sparer and Dennerlein 2013). These safety audits include measures of both the controls in place and the uncontrolled hazards, as it is acknowledged that an overall worksite safety assessment should include metrics of both safe and unsafe work conditions (Mikkelsen, Spangenberg et al. 2010). However, while some anecdotal evidence exists from the field, we were not able to find rigorous studies in the existing scientific literature that describe the mechanics of such a program or test its effectiveness in changing safety conditions and injury rates.

Our long-term goal is to evaluate the impact of a leading indicator-based incentive program, referred to herein as a safety communication and recognition program, for the construction industry, through which data on safety conditions are shared regularly with foremen and workers on safety conditions and injury rates. As a first step however, we must develop a program that can be implemented and identify components that will make it acceptable to both worksite managers and the workers. Lessons learned through implementation of an intervention are often not discussed in the scientific literature; however, without such trials the evaluation of an intervention can only fail. Such development steps are imperative for a successful intervention development and are a necessary first step in the evaluation of an intervention.

Our goal for this article is therefore to qualitatively document the development and feasibility testing of a safety communication and recognition program in a dynamic work environment. We aim to share the process and our experiences in designing, piloting, redesigning, and re-piloting a safety communication and recognition program on a construction worksite; we will also document the final design. The lessons learned from this program development experience relate to program mechanics, feasibility of implementation, and potential for scientific evaluation that will inform our future studies on program effectiveness and can serve to inform others engaged in program design and development.

METHODS

Development and feasibility testing of the safety communication and recognition program were competed and evaluated through qualitative methods and consisted of the following iterative steps: 1) initial program design; 2) implementation; and 3) feasibility testing (Bartholomew, Parcel et al. 1998, Oude Hengel, Joling et al. 2011). All data collection methods used in this study were reviewed and approved by the Harvard School of Public Health's Office of Human Research Administration.

Step 1: Initial Program Design

The first step of the initial program development was to consult the scientific literature on safety incentive programs (both leading- and lagging-indicator-based), safety communication programs, systems of safety performance measurement, and safety behavioral change models (Cooper and Phillips 1994, Duff, Robertson et al. 1994, Neal, Griffin et al. 2000, Fell-Carson 2004, Geller 2005, Brown and Barab 2007). The literature review was supplemented by interviews with construction industry experts including construction project managers, health and safety managers, and academics in health and safety research to understand how incentive programs had been implemented in past and current practice, as well as how safety is measured and communicated on the worksite.

We then vetted the initial design with an expert panel of construction project managers and environmental health and safety (EH&S) practitioners in May 2010. The panel consisted of a safety inspector from the Harvard Construction Safety Group, two project managers from the Harvard Planning and Project Management department, and three EH&S managers from general contractor companies engaged in construction in the greater Boston area. All participants of the panel had several years of construction management experience on a range of worksites, with the majority of their current work focusing on medium- to large-scale commercial construction projects. Participants also all had experience with running varying types of safety incentive programs on construction sites. The panel provided feedback on the feasibility of implementing our program on a construction site and suggested ways to improve the design. We sought feedback on the perception of our program's fairness and its competitive reward distribution scheme in the context of the dynamic construction environment, where different companies, trades, and individuals are constantly coming and going from the worksite. Additional topics discussed included the type of recognition that should be distributed, the frequency of and the method of recognizing workers, and the unit of recognition (e.g., individual workers, subcontractor, or overall worksite).

Step 2: Implementation

The safety communication and recognition program was piloted on a 100,000-square foot construction site on the Harvard University campus with an average of 60 workers on site per month for two months during the summer of 2010. The site was selected because it was representative of the medium to larger construction sites on campus in terms of trade composition, budget, number of workers, and duration (Table 3.1).

Table 3.1. Comparison of Harvard University Construction Projects to Project Recruited for this Study

	Project duration (weeks)		Individual workers on-site at one time		Subcontractors on-Site at one time	
Harvard-owned projects between January 2009 and July 2010	Minimum	8	Minimum	10	Minimum	1
	Maximum	60	Maximum	175	Maximum	17
	Median	16.7	Median	45	Median	8
	Average	15.5	Average	35	Average	7
Recruited project	52		150		15	

Step 3: Program Feasibility Testing

Feasibility testing of the safety communication and recognition program involved several steps, all of which took place concurrently. First, we recorded aspects of the practicalities involved in administering the program. For example, we documented accessibility and timeliness in obtaining safety inspection scores from our partnering organizations. For the worksite itself we noted high-visibility places on site to hang program posters that delivered feedback. In terms of workload to manage the program given the resources, we documented the effort required to maintain the program feedback infrastructure. We also documented participant and site observation on program-related activities (Maxwell 2005), such as how program elements appeared to be accepted by workers and management. Second, we conducted semi-structured interviews with workers and site management during lunches, breaks, and toolbox talks using convenience sampling methodology. Third, following completion of the two-month initial pilot, we held a focus group with eight workers and collected feedback on the on-site program, as well as information about past experiences with similar programs. All qualitative data were recorded and transcribed by project investigators.

Following the initial piloting, and based on lessons learned in the two-month implementation, we repeated these three steps to reach a final system design. First, we redesigned certain program elements. Second, we tested the feasibility of the redesigned program on the same construction site for six months (following a two-month break with no safety communication and recognition program on the worksite). The goal of the six-month implementation was to test the feasibility of the redesigned program, as well as to evaluate the program's sustainability for a longer duration. Third, we repeated our qualitative evaluation with a focus group and multiple key informant interviews with managers.

RESULTS

The iterative process for developing the program provided a set of key results for each step in the process including an initial program through formative research, limitations of the initial program discovered through testing its feasibility, and a redesigned program that addressed these limitations.

Step 1: Initial Program Design

The formative research resulted in an initial program design that consisted of communication with workers via their foremen and recognition of the top-performing subcontractors based on leading indicators of safety performance (obtained from safety inspections completed through worksite walkthroughs by a professional safety and health manager from the Harvard Construction Safety Group). At the time, practice dictated that these inspections were unannounced to site supervisors and foremen. They were completed at a minimum of once per week. These inspections followed a standardized protocol that assigned observations obtained during the walkthrough to one of 22 categories on a checklist (Table 3.2). These categories included a range of common tasks and their associated hazards and controls (e.g. use of hand and power tools, electrical safety). The observations were then assigned to a subcategory (e.g., Electrical Safety: Cords in Good Condition) and determined to be either an unsafe or safe observation (referred to in the program as “unsafes” and “safes”). Unsafes were then assessed for severity and likelihood of injury based on a risk matrix of “low,” “medium,” “high,” or “life-threatening” (HarvardConstructionSafetyGroup 2010). Each observation denoted the subcontractor and included where the observation occurred, the project’s general contractor, and date of observation. All observations reflected both individual-level behaviors and overall worksite conditions. Since our program emphasized worksite conditions rather than individual actions, we created a weighting system to reflect this (Tables 3.2 and 3.3). Observations from the walkthrough were recorded into an online data management program called Predictive Solutions (Industrial Scientific, Oakdale, PA, http://www.predictivesolutions.com/solutions/SafetyNet/), formerly known as Design, Build, Own, and Operate (DBO2). Unsafes were also reported verbally by the Harvard safety inspector to site management and foremen in order to initiate immediately correction of the unsafe conditions.

Table 3.2. Safe Categories and Weights[a]

Safe observation category	Weight
Administration	1
Aerial lifts	2
Asbestos	2
Confined space	3
Control of hazardous energy	2
Cranes and hoisting equipment	3
Demolition	3
Electrical safety	2
Environmental	1
Excavation and trenching	3
Fall prevention and protection	3
Fire prevention and protection	2
Fire prevention and protection—hot work operations	2
Hand and power tools	2
Hazard communication	1
Heavy equipment	2
Housekeeping	2
Ladders	2
Personal protective equipment	1
Powder-actuated tools	2
Public protection	2
Scaffolding	3

[a]During the safety inspection, all safe observations were characterized into one of these categories. A weight was then assigned to the observation in order to calculate a safety performance score that was fair and reflective of the risks avoided, and placed greater emphasis on physical working conditions rather than individual behaviors.

Subcontractor safety performance was based on a weighted score, calculated as the ratio of the weighted number of safe observations to the weighted number of total observations recorded in the database assigned to the subcontractor. Unsafe observations of higher severity resulted in a greater deduction of points from the score than lower-severity observations (Table 3.3). Weighting of safe observations was based on the severity of an injury that could result from the hazard accounting for variability in task difficulty and risk level. Dangerous tasks observed to be performed safely received additional points, based on category of observation (Table 3.2). Weights assigned to the safe categories were determined based on expert opinion of what the likely severity of injury, should the task be performed unsafely. The weights for both safe and unsafe observations aimed to increase the accuracy of the safety inspection score as a reflection of site safety by acknowledging differences in risk for various work tasks.

Table 3.3. Unsafe Categories and Weights

Unsafe observation category[a]	Weight
Low	1
Medium	3
High	5
Life-threatening	10

[a]During the safety inspection, all unsafe observations are characterized into one of these categories. A weight is then assigned to the observation in order to calculate a safety performance score that is fair and reflective of the risks incurred.

These subcontractor performance scores were communicated weekly to workers and foremen via on-site posters and toolbox talks. The weekly subcontractor safety performance scores were displayed on a large graph prominently displayed on the worksite. The graph denoted each subcontractor's safety inspection score by a code in order to ensure confidentiality of the scores. Workers were informed of their subcontractor's identification code during the program introduction toolbox talk. We also held weekly toolbox talks with each subcontractor to provide feedback on their specific performance based on the inspection data. Since the project owner already required weekly 10-minute toolbox talks, the program simply augmented a procedure already in place. At the talks, inspection scores from the previous week that highlighted both the safe and unsafe observations were presented.

For the initial design, the unit of recognition was the individual subcontractor, as this was thought to encourage competition between subcontractors, as well as a team effort within each subcontractor. Recognition of top-performing subcontractors was based on their cumulative monthly safety performance score. Subcontractors with a monthly safety performance score above the predetermined threshold of 95.4 percent (Sparer and Dennerlein 2013) were recognized with a free lunch at the end of the month. To determine the threshold value, we used the approach described by Sparer and Dennerlein (2013) in which the threshold is the median monthly safety performance score for all construction projects under the same owner (in this case, Harvard University) over a 19-month period (January 2009 to July 2010) prior to program implementation. This method of using the median monthly safety performance score was found to result in a threshold that is competitive, attainable, fair, and consistent.

Recognition involved a catered on-site lunch and a public acknowledgement of the achievement made by each subcontractor that surpassed the threshold score. This is the final step outlined in the process flow depicted in Figure 3.1. The lunch was selected because it provided both individual and social reward elements, in gathering the group as a whole, but providing something specific to each worker. Rewards that provide a social incentive, such as a company lunch, a handwritten note of appreciation, or even verbal recognition from management have been found to have a larger impact than money in construction and manufacturing environments (Arnolds and Boshoff 2002, Fell-Carson 2004).

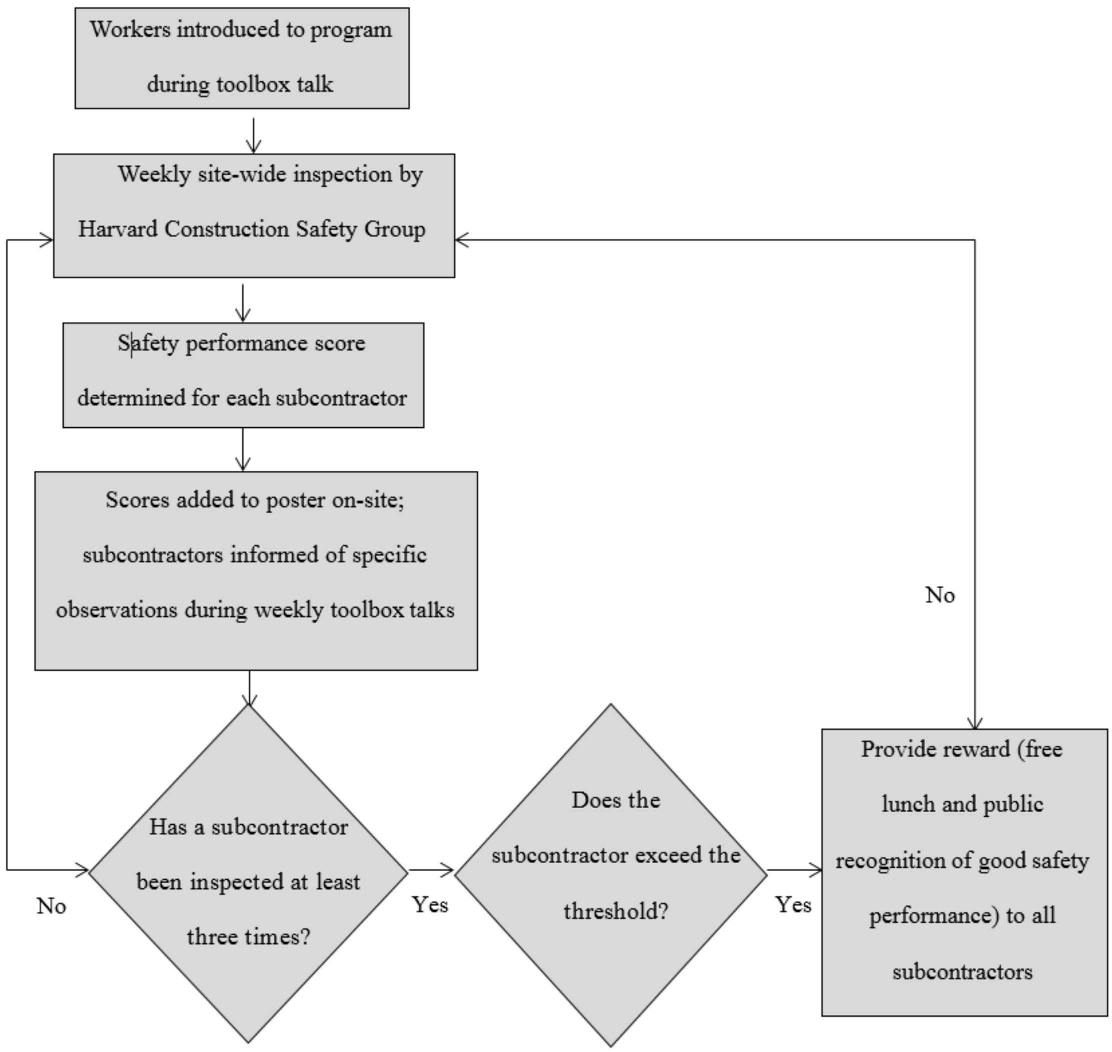

Figure 3.1. Initial safety incentive and communication program design. Individual subcontractors were the unit of reward and the evaluation period was one month. At the end of the month, subcontractors who had scores that exceeded 95.4 percent received a reward. The evaluation and reward process would repeat for each month of the program.

Implementation and Feasibility Testing of the Initial Design (Steps 2 and 3)

The two-month pilot of the initial design identified several key weaknesses of the initial design, specifically the communication program's reliance on toolbox talks, coding of the subcontractors, and the recognition of only the top performing subcontractors at the lunches. Introducing the program and providing the inspection data to workers via the toolbox talks was not feasible as these talks were not held at the same time each week and were often scheduled at the last minute. Furthermore, as the construction project grew in size and complexity, more subcontractors were on-site at one time (each with their own toolbox talks), which only added to the challenge of introducing the program to workers within their first few days on-site. In addition, it was apparent from conversations with workers and management that safety performance feedback from the researchers via these toolbox talks was not appropriate as the researchers were neither directly in charge of the workers nor conducting the inspections. For the posters, many workers commented that the poster coding of subcontractor's safety performance score was confusing and that they often did not know which code corresponded to which company. As a result, they noted that they lost interest in the scores.

Recognizing only the top performers meant that there were a number of subcontractors who were excluded from recognition, which led to a very uneasy atmosphere, with many of those that qualified for recognition being unhappy with the separation and unclear as to the reasoning behind the exclusion. Many expressed resentment towards the program as a result of being excluded or seeing others excluded at the lunch. Qualitative data collected during the focus group indicated that even though the site was made up of different companies working on different time schedules and tasks, the work was perceived to be team-based effort and the worksite unity should be reflected in the program design.

While workers seemed to appreciate the recognition through a communal lunch, they noted that a larger reward might have more of an impact on-site, with many suggesting free parking due to the worksite's urban location and the high cost of parking.

Redesigned Program (Repeat of Step 1)

In the redesigned program, the introduction to the program took place during new worker orientations and weekly foreman meetings, safety performance feedback was listed by subcontractor name on the weekly posters, a high-value item (free parking) was added to the recognition lunch, and the site was evaluated as a whole for overall safety performance at the end of a month. The structure for introducing the program to workers changed from toolbox talks to new worker safety orientations (mandatory meetings held twice per week), which allowed the capture of new workers from all subcontractors at a single event as they entered the worksite. In addition, in the redesigned programs, weekly foremen meetings, not toolbox talks, were used to convey safety performance feedback. Here, detailed reports were provided to foremen about the specific observations from recent inspections that related to their company. The foremen were then strongly encouraged by the research staff to share this information with their workers.

We continued to use posters to convey the safety performance scores; however, in addition to displaying the individual subcontractor scores, we plotted the score for the whole site. We also posted a list of the individual subcontractor scores, now with company names identified. Recognition of safety performance was provided for everyone on site if the safety performance score for the whole site exceeded the threshold. At the site-wide recognition activity (the lunch), we also added a raffle for a one-month parking spot at a local garage, valued at $247. All workers were eligible for the raffle, although only one individual worker received the parking spot prize. While the use of monetary items as a reward in safety incentive programs is controversial (Kohn 1998), we included a high-value raffle that included everyone on-site in this program largely based on worker feedback and the desire to encourage safe work practices and conditions at the worksite level. The combination of the social and individual reward elements of both the lunch and the raffle enabled the formal recognition of all workers for their achievements as a group. All other aspects of the program, such as the performance metric, the inspection process, and the timing of the recognition cycle, remained the same.

Implementation and Feasibility Testing of the Redesigned Program (Repeat of Steps 2 and 3)

During the revised program implementation, the cumulative safety performance score of the whole worksite exceeded the recognition threshold in three out of the six months, resulting in a 50 percent recognition frequency (Sparer and Dennerlein 2013). During each of the six months, there were some subcontractors whose individual safety performance score never exceeded the threshold value, others that exceeded the threshold each month, and others that varied from month to month. However, as the site was evaluated as a whole, it was only the overall cumulative score of all subcontractors that determined whether or not the site would be recognized. At each of the three safety recognition distributions, all workers on-site were invited to participate in the lunch and enter the parking spot raffle. We received positive feedback from workers and management at each safety recognition lunch.

Workers and management noted that the change in delivery of safety performance feedback and unit of recognition led to an improvement of the “camaraderie” and teambuilding at the worksite. Workers checked the safety performance poster regularly and frequently asked the safety manager for ways to improve the scores. They demonstrated collaborative competition through an expressed interest in improving their both their individual scores and the overall score (now displayed as a single value), as well as the scores of other subcontractors. Direct feedback from workers indicated that none of the subcontractors wanted to have the lowest scores of the week, so there was constant competition among the various companies on site to not be at the bottom of the list, yet each week there was also the desire to keep the overall score high. This meant that companies with higher scores had an interest in helping companies at the bottom to keep the scores high. This collaborative competition appeared to increase interactions between trades that previously did not communicate with one another. Foremen in particular noted that they found the individual subcontractor feedback helpful, as it provided detailed information on observations made during inspections that they could share with their team. Prior to the program implementation, details on the inspections, especially feedback from safe observations, was not readily available to foremen.

DISCUSSION

The goal of this paper was to document the development and feasibility testing of an alternative to the traditional lagging-indicator–based safety incentive program—one that instead relied on pre-incident worksite safety metrics to incentivize safety through communication and recognition. As described above, we developed an initial design, piloted the program mechanics on a construction site, redesigned the program, and re-piloted the improved redesign. Implementing the redesigned program was successful in that it was feasible for the research team to complete, was well received by everyone on the worksite, and led to worksite unity and team-building.

The lessons learned highlighted three important elements of a successful safety communication and recognition program: 1) the site should be evaluated and recognized as a whole; 2) safety performance feedback should target both individual subcontractors and the worksite as a whole; and 3) the program design and objectives should be clearly communicated to all workers. The redesigned program accounted for these elements and in turn, helped promote an approach to safety that emphasized teamwork and was well accepted by workers. In the redesigned program, we changed the focus of the program from the subcontractor level to the worksite level, which led to increased collaborative competition and team-building. Furthermore, the program was easily incorporated into the existing on-site health and safety structure.

While the program described here was developed to include communication and recognition components, we acknowledge that it was the modified communication structure of the redesigned program that was the integral part of the program's success, as it helped strengthen the link on safety-related issues both between workers and management, and among the various trades on-site. Safe working conditions and practices should be expected on all construction sites; safety should not be seen as an “extra” or something that occurs only because of extrinsic motivators. In many ways, the inclusion of the recognition component in the program serves as just another mechanism to facilitate safety communication between workers, foremen, and management. The program could probably be implemented with the recognition component; however, testing of a modified program was not part of the scope of this article. The program’s multiple sources of safety performance feedback aimed to increase communication and improve safety through an emphasis on hazard recognition and control. The importance of safety communication as a driver of this program’s success is supported by other research that demonstrates the strong link between safety communication and improvements in safety conditions at the construction site (Borcherding, Samelson et al. 1980, Samelson and Borcherding 1980, Probst, Brubaker et al. 2008, Cigularov, Chen et al. 2010, Kines, Andersen et al. 2010).

While the final program demonstrated many successful components, it is not without limitations. The final design relies on inspection data as the recognition metric, which may involve some observation bias. However, any bias is likely to be minimal, as the same individual conducted all inspections. The inspector was a representative of the site owner and their primary concern was to keep the site as safe as possible; therefore, they had no vested interest in manipulating the safety performance scores. While knowledgeable on the components of such safety audits, the inspector was still vulnerable to inherent biases associated with any observational set of data. In conversations with safety inspectors, multiple individuals noted that it is much easier to identify and record unsafe activities than safe activities. Thus, the inspectors acknowledged that any observer bias would most likely have led to an overestimation of the number of unsafes and cause a lower final safety performance score. This further strengthens the selection of a final program that evaluates the worksite as a whole, not by individual subcontractors, as it is the most equitable and unaffected by bias towards certain subcontractors or working conditions (Sparer and Dennerlein 2013).

In addition, this is a qualitative study with no quantitative metrics to evaluate the program effectiveness; however, piloting the program and using a qualitative evaluation are necessary steps in program development, as they uncovered many of the logistical issues and opportunities. Without such implementation research, the evaluation step would be useless as the assumptions about the program design were incorrect and would have led to an unintended negative outcome. Once completed, the next step is of course implementation on multiple sites, which will help identify challenges faced with such a program on sites of varying sizes, duration, and scope of work, as well as with different general contractors and site owners in the Boston area. To do this, a large effectiveness study will be implemented in a future cluster randomized controlled trial (RCT) that compares worksite safety conditions, injury rates, and worker survey responses at sites with the program to sites without the program. There are major challenges to conducting RCTs on construction sites, including recruitment of worksites and individual workers and cross-contamination of workers between control and intervention projects. In the RCT, we plan to use some of the lessons learned during this pilot study to circumvent these challenges. For example, in order to reflect the finding about the importance in site solidarity, we will be recruiting pairs of worksites from general contractors and owners, and the entire worksite will be given either the control or intervention treatment. We plan to measure cross-contamination and related potential issues during data collection.

In conclusion, the lessons learned during this program development demonstrate the importance of providing a whole worksite safety performance metric, having a reliable and consistent communication structure for the program elements and inspection data feedback, and using recognition that is relevant and desired by workers at the specific program site (Figure 3.2). The final program design recognized the worksite as a whole and led to collaborative competition and a team approach to safety that took advantage of and promoted worksite unity.

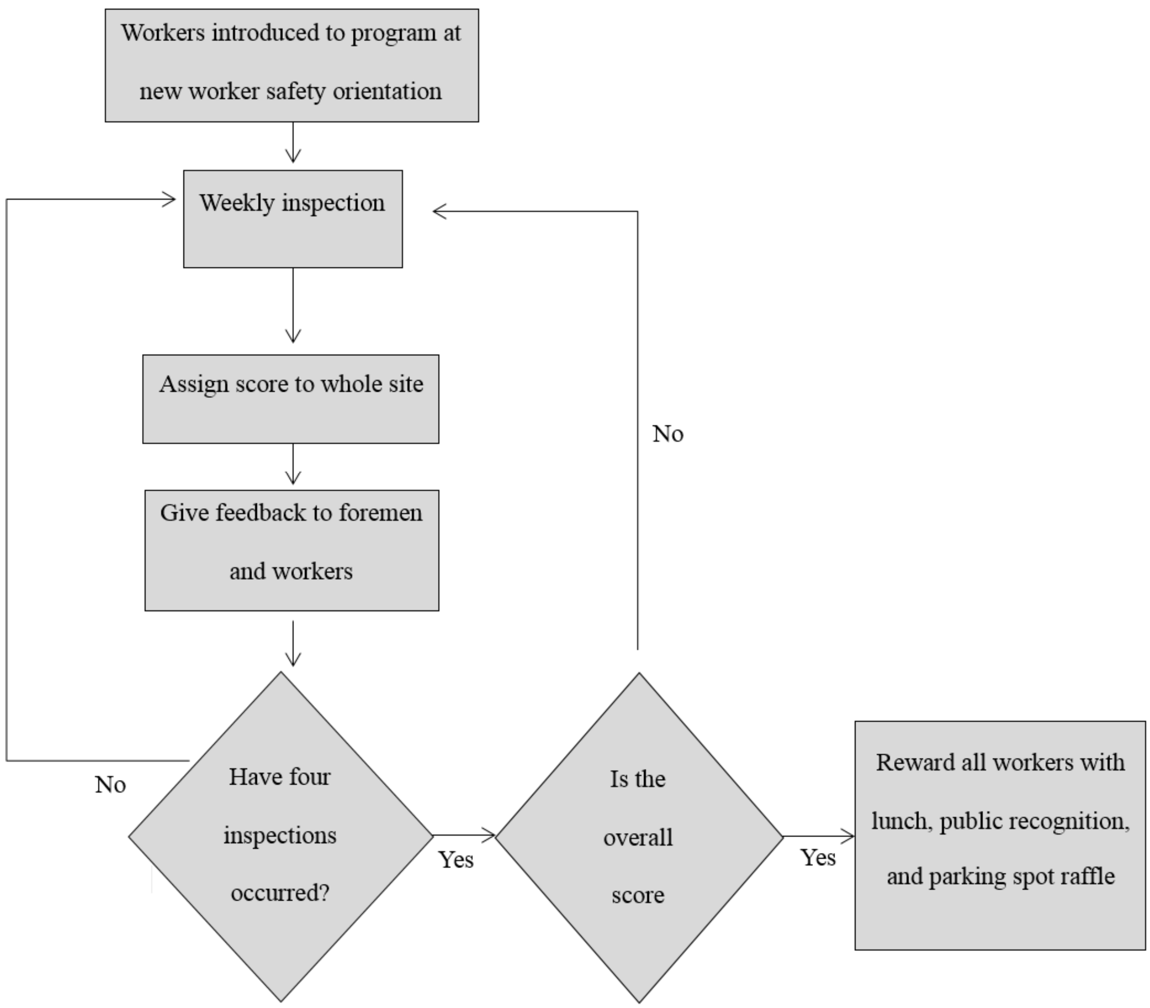

Figure 3.2. The redesigned incentive program design. The whole site is now the unit of reward. If the entire site exceeds the threshold score at the end of the month, all subcontractors receive the reward.

CHAPTER 4

Safety Climate Improved through a Safety Communication and Recognition Program for Construction: A Mixed Methods Study

Working paper

ABSTRACT

Objectives: To evaluate the effectiveness of a safety communication and recognition program (Building Safety for Everyone), designed to incentivize improvement of physical working conditions and hazard reduction.

Methods: A matched pair cluster randomized controlled trial was conducted on 8 worksites (4 received the intervention, 4 served as control sites) for approximately five months per site. Pre- and post-exposure worker surveys were collected at all sites (n=615, pre-exposure response rate=74%, post-exposure response rate=88%). Focus groups (n=6-8 workers/site) were conducted following data collection. Transcripts were coded and analyzed for thematic content using Atlas.ti(V6). Multi-level mixed effect regression models evaluated the effect of the program on safety climate.

Results: At intervention sites, workers noted increased levels of safety awareness, communication, and teamwork, when compared to control sites. The mean safety climate score at intervention sites increased 1.3 points between pre- and post-program exposure, compared to control sites that decreased 0.2 points (scale ranged: 0-90). The intervention effect size was 2.29 (p-value=0.012), when adjusted for month the worker started on-site, total length of time on-site, as well as individual characteristics (trade, title, age, and race/ethnicity).

Conclusions: Building Safety for Everyone led to many positive changes, including an improvement in safety climate, awareness, teambuilding, and communication. All sites had relatively strong systems of safety prior to program implementation, which partly explains the small effect size. The observed effect size was comparable to the only previous study on safety climate changes. The program was a simple intervention that engaged all workers through effective communication infrastructures and improved worksite safety.

INTRODUCTION

Recent decades have brought large improvements in health and safety conditions to the construction industry, yet the number of fatal and non-fatal injuries in the industry remains high (BLS 2014). In addition to their existing efforts, some employers have implemented safety incentive programs, such as those that use injury-based safety performance metrics to evaluate and reward workers. However, these lagging indicator-based programs may be a form of employee discrimination (Fairfax 2012), and may lead to reduction of reporting of injuries (Brown and Barab 2007, Lipscomb, Nolan et al. 2013).

As an alternative, programs could rely instead on leading indicators of safety, such as hazard control. Leading indicator-based programs can focus more on the root causes of injuries that include a worksite's safety management systems. We, in partnership with individuals from the local construction industry developed a leading indicator-based program(www.northeastern.edu/buildingsafetyforeveryone/) (Sparer, Herrick et al. In Press). The program facilitates communication on a worksite's safety performance between workers and management regarding hazard controls as identified by safety inspections/walkthroughs completed by in-house safety professionals. The program is rooted in frequent (more than once per week) inspections that focus on positive safety communication (such as emphasizing the importance of hazard controls), which has been shown to be a significant predictor of safety behavior (Cigularov, Chen et al. 2010). However, the effectiveness of such programs is unknown.

The aim of this paper was to evaluate the effectiveness of the program on measures of safety at the worksite through a cluster randomized controlled trial using a mixed methods approach. We hypothesized that intervention sites would show a greater improvement over time in both quantitative and qualitative measures of safety than control sites. Because of its strong association with injury outcomes, our primary outcome from worker surveys was safety climate (Huang, Ho et al. 2006, Johnson 2007, Probst, Brubaker et al. 2008). Measures of safety examined through qualitative methods included the following items identified in our pilot work (Sparer, Herrick et al. In Press) and related to injury and behavior outcomes (Cigularov, Chen et al. 2010, Cheng, Leu et al. 2012): safety awareness, safety communication, teambuilding, and collaborative competition.

METHODS

Study design and sample population

We conducted a cluster randomized controlled study on four pairs of commercial construction worksites. One pair was recruited from an owner and three pairs were recruited from general contractors, all in the greater Boston area. Their sites had to utilize the online data inspection management program Predictive Solutions (Industrial Scientific, Oakdale, PA, http://www.predictivesolutions.com/solutions/SafetyNet/). The two sites within in a pair needed to be expected to operate for greater than 4 months in duration from study initiation and be planning to have between 30 and 125 workers at any one time. The sites within each pair were randomly assigned a treatment status of either control or intervention.

Treatment conditions

The intervention sites implemented the program on the worksite level for five months or the duration of the worksite project, which ever was shorter (never less than four months). The program's primary components were: 1) weekly worksite safety assessments; 2) weekly feedback and communication; and 3) monthly recognition and reward. With the exception of the safety assessment, members of the research team led all aspects of the implementation. The worksite safety assessments were conducted via weekly walkthrough by a trained safety manager from either the general contractor or owner.

The weekly safety assessments provided weekly safety performance scores for the worksite and each subcontractor. Assessments were comprehensive of all trades and tasks on-site and focused on both the safe (controls) and unsafe (hazards) physical working conditions and practices. The inspector entered all walkthrough data into the online Predictive Solutions database and denoted each observation by subcontractor. Once per week, the research team downloaded the inspection data to generate a weighted safety performance score, the percent of safe observations out of the total observations, for the overall site, as well as for the individual subcontractor companies (Sparer and Dennerlein 2013, Sparer, Herrick et al. In Press). By including the weighted safe observations in the overall safety performance score, the program aims to positively reinforce hazard control.

The weekly feedback and communication consisted of a worksite poster and detailed reports distributed to each subcontractor on safety observations at the weekly foremen meetings. Large posters located in high visibility areas throughout the worksite displayed a graph of the overall site safety performance score along with a list of the individual subcontractor most recently weekly scores next to the poster. At weekly foremen meetings, the research team distributed reports to the subcontractor foremen that detailed all of the observations, both safe and unsafe, from the previous week that were specific to their company. The poster contained an inspection score goal that ranged from 94.8% to 96.3% depending on the site. This goal was determined by calculating the median monthly safety performance score over the previous twelve months from sites of similar size and scope from either the site owner or general contractor's (based on how the pair was selected) (Sparer and Dennerlein 2013).

The monthly recognition and reward depended upon the overall safety performance score for that given month. If the score was above the goal score, the whole site would be recognized for their strong safety record with a catered lunch and participation in a raffle for either a one-month parking pass at a location near the worksite or a gift certificate at a gas station. If the score was below the goal, the research team conveyed this information to workers during foremen's meetings and any other whole site gatherings (such as stretch-and-flex).

The control sites provided the contractors standard safety programs with a few posters with the Building Safety for Everyone logo only. Data collection methods were identical at both types of sites. Given the rigor of the methods and high frequency of site visits required to do so, research team members were on both control and intervention sites almost daily, leading to a strong presence at both.

Intervention effectiveness evaluation

We used a mixture of quantitative and qualitative methods to evaluate the effectiveness of the program. Quantitative methods (worker surveys completed pre- and post-exposure to the intervention program or control conditions) assessed changes in the primary outcome of safety climate, a mediating mechanism for the less occurring workplace injury (Figure 4.1). We were limited in our time for data collection on the construction worksites to the 10-15 minute coffee breaks and thus could not include all constructs in the survey. We therefore used qualitative methods to assess all other mediating mechanisms.

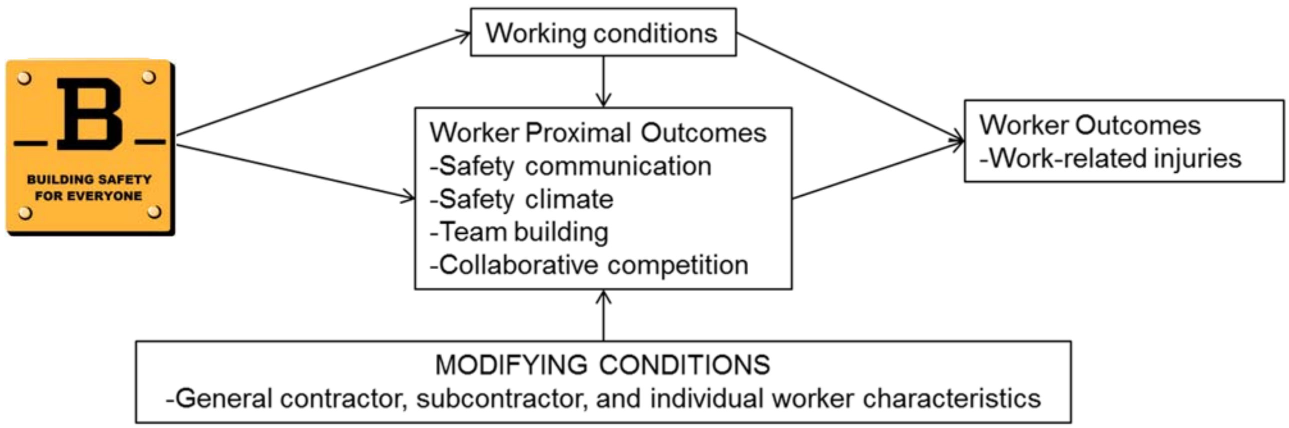

Figure 4.1 Building Safety for Everyone program conceptual model. The relationships in this model were generated based on a review of the scientific literature and based on observations noted during intervention development and pilot testing.

Quantitative data collection

To assess changes in safety climate, we invited workers to complete a pre-exposure survey at a study kick off meeting to capture workers on site at the time the study began and then during new worker safety orientations held multiple times per week to capture workers new to the site. At intervention sites, after collecting all completed surveys, we gave a 5-10 minute oral presentation that introduced the program to the site. At control sites workers were simply told that Building Safety for Everyone was a study of worksite safety and researchers would be on site regularly to collect surveys. Workers aged 18-65 who could read and write English were eligible for the pre-exposure baseline survey.

To assess post-exposure safety climate we invited workers who provided their names and mobile phone number (for texting purposes) during the pre-exposure survey to complete monthly follow up post-exposure surveys. We used a mixture of text messages and communication with on-site foremen and management to determine if a worker was still on the study site to complete the monthly follow survey (Sparer, Okechukwu et al. Under re-review).

The safety climate scale contained nine items that covered the two factors of worker involvement and management commitment (Dedobbeleer and Béland 1991). Each item was scored between 0 and 10, resulting in a total scale range of 0-90, with high values representing more positive safety climate scores. If a minority (≤4) of items were missing, the total score based on the completed answers was scaled to match the distribution of responses by the completed score.

The pre-exposure survey captured workers' age in years, gender, union membership status, specific trade, job title, tenure in the construction industry in years and highest educational attainment. Although race and ethnicity were collected separately, given the number of respondents in each category, we combined the two questions to classify workers as Non-Hispanic White or Other. Lastly, respondents indicated their weight and height, which were used to calculate their self-reported body mass index (BMI).

Post exposure surveys also included four questions on intervention penetration. The questions were: 1) Are you familiar with the worksite safety performance poster? 2) Are you aware of how your safety scores compare to other subcontractors? 3a) Have you received feedback from foremen or other site personnel on your company's safety performance? If the answer to three was yes, then 3b): How does your foreman share information with you? Responses at intervention sites were compared to those at control sites through Chi-squared and Fisher's exact testing.

We tabulated the cost of implementing the intervention. These cost include the recognition lunches (food and raffle items), posters, flyers, and stickers. In addition, we recorded the hours to generate the safety scores and provide feedback to workers and foremen.

Quantitative data analysis

To test the hypothesis that the change in safety climate between pre- and post-measures of exposure would be greater at intervention sites than at control sites, we first completed a bivariate analysis comparing worker demographics between control and intervention sites using Chi-squared tests of homogeneity for categorical variables and *t*-tests for continuous variables.

Second, we generated three mixed effects regression models with the difference in pre- and post-safety climate score as the dependent variable, and treatment status (intervention or control) as the independent variable. For the first model, we included a worksite variable as the random effect in the model to better account for the observed site-to-site variability in safety climate scores. For the second model, we expanded the first model to include a matched pair variable as a fixed effect based on our block randomization procedure. For the third model, we expanded the second model with the month the worker started on-site, the total amount of time the worker spent on-site, and added the variables from the bivariate analysis with p-value less than 0.2 using stepwise addition variable selection methods.

Qualitative data collection and analysis

At each of the eight sites, following quantitative data collection we conducted a focus group with workers. Participants were recruited with assistance from the general contracting management team and were selected based on the work schedule flexibility. Each focus group had six to eight participants, all from a mixture of trades, titles, and length of time on the study site. Focus groups were open to all workers on-site at the end of the quantitative data collection.

We followed a discussion guide during the sessions that included questions on overall perceptions of site safety and related constructs (e.g. management commitment to safety, teamwork, and safety awareness). All sessions were recorded and subsequently transcribed. Using Atlas.ti(V7), transcripts were then coded and analyzed for thematic content independently by three research assistants.

RESULTS

Quantitative data

Study population and response rates

The overall company-level recruitment was 57%, and the site level recruitment was 80% (Figure 4.2). In total, 1289 workers completed the pre-exposure baseline survey, with a response rate at intervention sites of 71% and control sites of 81%. The response rate for the post-exposure follow up survey for eligible workers was 88% at intervention sites and 86% at control sites. The study sample used in the analysis in this manuscript included only those workers with both a baseline and follow up survey.

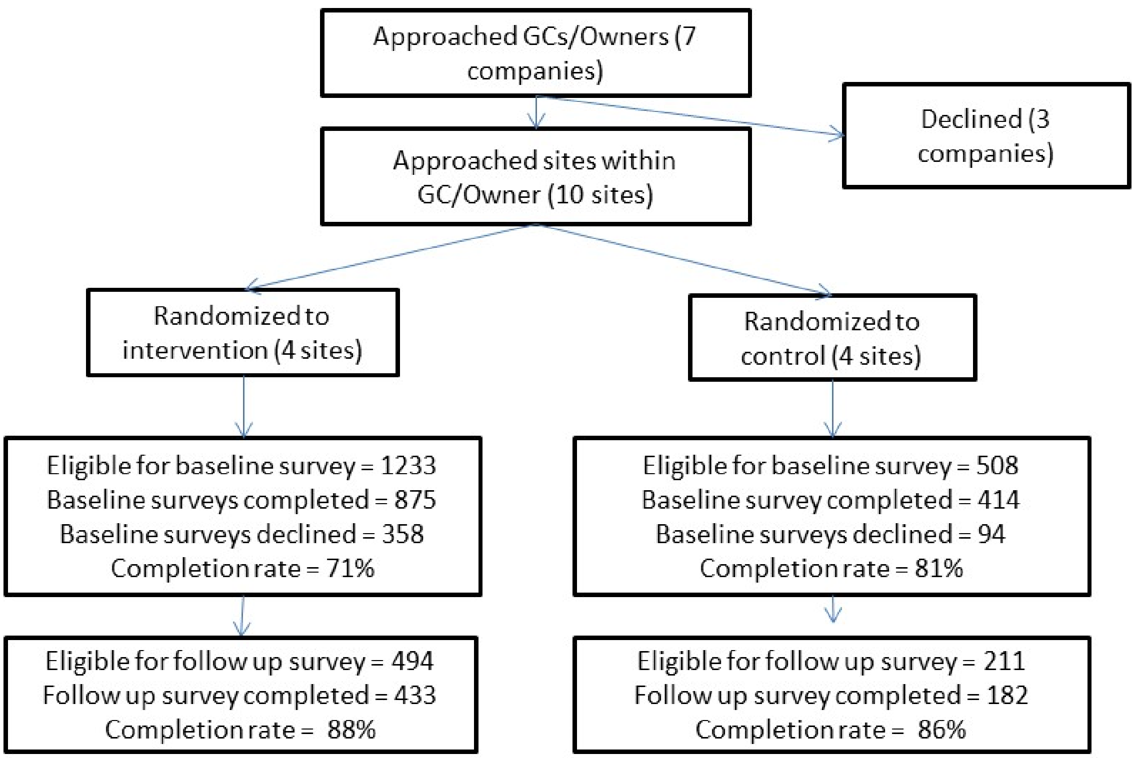

Figure 4.2 Overview of site and participant recruitment.

The distributions of certain demographic characteristics differed between the control and intervention sites (Table 4.1). The number of workers was also very different between intervention and controls. Baseline safety climate scores differed between intervention and control sites (p-value of 0.026). The Cronbach's alpha, a measure of psychometric reliability, for the baseline safety climate scale was

0.71 (on a scale of 0-1). Higher correlations are indications of stronger internal consistency (Cronbach 1951).

At intervention sites, workers were more likely to have been aware of how their safety performance compared to other subcontractors, and to have received/shared feedback from their foremen/to their workers (Table 4.2).

The additional cost of running the program for five months was $3,055 plus one man hour per week, which represents the time for a staff member to compile the scores and the reports (Table 4.3). This cost estimate assumes that weekly safety inspections are already part of the worksite health and safety program.

Table 4.1: Bivariate analysis of worker characteristics between control and intervention sites				
Individual characteristics	Total n* (%)	Control n (%)	Intervention n (%)	p-value
Gender				0.72
Male	577 (97.0%)	170 (96.6%)	407 (97.1%)	
Female	18 (3.0%)	6 (3.4%)	12 (2.9%)	
Race/Ethnicity				0.16
White, Non-Hispanic	499 (82.9%)	156 (88.6%)	343 (80.5%)	
Other	103 (17.1%)	20 (11.4%)	83 (19.5%)	
Union member				0.32
No	12 (2.1%)	2 (1.2%)	10 (2.4%)	
Yes	571 (97.9%)	170 (98.8%)	401 (97.6%)	
Education				0.52
Some High school/High School or GED	220 (38.1%)	62 (36.1%)	158 (38.9%)	
Vocational school/Associate's degree or more	358 (61.9%)	110 (64.0%)	248 (61.1%)	
	Total n	Control Mean (std dev)	Inverv. Mean (std dev)	p- value
Age (years)	603	43.1 (10.1)	39.5 (10.8)	<.0001
Tenure (years)	582	19.8 (10.1)	16.7 (10.4)	0.0012
BMI (kg/m^2)	553	28.1 (4.4)	28.2 (4.4)	0.77
Job Title				0.006
General Foreman/ Foreman	108 (17.9%)	43 (24.4%)	65 (15.3%)	
Journeyman	370 (61.4%)	108 (61.0%)	262 (61.5%)	
Apprentice	109 (18.1%)	20 (11.3%)	89 (20.9%)	
Other	16 (2.7%)	6 (3.4%)	10 (2.4%)	
Trade				<.0001
Finishing	103 (17.1%)	22 (8.5%)	81 (6.6%)	
Mechanical	382 (63.2%)	105 (59.3%)	277 (64.9%)	
Operators	10 (1.7%)	2 (1.1%)	8 (1.9%)	
Laborer	43 (7.1%)	15 (12.4%)	28 (19.0%)	
Ironworkers	47 (7.8%)	30 (17.0%)	17 (4.0%)	
Other/unknown	19 (3.1%)	3 (1.7%)	16 (3.8%)	
	Total n	Control Mean (std dev)	Intervention Mean (std dev)	p-value
Safety climate	604	73.4 (9.3)	71.3 (10.9)	0.026

Note: *Sample size differed slightly across categories due to small amounts of missing data

Table 4.2: Penetration Building Safety for Everyone program components at intervention and control sites			
	Control n (%)	Intervention	p-value
1. Are you familiar with the worksite safety performance poster?			
Yes	129 (70.9%)	403 (93.5%)	<0.0001
No	44 (24.2%)	27 (6.3%)	
N/A	9 (4.9%)	1 (0.2%)	
2. Are you aware of how your safety scores compare to other subcontractors?			
Yes	43 (24.0%)	328 (76.1%)	<0.0001
No	127 (70.9%)	96 (22.3%)	
N/A	9 (5.0%)	7 (1.6%)	
3a. Have you received feedback from foremen or other site personnel on your company's safety performance?			
Yes	102 (58.0%)	319 (74.5%)	<0.0001
No	66 (37.5%)	99 (23.1%)	
N/A	8 (4.5%)	10 (2.3%)	
3b. How does your foremen share information with you?			
During weekly toolbox talks	95 (84.8%)	290 (88.1%)	<0.0001
One-on-one with workers	13 (11.6%)	19 (5.8%)	
Other (e.g. coffee/lunch breaks, monthly safety meetings)	2 (1.8%)	7 (2.1%)	
Does not share information	2 (1.8%)	13(4.0%)	

Table 4.3: Estimated cost of running the Building Safety for Everyone program on worksite for five months			
Item	**Cost per item**	**Number of items per site**	**Total**
Banner	$50.00	1	$50
Posters	$35.00	3	$105
Stickers	$1.50	100	$150
Flyers	$0.50	100	$50
Lunches	$10	225 (75 workers x 3 lunches)	$2,250
High value item (gas card, parking pass)	$150	3	$450
Running of the Building Safety for Everyone program	Depends on site	20 hours (1 hour per week, which includes a ½ hour to calculate scores and a ½ hour to distribute reports and post scores, over the course of 5 months)	20 hours x employee hourly rate
Total			$3,055 + person-hours for running program

Notes: This cost estimate relies on the following assumptions:

1. The site has a health and safety program that includes frequent safety inspections and entering data into the Predictive Solutions database.
2. The person running the program is a trained health and safety manager.
3. The intervention is run on a worksite for five months.
4. The site surpasses the safety performance threshold three out of five months.
5. There are 75 workers on the site during recognition lunches.

Change in Safety climate

The mean score of the intervention sites increased by 1.3 points between pre- and post-exposures, compared to the control sites, which decreased by 0.2 points (Figure 4.3). Three out of four pairs showed a positive increase between pre- and post-exposure measurements.

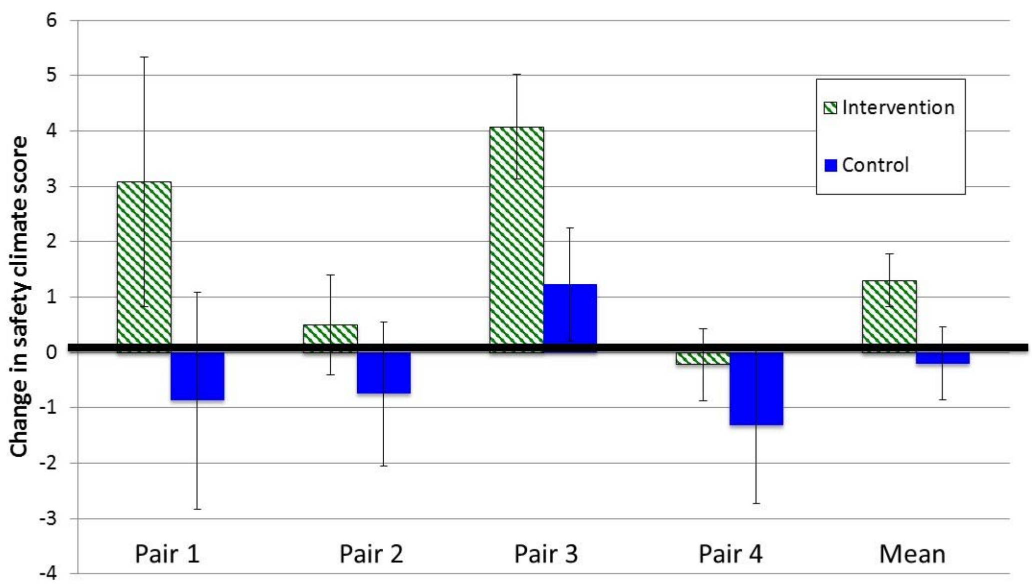

Figure 4.3 Safety Climate: Change in scores between pre- and post-exposure

This effect increases and becomes significant in the mixed effects regression models (Table 4.4). The addition of pair in Model 2 highlights the importance of accounting for variability between pairs. We take the model one step further in Model 3 and account for additional worker-specific characteristics. The final model included adjustments for worker trade, job title, age, race/ethnicity, month the worker started on-site, and total amount of time the worker was on-site.

Table 4.4: Results of Mixed Effects Regression Model				
	Effect estimate	N	Standard error	P-value
Model 1 – Unadjusted [a]	1.98	604	1.37	0.15
Model 2 – Adjusted [b]	2.06	604	0.85	0.016
Model 3 – Adjusted [c]	2.29	600	0.91	0.012

[a] Model 1: Dependent variable is the change in pre- and post- Building Safety for Everyone exposure safety climate scores. Independent variable is worksite treatment status (control or intervention). Random effect is site.
[b] Model 2: Same parameters as Model 1. Also adjusted for worksite pair.
[C] Model 3: Same parameters as Model 2. Also adjusted for worker trade, title, race/ethnicity, month started on-site, total amount of time on-site.

Qualitative data

The individuals that participated in the focus groups (intervention groups: n=33; control groups: n=24) had a mean tenure in the construction industry of 17.5 years, and were from trades including pipefitters, electricians, carpenter, ironworkers, and laborers. Other individual identifying information was not collected from the focus group participants.

At all intervention sites, workers noted increased levels of safety awareness, collaborative competition, positive re-enforcement of safety work practices, safety communication, and teamwork when compared to control sites (Table 4.5).

Table 4.5: Summary of themes identified in review of focus group transcripts										
		Intervention			Average	Control			Average
Them	Example quote	Researcher			Intervention	Researcher			Control
		1	2	3		1	2	3	
Safety communication	“"It helped safety wise definitely, to be cautious of other people and what’s around you, and that's huge. Communication is key between the trades. First couple of times you do it looks like you’re a jerk but now everyone sees the reason why and are looking out for everyone’s safety.” (Intervention)	13	25	15	17.7	1	15	8	8
Collaborative competition	"No sub wanted to mess up and cost the other guys -who were trying hard- the lunch“(Intervention)	9	9	7	8.3	0	0	0	0
Positive reinforcement of safe work practices	“It felt good to finally get a piece of paper in a meeting to say I did something right“ (Intervention)	7	12	4	7.7	0	5	0	1.7
Safety awareness	During the program: "With ladders--normally you’d just want to get it done, and you’d take the extra foot on the ladder, now guys are conscious to go get a higher ladder. You see the guys making the change. It makes you more aware. Now, you’re being more conscious of everything else.” (Intervention)	8	20	5	11	1	0	0	0.3
Teambuilding	“The trades were working together with the program, and other trades were watching out for everyone else. Normally they would never do that, but now I see talking amongst the trades—this came from the program.” (Intervention)	4	11	1	5.3	0	9	0	3
No noticeable changes during the program	"No changes [during the program]—its safety first from day one." (Control)	3	16	2	7	8	17	5	10

DISCUSSION

The goal of this study was to evaluate the effectiveness of Building Safety for Everyone, a safety communication and recognition program on a set of worksite safety measures. The results indicated that the program had a positive impact on site safety, leading to an increase (improved) safety climate of approximately two-points on the intervention sites compared to the control sites. Qualitative data also indicated a higher occurrence of positive safety-related themes of teamwork and increased awareness at intervention sites, when compared to control sites. These improved safety metrics may lead to reduced rates of work-related injury.

In terms of effect size, our results were similar in magnitude to changes in safety climate observed by Zohar and Polachek (Zohar and Polachek 2014). They examined the effect of a supervisor communication program in the manufacturing sector. Their communication intervention had an effect size of 0.15 on a 5-item scale, a 3.8% change. The effect size in the study was 2.29 (in the fully adjusted model) on a 90-item scale, a 2.5% change. In addition to differences in the type of communication program and intervention, the smaller effect size of the study can also be attribute to the high variability of the construction environment compared to the stable environment of manufacturing, and the added challenges faced of running and evaluating the effect of a program when the population of workers changes constantly. We found no other studies in the indexed peer reviewed literature describing safety climate as an outcome measure of an intervention study.

While the approximate two-point effect size is a relatively small number on the 90-point overall safety climate scale, we believe that this still has practical significance for a number of reasons. The approximate two-point change represents close to a 10% increase in the available range of positive change, as the mean baseline scores at intervention and control sites were in the low 70s, indicating each site type has an approximately 20 points to increase. Additionally, a comparison of our results to a 2002 cross sectional study on the association of safety climate and injury severity among construction workers, suggests that the Building Safety for Everyone program could be predicted to have a notable impact on injury reduction. Gillen et al. reported that for every one point increase in safety climate score (using a modified version of the same scale we used), injury severity decreased by 5.97%, when adjusting for other parameters such as decision latitude, coworker support, and job demands (Gillen 1999, Gillen, Baltz et al. 2002). Therefore, a 2.29 increase in safety climate scores could possibly lead to a decrease in injury severity of more than 13%.

The measured effect of the program increased in magnitude and significance when we adjusted for factors that accounted for the variation in work environments across sites and across general contractors. The effect estimate of the intervention was not statistically significant at the 0.05 level in Model 1 (the crude analysis) but became so when adjusting for various factors in Models 2 and 3. In these models, the standard error was reduced, and the estimates became statistically significant. This is likely an indication of the high level of variability observed between the various general contractors and owners that we partnered with. While the increase in statistical significance was in part due to the fact that additional parameters were added, it also highlights the importance of accounting for the variations of work environment in the model.

The data used in this analysis were collected from workers who were on-site for more than 30-days, thus representing a population that may not be reflective of all workers, and therefore is a potential limitation of our results. We previously analyzed worker characteristics between workers on-site for shorter periods of time (<30-days) and longer periods of time (≥ 30 days) on the study sites and found statistically significance differences in the distribution of trade, job title, race/ethnicity, and baseline musculoskeletal pain between the groups of workers (Sparer, Okechukwu et al. Under re-review), raising the possibility of length-biased sampling, a type of selection bias in which individuals with longer duration diseases are more likely to be captured in surveys (Delgado-Rodríguez and Llorca 2004). In intervention efficacy and effectiveness studies in the construction industry, this is an important bias to consider, as many of the people who were intervened upon left the site before measurement. The surveys analyzed in this study may not reflect a population representative of the true worksite composition, with those captured tending to be healthier (Kafadar and Prorok 2009). We addressed this issue of potential bias by controlling for time-varying parameters in our analysis. When we controlled for length of time on-site the effect estimate increased and standard error decreased, further demonstrating that the original effect estimate was an underestimate.

Another important bias that should be considered is misclassification of our outcome variable, change in safety climate, which could lead to an underestimate of the true effect size. In the pre-exposure survey completed on the first day on the jobsite, workers answered the safety climate questions based on a mixture of their previous experiences in construction in general, as they had not yet received any information about the specific experience on the study site. As a result, there was high likelihood of error and greater level of variability observed. This differed from the post-exposure measurement, which was a better reflection of their experiences on the study site. However, because any error in the pre-exposure measurements would have equally affected both the intervention and control sites, the bias on the results, if any, would most likely be non-differential, that is, towards the null (Pearce, Checkoway et al. 2007).

Our results showed improvements in safety measures with companies and sites that have sophisticated systems of safety as indicated by their use of Predictive Solutions and the high safety climate scores we observed at baseline, representing an important limitation of the generalizability of our results. Additionally, we observed that the sites that started out with the lowest safety scores had the highest level of improvement in site safety scores in post-exposure measurements, possibly indicating a ceiling effect of our measurements. The findings in this study indicate that Building Safety for Everyone can have a positive impact on site safety, but it must not be a standalone safety program. Rather Building Safety for Everyone was designed to be an add-on to an existing health and safety program of high quality that includes a robust safety inspection program.

In conclusion, Building Safety for Everyone led to many positive changes on the worksites, including an improvement in safety climate, awareness, teambuilding, and communication. It was a simple, low cost intervention that can increase safety climate and can be used by the construction industry. Safety incentive programs that rely on leading indicators of safety and are not tied to injury outcomes and engage all workers through strong communication infrastructure offer an alternative to controversial lagging indicator-based programs. Simple programs that engage all workers through strong communication infrastructures can have a positive impact on worksite health and safety.

CHAPTER 5

Length of Time Spent Working on a Commercial Construction Site and the Associations with Worker Characteristics

American Journal of Industrial Medicine. Under re-review.

ABSTRACT

Background: Construction workers move frequently from jobsite to jobsite, yet little is documented about length of stay on-site and associations with worker characteristics.

Method: Using cross-sectional data, we investigated associations between worker characteristics (including trade and musculoskeletal pain) and length of stay on-site (dichotomized as <one month, n=554, and ≥one month, n=435).

Results: Approximately 56% of workers remained on the worksite for at least one month. Length of stay was significantly associated with workers' race/ethnicity, union status, title, trade, and musculoskeletal pain (p-values<0.05). Trades associated with longer length of stay included pipefitters and plumbers. Trades associated with shorter length of stay included operators and piledrivers. Workers with single-location pain had 2.21 times (95%CI: 1.52, 3.19) the odds of being short-term versus long-term, adjusting for trade, title, and race/ethnicity.

Conclusion: The length of stay and associated characteristics provide important insight into how workers come and go on construction sites and the methodological challenges associated with traditional intervention evaluations.

INTRODUCTION

Construction, often termed a “mélange of order and chaos” (Carlan, Kramer et al. 2012) is a dynamic work environment in which job demands and related hazards are constantly changing as phases of a project are completed and others begin. The composition of the workforce on a construction project also constantly changes with the varying phases of project (Ringen and Stafford 1996, Carlan, Kramer et al. 2012). Some workers may stay for several months on a given construction site, whereas others only stay for a few days or weeks, being reassigned to new construction sites where their specific skills are needed next. This frequent movement of workers from worksite to worksite and constant changing of the composition of workers at a construction site can create a form of “temporariness” for the construction worker. The co-workers, management, and physical space change frequently, causing the worker to constantly need to adapt to new conditions.

The amount of time spent on a worksite is likely related to a number of different factors, including the phase of the project and the type of work needed at a given time, as well as overall project scheduling or budget, and even worker injury. Due to the inherently dynamic nature of construction, workers from different trades and levels of experience are needed at various time points during the building process. In both practice and research, the construction site is frequently described as dynamic (Dunlop 1961, Ringen and Stafford 1996, Becker, Fullen et al. 2001, Tak, Buchholz et al. 2011, Carlan, Kramer et al. 2012). However, the word dynamic is rarely quantified and we did not find any published literature that detail the construction site-employment patterns and associated factors.

In non-construction industries, strong associations between the health and safety of workers and their employment patterns have been demonstrated. Much of the research in this area has focused on contingent work, which is a broad category of employment status that includes temporary contracts or fixed term employment, as well as jobs without an explicit or implicit contract for longer employment (Benach, Benavides et al. 2000, Quesnel-Vallée, DeHaney et al. 2010). Numerous studies have shown that these types of jobs are associated with decreased job satisfaction as well as increased risks of work-related injuries and illnesses, when compared to those with permanent or standard jobs (Benach, Benavides et al. 2000, Kivimäki, Vahtera et al. 2003, Metcalfe, Smith et al. 2003, Cummings and Kreiss 2008, Smith 2012, Wilkin 2013).

Yet it is unclear from the literature what, if any, individual worker characteristics might be associated with patterns of length of stay on a construction site. This is especially relevant to the construction industry, where movement from site to site is inevitable. A better understanding of the factors associated with worker movement could help researchers and practitioners design, implement, and evaluate health and safety interventions.

There are two primary goals of this paper. First, we describe patterns surrounding the length of time construction workers spent at eight commercial worksites in the Boston area. Second, we investigate the association of worker characteristics including trade, title, and a measure of health status (self-reported musculoskeletal pain) with the length of time workers spent onsite.

METHODS

Study sample and data collection

The sample for this cross-sectional study came from baseline survey data collected in the Building Safety for Everyone study; a cluster randomized controlled trial on the effectiveness of a safety communication and recognition program in construction (Sparer, Herrick et al. In Press). The program was implemented at eight sites (four controls, four interventions) in the Boston area for approximately five months per site between August 2011 and December 2013. The sites ranged in size from 8,500-square feet to 495,000-square feet, and all were commercial construction projects that spanned a range of project phases. Three were renovation projects, four were new construction, and one was a mixture of renovation and new construction. In the analysis described in this paper, we used only baseline survey data collected when workers first came on site as part of their on-site safety orientation training. Length of stay was determined if a worker was present or not for the follow up surveys. No other data from follow up surveys were used in these analyses.

All construction workers at the sites were eligible to participate in the study; however, for this paper we are including only those who started after we initiated baseline data collection at site orientations. To collected baseline surveys, research staff attended every new (to the site) worker safety orientation (site-specific meetings that were required by the site management) at all eight sites. These orientations occurred daily at some sites, and every other day at other sites. Workers were continuously enrolled in the study for the duration of the Building Safety for Everyone program (approximately four to five months). The analytical cohort consisted of 989 workers who completed the baseline survey at site orientations and agreed to provide their name for monthly follow up (89% response rate). Workers were also asked to provide company name and mobile phone number, and to give permission for researchers to contact them via SMS text message in order to help locate them at follow up.

Building Safety for Everyone staff members returned to the construction sites multiple times per week to administer one month follow-up surveys to workers who remained on the sites, thus, affording the opportunity to determine if workers were still onsite. As workers were enrolled into the study on a rolling basis, follow up surveys were also conducted on a rolling basis, at one-month intervals following baseline survey completion. Prior to visiting the sites, study staff informed the construction workers of the time and location of surveying via text messages. Once at the sites, study staff members were able to confirm whether workers were still working at the sites through communications with site personnel (foremen, union stewards, etc.). Workers who had left the site were not questioned about possible reasons for their departure from the site.

All study participants gave informed consent prior to survey initiation. The Harvard School of Public Health's Office of Regulatory Affairs and Research Compliance and the Northeastern University's Office of Human Subject Research Protection reviewed and approved all procedures and methods for the study.

Worker Characteristics

All sociodemographic and health variables were captured in the baseline survey through self-report. Workers provided their age in years, gender, union membership status, specific trade, job title, tenure in the construction industry in years and highest educational attainment. Although race and ethnicity were collected separately, we combined the two questions to classify workers as Non-Hispanic White, Non-Hispanic Black, Hispanic, and Non-Hispanic Other.

Lastly, respondents indicated their weight and height, which were used to calculate their body mass index (BMI).

Only one direct health status measure was recorded in the survey: musculoskeletal pain. The following seven body regions were assessed: head/skull/face; neck; shoulders; hand/wrist/fingers; chest/ribs/sternum; lower back; and, knees. Respondents were asked to indicate if they had experienced pain every day for at least one week in the last month using a version of the Nordic Questionnaire (Kuorinka, Jonsson et al. 1987), which was previously modified by Cigularov et al (2010) and used with other construction worker populations. We operationalized pain into three categories: no pain (did not indicate pain at any region), single-location pain (indicated pain in at one region only), or multi-location pain (indicated pain in two or more regions).

Length of time on-site

We were able to determine the length of time that all 989 workers remained on the sites using our data on whether workers were still working at the site at the time of each 30 day follow-up survey. All workers were followed up with for at least one month in order to determine their term-length classification. Length of stay was dichotomized to classify workers as either short- or long-term worker. Short-term workers were those who spent less than 30 days on-site and were therefore not present for the first follow-up survey, whereas long-term workers spent 30 days or more on their site of recruitment.

Statistical Analyses

To address the first research goal, which was to characterize the length of stay on a construction site among our 989 construction workers, we determined the length of time each of the workers remained on a study site. These rates were determined by first grouping the workers into separate cohorts, based upon the month in which they started on-site. For example, all workers that started in Month 1 were considered Cohort 1; workers who started in Month 2 were Cohort 2 and so on. Workers were grouped into cohorts based on the months started at the worksite because of the likelihood of similar conditions (e.g. project phase, seasonality) on-site at the time of start. We then determined the number and percent of workers within each cohort who were present for follow ups. We also examined the length of time workers remained on the individual sites by calculating the number of workers who were on-site at each one-month follow up period.

For the second research goal, that of the association of worker characteristics and term-length, we used the Chi-square test of homogeneity for categorical variables and *t*-tests for the continuous variables. Term-length was treated as a dichotomous variable because first and foremost, it is unclear if the relationship between the worker characteristics and length of stay follows a linear dose-response pathway, which is what a continuous or scaled measure would imply. Additionally, as approximately 50% of our population had a length of stay of less than one-month, the power to detect a linear relationship would be low.

We then completed a multiple logistic regression analysis that included worker characteristics (including pain) associated with length of stay on-site at $p<0.2$ in bivariate analyses.

The multivariable model was constructed using a backward variable selection process, that eliminated worker characteristics (BMI, gender, union membership status, education level, and construction industry tenure) with $p>0.05$ to reach a parsimonious model consisting only of statistically significant covariates of job title, trade and race/ethnicity. This final model was confirmed using forward and stepwise selection methods. None of the eliminated covariates had a significant impact (greater than 10% change) on the magnitude of the final coefficients in the final models, indicating that none of the variables were confounders

. The analyses investigated the independent variable, musculoskeletal pain, in three categories: no pain, pain in a single body area or pain in multiple body areas. All data analyses were completed in SAS version 9.3 (SAS Institute, Inc., Cary, NC), with two-sided hypothesis tests considered significant at $p < 0.05$.

RESULTS

The study participants, who were all workers new to one of the eight study jobsites, were primarily male (96.8%), with a mean age of 40.7 and mean body mass index (BMI) of 28.1 (Table 4.1). The majority of the participants were non-Hispanic white (82.1%). They were largely union members (96.5%) and had an average of 17.5 years of tenure in the construction industry. Participants came from a variety of trades, although the electrical and telecommunications trades (19.0%) and the carpentry trade (17.7%) had the largest number of workers in the sample. The individuals were predominately journeymen (67.3%) (a skilled worker who had completed apprenticeship training but who was not yet in a management position). The distribution of short and long term workers at the control and interventions sites did not differ significantly, thus, we did not account for the site treatment effect from the Building Safety for Everyone program in the subsequent analyses. Thirty six percent of workers reported either pain in one location only (18.8%) or pain in multiple areas (17.2%) at baseline.

Table 4.1: Bivariate analysis comparing characteristics of those who are long-term workers compared to those that are short-term workers (n=989)				
Individual characteristics	**Total n**	**Long-term N (%)**	**Short-term N (%)**	**p-value**
Gender				0.35
Male	940	526 (56%)	414 (44%)	
Female	31	20 (65%)	11 (35%)	
Race/Ethnicity				**0.011**
White, Non-Hispanic	720	411 (57%)	309 (43%)	
Black/African-American, Non-Hispanic Black	39	28 (72%)	11 (28.2%)	
Other, Non-Hispanic	54	24 (44%)	30 (55.6%)	
Hispanic	58	25 (43%)	33 (56.9%)	
Union member				**0.046**
No	33	13 (39%)	20 (60.6%)	
Yes	909	517 (57%)	392 (43.1%)	
Education				0.078
Some High school/High School or GED	405	216 (53%)	189 (46.7%)	
Some College/ Vocational/ trade school/ Associate's degree	451	272 (60%)	178 (39.6%)	
Bachelor's degree/Post graduate degree	75	39 (52%)	36 (48.0%)	
Job Title				**0.0002**
General Foreman	22	13 (59%)	9 (41%)	
Foreman	108	62 (57%)	46 (43%)	
Journeyman	642	356 (56%)	286 (44%)	
Apprentice	153	101 (66%)	52 (34%)	
Other	30	6 (20%)	24 (80%)	
Trade[†]				**<0.0001**
Bricklayer/mason/plasterer/tiler/floorlayer	101	45 (45%)	56 (55%)	
Carpenter	174	92 (53%)	82 (47%)	
Electrical/Telecommunication	187	116 (62%)	71 (38%)	
Finisher/taper/drywall/glazier/ insulator/painter	106	65 (61%)	41 (39%)	

(Table 4.1 Continued)

Ironworker	84	48 (57%)	36 (43%)	
Laborer	57	32 (56%)	25 (44%)	
Operator/Operating Engineer/Elevator/Piledriver	38	15 (39%)	23 (61%)	
Pipefitter/Plumber/ Sprinklerfitter	117	82 (70%)	35 (30%)	
Sheetmetal	59	37 (63%)	22 (37%)	
Waterproofer/roofer	16	2 (13%)	14 (87%)	
Unknown/Other	50	20 (40%)	30 (60%)	
Reporting of Pain by Number of Locations				**0.0006**
No pain	634	377 (59%)	257 (41%)	
Single site pain	186	81 (44%)	105 (56%)	
Multi-site pain	169	96 (57%)	73 (43%)	
Treatment status				0.20
Control	324	172 (53%)	152 (479%)	
Intervention	665	382 (57%)	283 (43%)	
	Total n	**Long term Mean (standard deviation)**	**Short term Mean (standard deviation)**	**p- value**
Age (years)	973	40.3 (10.8)	41.1 (10.3)	0.27
BMI (kg/m^2)	906	28.1 (4.4)	28.1 (4.6)	0.83
Tenure (years)	938	17.2 (10.3)	17.8 (10.4)	0.39

The distribution of pain between short and long term workers among the various demographic categories was fairly consistent, with similar proportions in each category (Table 4.2). For example, of the long-term carpenters, approximately 65% did not report pain, with approximately the same percentage of short-term carpenters reporting no pain (67%). However, some categories, including sheet metal workers and foremen, did have distributions of pain that varied between long and short-term workers.

Table 4.2: Distribution of reported pain among long- and short-term workers						
	Long term			Short term		
	No pain (% of long term)	Single-Location Pain (% of long term)	Multi-Location Pain (% of long term)	No pain (% of short term)	Single-Location Pain (% of short term)	Multi-Location Pain (% of short term)
Trade						
Bricklayer/mason/plasterer/tiler/floorlayer	26 (58%)	9 (20%)	10 (22%)	37 (66%)	13 (23%)	6 (11%)
Carpenter	60 (65%)	10 (11%)	22 (24%)	55 (67%)	17 (21%)	10 (12%)
Electrician/Telecommunication	82 (71%)	21 (18%)	13 (11%)	40 (56%)	18 (25%)	13 (18%)
Finisher/taper/drywall/glazier/insulator/painter	54 (83%)	5 (8%)	6 (9%)	28 (68%)	8 (20%)	5 (12%)
Ironworker	33 (69%)	8 (17%)	7 (15%)	17 (47%)	9 (25%)	10 (28%)
Laborer	21 (66%)	4 (13%)	7 (22%)	14 (56%)	8 (32%)	3 (12%)
Operator/Operating Engineer/Elevator/Piledriver	11 (73%)	1 (7%)	3 (20%)	16 (70%)	3 (13%)	4 (17%)
Pipefitter/Plumber/Sprinklerfitter	51 (62%)	10 (12%)	21 (26%)	16 (46%)	10 (29%)	9 (26%)
Sheetmetal	22 (59%)	11 (30%)	4 (11%)	8 (36%)	8 (36%)	6 (27%)
Waterproofer/roofer	1 (50%)	0 (0%)	1 (50%)	8 (57%)	4 (29%)	2 (14%)
Unknown/Other (e.g. architect, security, asbestos)	17 (85%)	1 (5%)	2 (10%)	18 (60%)	7 (23%)	5 (17%)
Gender						
Male	357 (65%)	80 (15%)	89 (16%)	239 (58%)	103 (25%)	72 (17%)
Female	15 (75%)	0 (0%)	5 (25%)	9 (82%)	1 (9%)	1 (9%)
Race/Ethnicity						
White, Non-Hispanic	278 (68%)	62 (15%)	71 (17%)	173 (56%)	82 (27%)	54 (17%)
Black/African-American, Non-Hispanic Black	18 (64%)	3 (11%)	7 (25%)	7 (64%)	4 (36%)	0 (0%)
Hispanic	17 (71%)	4 (17%)	3 (13%)	24 (80%)	5 (17%)	1 (3%)

(Table 4.2 Continued)

Non-Hispanic, Other	18 (72%)	3 (12%)	4 (16%)	16 (48%)	5 (15%)	12 (36%)
Union member						
No	12 (92%)	1 (8%)	0	13 (65%)	2 (10%)	5 (25%)
Yes	344 (66.5%)	79 (15%)	94 (18%)	223 (57%)	101 (26%)	68 (17%)
Education						
Some High school/High School or GED	162 (75%)	24 (11%)	30 (14%)	105 (56%)	52 (28%)	32 (17%)
Some College/ Vocational/ trade school/ Associate's degree	167 (61%)	49 (18%)	56 (21%)	107 (60%)	41 (23%)	30 (17%)
Bachelor's degree/Post graduate degree	26 (67%)	6 (15%)	7 (18%)	20 (56%)	8 (22%)	8 (22%)
Job Title						
General Foreman	11 (85%)	0 (0%)	2 (15%)	3 (33%)	2 (22%)	4 (44%)
Foreman	45 (73%)	10 (16%)	17 (11%)	18 (39%)	16 (35%)	12 (26%)
Journeyman	231 (65%)	55 (15%)	70 (20%)	172 (60%)	68 (24%)	46 (16%)
Apprentice	71 (70%)	15 (15%)	15 (15%)	30 (58%)	14 (27%)	8 (15%)
Other	5 (83%)	1 (17%)	0 (0%)	17 (71%)	5 (21%)	2 (8%)

Pattern of length of time on-site

For the eight worksites, the composition of workers on-site changed by approximately half each month (Figure 5.1). On average, in any given month, half of workers had been on that site for less than one month. For example, during the first month of data collection, 227 new workers started at one of the eight sites (Cohort 1). By the second month, 119 of these workers had left the site, leaving 108, while another 224 workers started (Cohort 2). By the third month, 318 workers had started on-site, while another 38 from cohort 1 left and another 96 from cohort 2 left. This pattern continued throughout the remainder of our data collection.

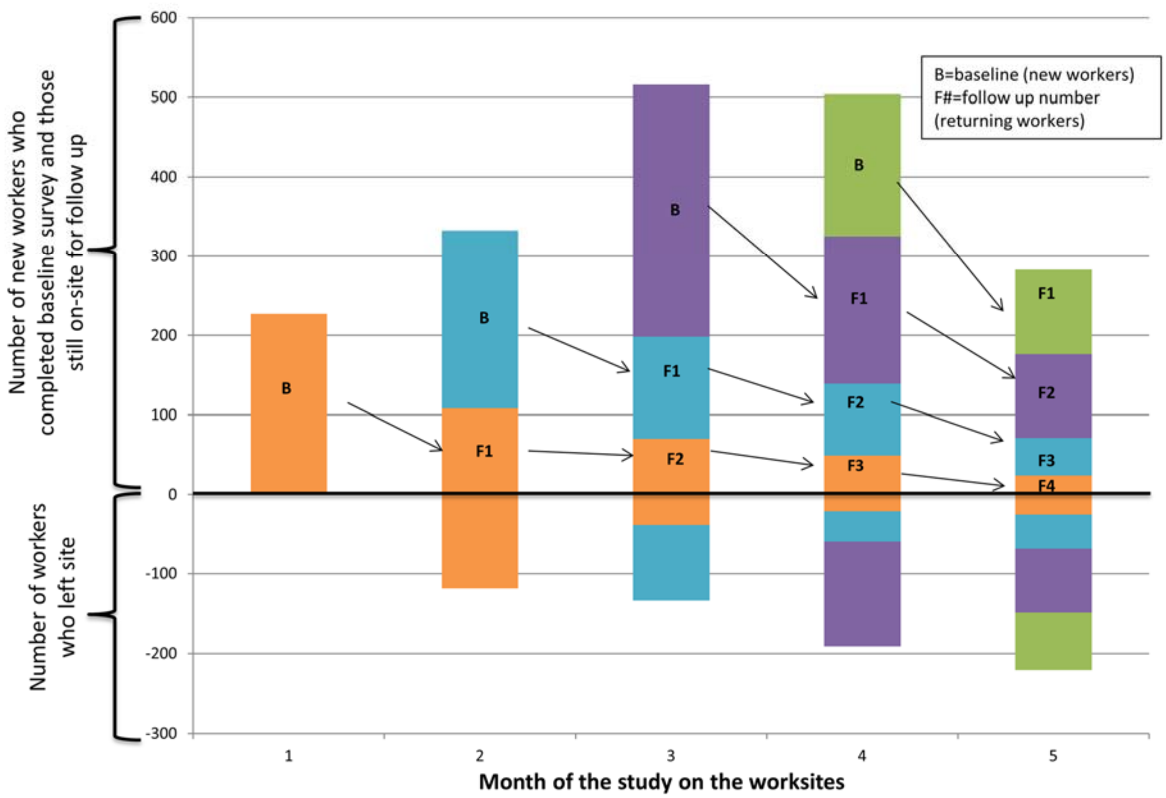

Figure 5.1: Workers completed a baseline (B) survey when they started on the worksite, and were followed up (F) with monthly until they left the site, with each color representing a new cohort of workers.

Of the 989 workers who completed the baseline survey, 554 (56%) were still on a study worksite after one month, 288 (29%) were still on-site after two months, and 133 (13%) were still on-site after three months (Figure 5.2). On an individual site level, the percent of workers who stayed on-site for one month or longer ranged from 41% to 68%, depending on the site. While the duration of time spent on-site varied from person to person, with some individuals staying for the duration of the project and others coming on for only a few days, the average and median length of time spent on-site was 0.93 months and 1 month, respectively.

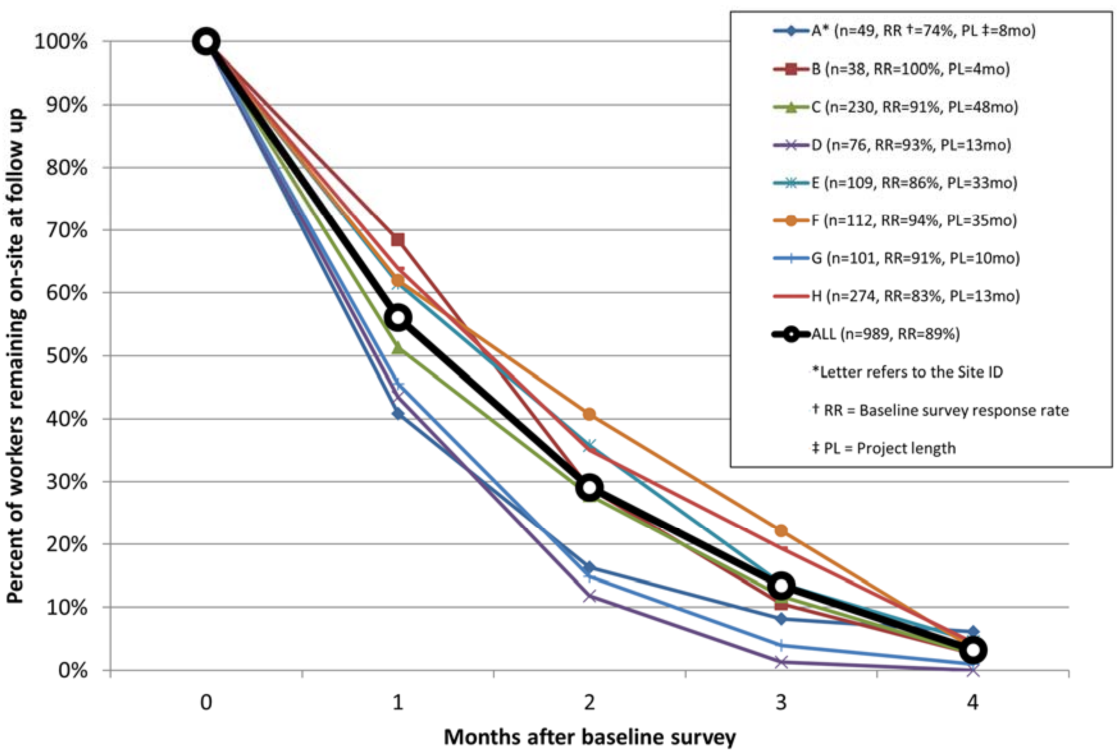

Figure 5.2: Percent of the workers who completed the baseline (B) survey and remained onsite at the various monthly follow-ups (F).

The percent of workers who remained on-site for at least one month did vary from site to site (Figure 5.2), which may be related to differences in site characteristics, such as size, number of workers, and phase of the project. While these characteristics might be related to the worker leaving the jobsite, it is apparent from this raw data that despite the overall differences at the site level, the same patterns persist. We accounted for these possible differences in site characteristics by adjusting for various individual-level factors such as trade and title that may be associated with phase of project.

Associations between worker characteristics and length of time on-site

There were significant bivariate associations between some worker characteristics and length of stay on-site at the sites. Musculoskeletal pain had significant bivariate associations with length of stay on-site, as did workers' race/ethnicity, union status, job title, and trade (p-values of 0.004, 0.011, 0.046, 0.0002, and <0.0001, respectively) (Table 5.1). For example, a greater proportion of non-Hispanic white workers were long-term workers (57.1%) whereas a lower proportion of Hispanic workers were long-term (43.1%). Trades varied as well, with longer length of stay on-site including pipefitters, plumbers, and sprinklerfitters (70.1% long-term) as well as sheetmetal (62.7% long-term), and trades with shorter term-lengths including operators, operating engineers, elevators, and piledrivers (with only 39.5% long-term).

The association of musculoskeletal pain at baseline and length of stay on-site was maintained in the multivariable analysis. The multiple logistic regression model indicated that reporting pain in one body area only was associated with more than double the odds of having short-term length of stay (OR: 2.21; 95% CI 1.52, 3.19), controlling for trade, job title, and race/ethnicity (Table 5.3). Reporting of pain in multiple body areas, while not statistically significant, was also associated with short-term length of stay (OR: 1.27; 95% CI 0.86, 1.86).

Table 5.3: Worker characteristics as a predictor of short-term length of stay on-site	
	Odds ratio (95% CI)
Pain	
No pain	1.00
Single-site pain	2.21 (1.52, 3.19)
Multi-site pain	1.27 (0.86, 1.86)
Trade	
Laborer	1.00
Bricklayer/mason/plasterer/tiler/floorlayer	1.35 (0.67, 2.71)
Carpenter	1.12 (0.59, 2.13)
Electrical/Telecommunication	0.74 (0.39, 1.42)
Finisher/taper/drywall/glazier/ insulator/painter	0.75 (0.37, 1.49)
Ironworker	0.68 (0.33, 1.43)
Operator/Operating Engineer/Elevator/Piledriver	1.38 (0.54, 3.52)
Pipefitter/Plumber/ Sprinklerfitter	0.55 (0.27, 1.11)
Sheetmetal	0.44 (0.19, 1.03)
Waterproofer/roofer	1.78 (0.61, 5.15)
Unknown/Other	11.65 (1.38, 98.69)
Race/ethnicity	
White, Non-Hispanic	1.00
Black/African-American, Non-Hispanic Black	0.60 (0.28, 1.28)
Other, Non-Hispanic	1.24 (0.66, 2.32)
Hispanic	1.92 (1.08, 3.42)
Job Title	
Journeyman	1.00
General Foreman	0.99 (0.37, 2.65)
Foreman	0.87 (0.55, 1.37)
Apprentice	0.63 (0.42, 0.95)
Other	4.02 (1.39, 11.64)

DISCUSSION

This paper aimed to (1) describe the patterns surrounding the length of time commercial construction workers spend at one of eight worksites in the Boston area and to (2) investigate the association of worker characteristics including trade, title, and a measure of health status (self-reported musculoskeletal pain) with the length of time workers spent on-site based on cross-sectional data. The results indicated that approximately 56% of workers remained on-site for at least one month. This is for the first time, a quantification of the dynamic nature of commercial construction. In addition, there were certain worker characteristics measured when coming onto a site including musculoskeletal pain and trade that were associated with length of stay on a construction site.

The fact that approximately 56% of workers remained on-site for at least one month has important implications for researchers in terms of evaluating worksite programs and interventions. It highlights the need for researchers to consider worksite mobility patterns when analyzing and interpreting data collected from construction sites and other workplaces with contingent or temporary workers, which are becoming more common for workers in the United States and abroad (Quesnel-Vallée, DeHaney et al. 2010, Alterman, Luckhaupt et al. 2013, Wilkin 2013). With individuals coming on and off worksites so frequently, the ability to accurately measure a worksite intervention or phenomena may be hindered, as the changing site population may mask the potential impact. As a result, traditional cohort analysis methodology for evaluating interventions may lead to biased results. For example, if the goal of an intervention is to reduce musculoskeletal disorders, but the workers who stay on a worksite for longer periods of time (and have more exposure to the intervention) are the workers with a lower prevalence of musculoskeletal disorders, the intervention might miss the high risk and arguably more important group for the intervention. The effect measurements of the intervention may thus be a form of survivor bias or length-biased sampling, and may underestimate the true intervention impact. On the other hand a quick messaging campaign may have great short-term effects but the sustainability of such messaging may be lost as soon as a worker moves onto another site overestimating the effect.

These results also highlight differences in worker characteristics between short- and long-term workers. Certain trades, such as electrical and telecommunications, and pipefitters, plumbers, and sprinklerfitters had more long-term workers than short-term workers. The duration a worker stays on a single site is likely related, at least in part, to the inherent nature of the construction jobs. Workers are contracted for varying amounts of time and may not be needed for longer periods of time based on job demands that would be associated with trade and job title. It is also possible that certain job titles and trades are associated with varying levels of musculoskeletal pain prevalence, thereby confounding the relationship between musculoskeletal pain and length of time on-site. However, in the multivariable model, when we control for items such as trade and title, we still see that there is an increased prevalence of musculoskeletal pain among short-term workers indicating that there is likely something else driving the relationship. For example, the categories of trade and title may not accurately describe the workers experience on a construction site, leading to misclassification of the independent variables in this analysis, which could underestimate the effect estimate (Pearce, Checkoway et al. 2007). A more refined classification system to distinguish experiences may be needed (Punnett and Wegman 2004). Finally, it should also be noted that the data used in this analysis are cross sectional in nature and cannot be used to draw causal inferences between independent and dependent variables."

We also observed differences in the associations between musculoskeletal pain and term-length in single-location and multi-location pain. Both were in the same direction, but larger in magnitude for single-location pain. The lower odds ratio for multi-location pain may be indicative of chronic rather than acute pain (Carnes, Parsons et al. 2007).

The practical implications for safety and health professionals includes the need for more reliance on systems of safety that recognize and adapt to the changing human element on a construction site. A system of safety should include all the elements of successful programs including clear hazard recognition and control that is embedded in the project management and day-to-day on-site activities (OSHA 2012). Because of the higher risk for injury during the first 30 days on a site, some construction managers and general contractors have implemented policies and practices to address the high level of transience among workers. We have observed policies and practices addressing this concern on different worksites, including new worker safety orientations and special hardhat stickers and/or t-shirts to indicate workers who are within their first month on the job. These programs help acknowledge the high risk period that a new worker experiences during the first 30-days on a new jobsite (Breslin and Smith 2006).

The results describing these workers' time on site are of course within the context of how the data were collected and limited to the eight construction sites we observed; however, we expect these patterns to extend to the other similar construction sites. In conversations with workers, they frequently noted that they move around from jobsite to jobsite quite often, spending a similar amount of time on each jobsite. The results of our bivariate analyses indicate that trade, job title, and race/ethnicity are significantly associated with term-length. As these characteristics are likely to remain constant while a worker moves from site to site, we assume that any bias resulting from a misclassification of length of stay on-site would be minimal. While the findings might not be generalizable to other forms of construction, such as residential or industrial, the discrepancy points to an important area of injury prevention research and practice. The assumptions regarding length of stay on the worksite would likely impact equally both groups of the independent variables. The potential impact of this limitation on the interpretation of the results would be non-differential and would likely bias these results towards the null.

Another limitation relates to the reporting of musculoskeletal pain. It is possible that workers who anticipate spending longer periods of time on the worksite might underreport pain in the baseline survey due to concerns of management viewing the response, despite our strictly enforced confidential handling of the surveys. Thus, it is possible that the results presented here are actually an underestimate of the true association of the relationship between musculoskeletal pain and length of stay.

A large driver behind this study's high follow up response rate was the novel use of text messaging to connect with study participants. Addressing occupational health issues faced by construction workers and other frequently mobile or contingent workers has been hindered by issues of recruitment in previous studies (Atrostic, Bates et al. 2001, Kidd, Parshall et al. 2004). National studies show that though there are still disparities based on race/ethnicity and socioeconomic position in access to broadband internet at home, no such disparities exist in access to mobile phones and smartphones (Smith 2012, Viswanath, Nagler et al. 2012). The high follow up response rate in our study indicates that the use of text messages is a potential medium through which occupational health researchers and practitioners can reach contingent workers and other frequently mobile populations.

In conclusion, approximately 56% of workers remained on-site for at least one month. Length of stay on-site was associated with several worker characteristics, notably trade and musculoskeletal pain. Workers who reported pain had almost twice the odds of being a short-term worker, compared to a long-term worker, controlling for trade, title, and race/ethnicity. Given these findings, researchers and practitioners should consider mobility patterns when implementing and evaluating worksite-based interventions and programs aimed at improving construction worker health and safety. The observed length of stay on a construction site and associated characteristics provide important insight into how workers come and go on commercial construction sites and the methodological challenges associated with traditional intervention evaluation protocols.

DISCUSSION AND CONCLUSIONS

The goal of this dissertation was to better understand how worksite-level programs, policies, and work organization impact site safety and ultimately work related injury, as measured through safety climate (Figure 0.1). The highlight the complexity of the construction work environment and provided lessons learned for other researchers and practitioners. They also emphasized the importance of safety communication on the worksite and some of the challenges of implementing and measuring communication-based interventions.

The results of Chapter One indicated that safety climate scores and CSAP scores were largely independent of one another. This result may be related to the challenges of measuring safety climate in construction. It also may be reflective of a disconnect that exists on many worksites between the written programs and policies and what is actually implemented. Often, this relates back to a lack of adequate safety communication infrastructure.

To meet this need, a safety communication and recognition program was developed, a form of a leading indicator safety incentive program, for commercial construction sites. The first two steps were to design and pilot test the program structure. Chapter Two explored the notion of a threshold for reward in a leading indicator safety incentive program that used safety inspections as the primary reward metric. It found that a safety inspection threshold should be competitive yet attainable, as well as fair and consistent across groups of workers on-site. These findings were upheld in Chapter Three, when other aspects such as the feedback loop and reward structure of the program were developed. This chapter also described in detail the testing and re-testing of the feasibility of the program, now referred to as a safety communication and recognition program (called Building Safety for Everyone). The results of this study indicated that a whole-site approach to rewarding safety was most accepted by workers. It also emphasized the importance of safety communication and the potential impact of the program to improve teambuilding, safety awareness, and collaborative competition.

Chapter Four presented the results of the intervention evaluation of Building Safety for Everyone, a safety communication and recognition program for construction sites, using both qualitative and quantitative methods. The program led to many positive changes, including an improvement in safety climate, awareness, teambuilding, and communication. The observed effect on safety climate (2.29 in the fully adjusted model) was statistically significant at the 0.05 level and was comparable to the only previous study on safety climate changes. Building Safety for Everyone was a simple intervention that engaged all workers through effective communication infrastructures and improved worksite safety.

In Chapter Five, using baseline data collected during the Building Safety for Everyone intervention evaluation, the patterns of movement on and off the worksite of commercial construction workers on eight sites in the Boston area were described. Approximately 56% of workers stayed on-site for at least one month, meaning that approximately 44% of workers were short-term, and remained on-site for less than one month. This chapter also explored worker characteristics associated with length of stay and found that factors such as race/ethnicity, trade, title, and musculoskeletal pain all had statistically significant associations with the length of stay at the 0.05 level of significance. Additionally, the results indicated that workers with single-location pain had 2.21 times (95%CI: 1.52, 3.19) the odds of being short-term versus long-term, adjusting for trade, title, and race/ethnicity. These results highlighted the methodological challenges associated with traditional intervention evaluations and helped to better define the patterns surrounding length of stay on a construction site.

Implications on Practice and Research

These results described in this dissertation provide an important contribution to the field of injury prevention in the construction industry, in the context of both practice and research. In terms of practice, the safety communication and recognition program evaluated here provides the construction industry with an effective, simple, and low cost alternative to a lagging indicator based safety incentive program. This is especially important given the 2012 OSHA directive that equated lagging indicator based incentive programs to a form of employee discrimination. The directive stated that programs that reward workers based on reported injuries incentivized the underreporting of injuries, rather than actual injury reduction (Fairfax 2012). Building Safety for Everyone instead focuses on the control of hazards at the workplace, aiming to improve the communication loop at the worksite horizontally (between workers in various trades) and vertically (between workers and management).

Additionally, the finding that the composition of workers on any given worksite changes by approximately 50% each month has important implications for practice. When implementing health and safety programs and policies it is critical for management to take this high rate of transience into account. Furthermore, the data described in Chapter Four highlight the high-risk period that workers face when starting on a new worksite. In the course of data collection for this dissertation, I observed and heard about some programs and policies that aim to address this period. These include new worker safety orientations and special hardhat stickers and/or t-shirts to indicate workers who are within their first month on the job.

Researchers can also use the finding about the length of time workers typically spend on a construction site to better target intervention dosing and evaluation. For example, many worker health and safety interventions involve, in general, one of two types of interventions: 1) a program or policy-level change that targets the whole site, or 2) discrete, onetime events such as safety training or health behaviors education. Often, both types of interventions are evaluated through survey-based metrics collected at specific time points (e.g. pre/post intervention). The patterns of worker movement described in this dissertation can help researchers identify ideal sampling strategies and intervention delivery mechanisms to meet the specific needs of their research question. Additionally, the quantification of these patterns can help with power and sample size calculations in order to maximize research impact.

Finally, the lessons learned in development of the Building Safety for Everyone intervention serve as a reminder to researchers about the importance of piloting interventions and the strength of mixed methods research. Many of the initial assumptions going into the program design were found to be incorrect during piloting, which forced me to restructure the program before embarking on a large scale randomized controlled trial. By combining qualitative and quantitative methods in the intervention evaluation, the ability to observe and effect of the intervention was maximized, which was especially important given the limited time each day for data collection with workers.

Limitations and Strengths

The work summarized in this dissertation must be considered within the context in which the data was collected. All data was collected from commercial construction sites in the Greater Boston area, in a workforce that was predominately unionized, and as such, generalizability may be limited. The study participants in this sample were largely homogeneous, being mostly white males, and the study sites all had relatively high levels of safety prior to data collection. Thus, generalizing to other forms of construction (i.e. residential or industrial) or to commercial construction in other parts of the United States may not be justifiable.

Another important limitation of this work is the reliance on safety climate as a primary outcome measure. Safety climate is defined as a reflection of shared employees perceptions about the extent to which an organization values and rewards safety in comparison to other competing priorities (Zohar 1980, Zohar and Polachek 2014). It was originally conceptualized in stable manufacturing environments, and may not capture the complexities of the construction work environment (Guldenmund 2000). The Dedobbeleer and Béland (1991) measure of safety climate was used in this dissertation, as it was one of the few measures that was specifically developed for the construction industry. However, the experience in using the measure in practice illustrated that the Dedobbeleer and Béland scale might not go far enough to capture the multiple organizational levels of the construction site. The referent group (manager in question) in many of the questions is unclear, and may refer to the subcontractor foremen, union steward, or general contractor safety manager. Workers may have answered the question with different supervisors in mind, which could increase the variability of responses and introduce a misclassification bias. As this bias would likely affect all respondents equally, the implications are likely to be non-differential and therefore attenuate the results in the study.

Despite these limitations, this dissertation has many important strengths that should be acknowledged. The work described here represents the first longitudinal evaluation of a leading indicator safety incentive program for construction and for the first time in the scientific literature quantifies the length of time construction workers stay on the worksite. Additionally, this work provides evidence that despite the complexities of the safety climate construct, it can be used as an outcome measure in a longitudinal study and can be improved. While anecdotally many health and safety practitioners (both in and out of construction) mention that certain programs and policies can improve safety climate, there was only one other in the scientific literature (Zohar and Polachek 2014) that did so, and this study took place in a manufacturing plant with a stable workforce.

The intervention evaluation described in Chapter 5 illustrates the importance of communication in building safety awareness and demonstrates that a simple, low cost intervention can have a big impact on site safety measures.

Future Work

While this dissertation represents a significant step towards improving injury prevention in the construction industry, there is still more to be done. Future work that expands the Building Safety for Everyone intervention evaluation study described in Chapter Five is necessary for understanding the full impact of the program on safety-related outcomes. For example, an study that includes all safety climate data in a longitudinal analysis, as opposed to only pre/post, would be helpful in understanding the dose-response relationship.

Another example of a future study would be a simulation model analysis in which the effect of Building Safety for Everyone on safety climate outcomes is examined under various assumptions regarding worksite mobility patterns. This could help us better understand the effect of length-biased sampling on our data as a result of the highly transient workforce.

Other future work related to the Building Safety for Everyone intervention relates to dissemination and implementation research, and the concept of Research to Practice (R2P). We have demonstrated the efficacy of the program in a controlled research environment, but in order to fully understand the impact of the program, it must be tested in a “real world” environment, with safety managers running the program, not university research assistants.

As a continuation of the work described in Chapter Five, it is recommended that future studies aim to better characterize the length of stay on construction sites through a longitudinal study of patterns of movement on and off sites over time. This work could be expanded to other parts of the United States as well as to other types of construction.

Finally, the work in this dissertation has highlighted some of the problems with measuring safety climate in the construction industry. Therefore, it is recommended that future work on this topic aim to develop a safety climate scale for the construction industry. The scale must take into account the work organization, focusing on the numerous levels of management and the multitude of messages workers receive on a daily basis from these levels.

In conclusion, the results of this dissertation help to illustrate the complexities of the construction work environment yet demonstrate that interventions such as Building Safety for Everyone that are designed with these peculiarities in mind can have a positive impact on site safety measures. Construction is an inherently dynamic industry and workers have a very difficult job. While we as public health researchers and practitioners cannot change this, we can work within the structure to design and evaluate interventions that address this fluidity to better protect the workers.

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