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Results of a fall prevention educational intervention for residential construction

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Keywords

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1. INTRODUCTION

Falls from heights remain the leading cause of construction worker mortality and morbidity in the U.S., accounting for 40% of all fatalities and 20% of the days away from work in

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2010.[1] Despite working at lower elevations than workers constructing high-rise buildings or bridges, one-third of the construction worker fall fatalities in 2010. Ladders are the most common piece of equipment involved in fall fatalities.[2] Among residential construction workers, ladder falls accounted for 16% of the fatalities in 2007, 20% in 2008, and 26% in 2009.[3] After evaluating the worksites of 95 carpenters who fell while working at a residential site over a 3-year period, Lipscomb and colleagues determined that conventional fall protection could have prevented many of the falls,[4] but such protection was rarely in place. At the time, OSHA's Residential Guidelines allowed alternative methods if conventional fall protection methods were deemed infeasible. However, many of these alternative fall prevention methods were practiced inconsistently in residential construction,[5] exposing workers to high risk activities. For example, at two-thirds of the worksites audited it was common to see workers walking on the narrow top of a 2-story wall in order to install roof trusses – an inherently dangerous activity. [6] Failure to follow fall prevention methods identified in a worksite plan is common in the United States and abroad, with reasons including lack of safety knowledge and competence among workers, lack of management support, and subcontractor lack of cooperation. [7]

Inexperienced construction workers are especially vulnerable to workplace falls, as are temporary workers, non-fluent speakers, and employees of small construction firms.[8] This paper describes results from an apprenticeship training program targeting inexperienced residential construction workers. A multi-faceted needs assessment identified gaps in the curricular content [9] and apprentice-preferred training methods [10], which echoed results from other construction worker populations [11]. The training utilized high engagement training methods, such as hands-on practice, simulations, and reality-based training; with limited use of passive information-based methods such as lectures, handouts, and videos. Apprentice survey and residential worksite audit results administered during the needs assessment were compared to results one and two years after implementation of the revised residential fall prevention training. We hypothesized that fall prevention behaviors at residential worksites, and apprentice carpenters' knowledge, risk perceptions, and safety climate would improve following implementation of the revised apprenticeship training.

2. METHODS

2.1 Site of work and needs assessment

This study was performed between 2004–2009 with the Carpenters Joint Apprenticeship Program in St. Louis, a carpentry training program operated in collaboration between the carpenters' union and local home builders. In addition to evaluating the timing, content, and teaching methods of pre-intervention training, we conducted surveys and focus groups with a cross-sectional sample of apprentice carpenters to measure fall prevention knowledge, reported worksite behaviors, risk perceptions, confidence ratings, and safety climate, as well as observed fall safety practices at the new home construction sites. Results of the focus groups [11] and surveys [9] have been previously reported.

2.2 Intervention Development and Implementation

Results from the needs assessment were organized to identify common unsafe work behaviors and misconceptions, the timing of task training versus on-the-job task performance, and preferred learning methods. For example, workers often reported working at heights before receiving fall training on the job or through the apprenticeship, and ladders were not perceived by apprentices as posing a high risk for falls despite being the most common equipment involved in a fall. Results of the needs assessment were shared with the apprenticeship trainers and a core group of trainers reviewed the existing fall prevention curriculum and revised the training to meet the identified needs using teaching methods preferred by this population, including participatory learning and active engagement. Working with the research team, carpenter instructors created detailed learning objectives and lesson plans, actively engaging learning experiences, and contextually-relevant examples and equipment. In order to demonstrate different fall prevention techniques, a teaching "prop" of a partially constructed home and a roof truss assembly were built. A variety of anchors and harnesses for personal fall protection, scaffold systems, and supplies for a fall simulation were purchased. Apprentices practiced applying safety harnesses, setting ladders and scaffolding, and observed the benefits of retracting lifelines. Risk perceptions were explored through group sorting of construction site pictures, shared stories, and small group problem-solving. Lectures, printed materials, and videos were followed by application to real-world situations. The revised curriculum targeted four areas identified in the gap analysis: ladders, leading edges and openings, truss setting, and personal fall arrest systems (PFAS). Elements of the curriculum were presented at several stages of the apprenticeship, building on principles learned as the apprentices gained real-world experience. Details of the gap analysis, curriculum development, and the intervention have been reported previously.[10]

Process evaluations of the new curriculum were administered to solicit apprentice feedback and determine utility of training methods; both surveys and focus groups were used. Fidelity of the intervention was monitored throughout the study using instructor logs to track achievement of learning objectives each time the training was delivered. The curriculum was formally rolled out in April 2007, with curricular adjustments made based upon results of ongoing process evaluations.

2.3 Outcome Measurements

In order to measure effects of the training, we surveyed all apprentices attending bi-annual training at the apprenticeship school during the measurement period, and conducted fall safety audits of residential construction worksites employing one or more apprentices. Apprentice surveys and worksite audits collected for the needs assessment served as pre-intervention baseline measures. Follow-up surveys were repeated 12 to 27 months following initiation of the new curriculum; follow-up worksite audits were performed 12 to 17 months after initiation of the intervention. The apprentice survey included questions about carpentry experience, fall prevention knowledge, ratings of fall risk perception for 12 different work situations (0–10 scale), past fall prevention training, confidence in ability to avoid falling at work (4-point agreement scale), self-reported crew behaviors (5-point frequency scale), perceived workplace safety climate (5-point agreement scale), and recent falls. A fall was defined as "falling from one height to another, like falling from a ladder or down several steps, but not a fall to the floor on which you are standing." In order to understand the severity of injuries sustained in the fall, respondents who had experienced a fall were asked if they received medical care or prescription medications, were placed on light or restricted work, or lost work time beyond the day of the fall. We have previously described the development of the apprentice survey, measures of scale reliability, and baseline results.[9] For this study, analyses were restricted to surveyed apprentices who had worked in construction during the preceding year.

The St. Louis Audit of Fall Risks (SAFR) was developed to measure worksite behaviors at residential construction sites. We reviewed construction-specific worksite audits used in previous research, OSHA's construction standards,[12] and Interim Guidelines for Residential Construction,[13] and solicited feedback from a panel of expert carpentry professionals. This audit computed scores based on 52 dichotomous response items in nine domains: general safety, floor joist installation, wall openings, floor openings/edges, roof truss installation, roof sheathing, scaffolds, ladders, and personal fall arrest systems (PFAS). A short worker interview was also performed at the time of the audit. Two retired journeymen carpenter research assistants with prior experience in residential construction and safety research were trained to administer the SAFR. Development, scoring, and psychometrics of the SAFR have been previously described; it was found to be content valid and to have good internal consistency and inter-rater reliability when administered by trained personnel.[5] The SAFR is publicly available at the Electronic Library of Construction Occupational Safety and Health (http://www.elcosh.org/index.php).

2.4 Data management and analysis

We evaluated outcomes of the training intervention by comparing survey and audit data from the baseline to a follow-up time point. For these analyses, contractor size was categorized by the number of carpenters survey respondents reported working for their current employer: small ≤25, medium 26–75, and large >75. For analyses of worksite audits, we used the same criteria for contractor size, based upon payroll records of carpenter hours paid in the previous year, with 2,000 hours equivalent to one full time worker. Recent residential experience was defined as working more than 3 months in residential construction in the past year. To assess the specificity of the intervention, we identified items on the survey and audits addressing equipment and safety behaviors that were emphasized in the revised training curriculum (use of ladders, leading edges and openings, truss setting, scaffold use, and personal fall arrest systems).

2.4.1 Apprentice Survey: We calculated scores for the safety climate, crew behavior, risk perception, and confidence domains using the mean of all items in that domain. If fewer than 75% of items were answered, the domain score was coded as missing. The knowledge score was calculated from the number of items answered correctly by each respondent; items that were skipped were counted as incorrect. This domain was coded as missing only if all knowledge questions were skipped. Survey domain scores were standardized to a 100-point scale. We generated descriptive statistics for all domains, and used t-tests to compare changes in survey domain scores. Multivariable linear regression analyzed relationships between predictors and survey outcomes, including areas emphasized and not emphasized in the training. We computed the incidence rate of reported falls from height in the past year, using person-years of exposure calculated from self-reported work hours. To assess predictors for falls from height, we entered candidate variables into a logistic regression model adjusted for the number of months worked in order to account for differences in time at risk.

2.4.2 Worksite Audit: We computed audit compliance scores, comparing the proportion of items performed safely to the total number of items observed. Since all phases of home construction could not be observed in a single visit at most sites, all audits had items coded as “not observed.” We examined changes in overall audit scores, changes in subscales, changes in the emphasized areas of training, and interactions between contractor size and training emphasis. We conducted a sub-analysis on compliance scores with audits of contractors who participated in both baseline and outcome audits to account for changes in participating employers over time. As these scores were proportions, they were modeled using logistic regression. We assessed model fit for logistic regression models using the Hosmer & Lemeshow goodness-of-fit test, and for the linear regression models by examining R^2 and checking model assumptions. Analyses were pre-specified and performed using SAS.[14] Sample size was set based on ability to show a significant difference in the fall safety behavior scale, based on data from a previous study.

3. RESULTS

3.1 Apprentice Surveys:

We obtained surveys from 2,291 carpenter apprentices (1,018 pre-intervention and 1,273 post-intervention). Participation rates for completion of the apprentice survey were above 97% at all time-points. Descriptive statistics of the apprentice respondents at pre-intervention and post-intervention time points are outlined in Table 1. The mean age of apprentices responding to both the pre and post-intervention surveys was 26 years, and apprentices had completed an average of just over 4 of the six-month training “terms” out of the 8 required for completion of apprenticeship. The post-intervention measures were collected during a major downturn in new home construction, and the respondents were different in several ways. Apprentices in the post-intervention period had more time in the construction trade but less recent experience in residential construction. Their work crews were characterized by fewer apprentices relative to journeymen carpenters, and large-size contractors were more heavily represented.

Post-intervention surveys for 2,291 apprentices demonstrated statistically significant increases from pre-intervention surveys on the 100-point scales for knowledge (7.7 points), crew safety behavior (9.8 points), safety climate (6.4 points), and risk perceptions (6.4). Post-training fall safety knowledge scores increased 10.6 points higher for items emphasized in the training versus 3.0 points higher for items not emphasized in the training ($p<0.0001$). All of these changes remained after adjusting for apprentice term, percent apprentices in the crew, contractor size, and residential experience in the past year. (Table 2) While several of these factors were statistically significant predictors of knowledge, crew safety behavior, safety climate, or risk perception of falls, the amount of variance explained was relatively low, with R^2 values ranging from 0.02 – 0.16. Apprentices working for small and medium-sized contractors reported less safe crew behaviors and poorer safety climate than apprentices working for large contractors at both time points. Since the contractor size was not provided by many apprentice survey respondents, we ran analyses both with and without contractor size. Changes in knowledge, crew behaviors, safety climate, and risk perception following the intervention were similar in models that included and excluded contractor size.

Apprentices were all actively employed; most worked exclusively in commercial construction or in residential construction, with some reporting work in both in the past 12 months. We chose 3 months or more of work in the residential sector in the past year to denote those with significant residential construction experience; workers with such residential experience were more likely to report a fall from height in the past year than those working less than 3 months in residential construction (OR= 2.26, 95% CI 1.59– 3.21). Over time we saw a reduction in the incidence of self-reported falls from height, from 18.3 (95% CI 15.5–21.1) to 14.0 (95% CI 11.7–16.2) falls per 100 person-years of work. While statistically significant in univariate analysis, this change was not statistically significant in a logistic regression model that adjusted for prior work experience, the percentage of inexperienced workers in the work crew, the contractor size, and for more time worked in the residential sector, the strongest predictor of self-reported falls in our study.

3.2 Worksite Audits:

We observed improvements in compliance in all domains of the worksite audit from baseline to follow-up time points except for Personal Fall Arrest Systems (PFAS), (Figure 1). PFAS was rarely used at the worksites visited. Larger changes in worksite behaviors were observed for areas emphasized in the training, with the greatest effect noted among small and medium-sized contractors (Table 3). We were unable to survey all of the same contractors at baseline and follow-up time points, but found similar results when we limited our analysis to contractors who participated in worksite auditing in both the pre- and post-intervention periods.

3.3 Process Evaluation:

Of the 150 early stage apprentices training participants asked to rate the effectiveness of various methods used in the training, ratings were highest for the prop of a partially constructed home (4.42 out of 5) and practicing using scaffolds in the shop area (4.27 out of 5). Ninety-six percent of apprentices surveyed strongly agreed that the house prop was an effective training method. Mid-stage apprentices rated discussion of work hazards as 4.1 and hearing stories about other carpenters' falls as 3.5 – 60% agreed these stories decreased their likelihood of personally experiencing a workplace fall. Qualitative data also supported the effectiveness of training methods meant to promote the engagement of learners, including training activities where small groups sorted construction site photographs from least to most risky. Regarding fidelity of delivery of the revised curriculum, the instructors' ability to address all training objectives improved from 89% early in the training to 98% by the end of the training. Reasons cited for inconsistent delivery included time, shortened work-week, new instructor that was not competent in the topic area, and equipment availability.

4. DISCUSSION

This study represented a unique partnership between academic researchers and a joint union – contractor apprentice training program. We developed an educational intervention for apprentice carpenters that addressed identified gaps in fall safety training and utilized adult learning methods that have been recently recommended for occupational safety and health training.[15] The teaching methods focused on work-related experiences, problem-solving, and experiential learning, and they took into account the effects of attitudes, beliefs, values, abilities, and motivational states on training success. Following implementation of this fall prevention training program, we identified positive changes in apprentices' fall prevention knowledge, reported worksite safety climate, reported worksite safety behaviors, and perception of the risks posed by fall hazards. Importantly, our study outcomes included observed fall prevention behaviors in addition to self-reported behaviors. Audits of worksites, conducted by experienced carpenter research assistants, showed improvements across multiple domains of fall safety practices by our study sample while working at home construction sites.

Our intervention study occurred during a downturn in new home construction, with consequent economic stress for construction contractors and carpenters, and changes in the construction workforce. While we cannot be certain that the improvements we measured in both self-reported and observed fall prevention behaviors were due to our educational intervention, at least two factors argue for an effect of the intervention. First, both self-reported and observed improvements in fall safety behaviors persisted after adjustment for temporal changes that may have affected results, including changes in prior work experience, changes in work crew composition, and changes in the distribution of contractor size over time. Second, the larger changes observed in knowledge and behavior for the five topics specifically emphasized in the revised curriculum demonstrates specificity of effect. Though there was a general increase in fall safety across many domains following our intervention, the largest changes occurred in the domains that were most emphasized in the training: use of ladders, leading edges and openings, truss setting, and scaffold use. The only emphasized domain that did not show improvements was use of PFAS. We rarely saw PFAS in use at participating worksites in this study, which occurred during a period when OSHA allowed alternative methods of fall prevention and did not require use of PFAS. It is of note that the training and other explanatory variables in our models accounted for a relatively small part of the overall variance in knowledge, crew behaviors, safety climate, and risk perception, meaning that additional unmeasured factors are of significant relevance in predicting inter-individual variation.

It is important to note that the surveys and audits occurred months or even years after initiation of training interventions at the school, arguing for long-term effects of the improved fall prevention training. Our study measured reported and observed fall safety behaviors, rather than falls, as the primary outcome. While a large proportion of workers reported falls from height, few resulted in injury; a study that used reduction in serious falls as its outcome would require a study population many times larger than our local carpenters. Strengths of this work include the large sample size, with the excellent rates of participation by apprentices and contractors suggesting that the sample is representative of carpenters in our region. Another strength of this research was the collaboration between union construction workers, construction contractors, apprenticeship trainers and academic researchers to address the major public health problem of falls among construction workers.

This research supports growing evidence that worksite safety can be improved by well-designed training.[16, 17] A recent comprehensive review concluded that safety education and training is as an integral component to improved construction safety.[18] There is empirical evidence that occupational health and safety training increases worker knowledge,[19] improves safety behaviors,[15, 20, 21] and decreases workers' compensation claims among construction workers.[22, 23] Two recent meta-analyses found that high engagement safety training promotes knowledge and skill acquisition[19] and has a greater impact than low engagement methods [15]. Dialogue between learners and action-focused reflection has been found to help workers develop cognitive, motor, and interpersonal skills needed to handle complex and ambiguous situations.[23] Adult learners prefer timely and practice training by field experts that builds on their existing skills and can be easily applied to their situation.[24] Our study is unusual in studying – and observing improvement - in a range of outcomes including knowledge and attitudes, self-reported and observed safety behaviors, and reported falls. Because we tested a single, integrated intervention we are unable to identify which aspects of training were most effective. However, we believe that our application of hands-on methods that highly engaged the learners were important to the success of this program.

5. CONCLUSION

Our study suggests that a revised fall prevention curriculum based on gap analysis and incorporation of high engagement training methods was effective in improving fall prevention knowledge, behaviors, and fall experiences among apprentice carpenters. These inexperienced crewmembers are exposed to construction work at height early in their careers, and need to learn appropriate work methods and equipment necessary for their protection. Continued training is important for all construction workers, as the construction environment is dynamic and subject to changes in work methods and construction type due to alterations the economy, local safety culture, and state or national regulatory policy. Our study was performed in the context of a union apprenticeship program providing training in both construction skills and safe work methods. Our fall prevention curriculum could be readily adapted to other union apprenticeship programs; in areas of the country where the majority of residential carpenters are not trained in a union apprenticeship, other methods of providing similar training are needed to change knowledge, attitudes, and behaviors affecting construction falls.

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Highlights

- Falls from heights abound in residential construction and research is limited
- Hands-on training improved apprentice carpenters' knowledge, behaviors, and falls
- Program can be adapted to other apprenticeships and new worker training programs

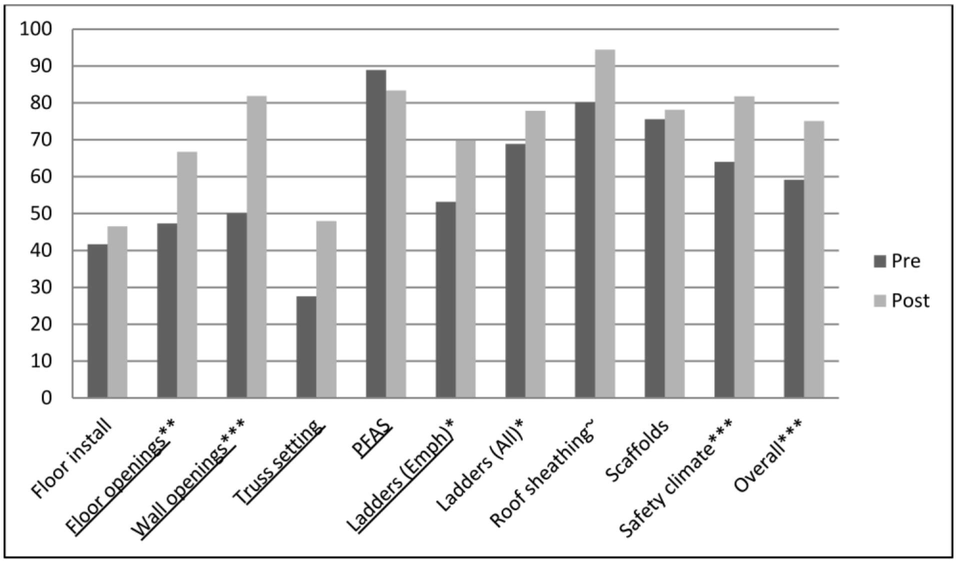

Figure 1.

Observational audit rating scales pre- and post-intervention (n=197 pre-intervention and 203 post-intervention audits). Domains emphasized in the revised curriculum are underlined.

p values denoted by symbols: ~ p<0.05; * p<0.01; **p<.001; ***p<.0001

Table 1:

Descriptive statistics of apprentice carpenters at pre-intervention and post-intervention time points. [SD= standard deviation]

Apprentice Survey	Pre-Intervention		Post-Intervention		p-value
N = 2,291	N=1,018		N=1,273		
	Mean	SD	Mean	SD	
Age (in years)	26.0	5.8	26.2	6.1	
Mean apprentice term [a]	4.4	2.1	4.6	2.2	
	n	%	n	%	
Time in trade					0.02
6 months to 1 year	167	16.4	169	13.3	
>1 year to 2 years	210	20.6	285	22.4	
>2 years to 5 years	509	50.0	610	47.9	
>5 years	132	13.0	205	16.1	
% apprentice in crew					<.0001
< 33.3%	83	8.2	322	25.3	
33.3% – 66.5%	405	39.8	596	46.8	
≥66.6%	349	34.3	279	21.9	
Contractor size					<.0001
Small: ≤ 25 employees	315	30.9	484	38.0	
Medium: 26–75 employees	172	16.9	352	27.7	
Large: > 75 employees	369	36.3	344	27.0	
Missing	162	15.9	93	7.3	
>3 months residential experience in the last year	747	73.4	582	45.7	<.0001
Worksite Audit	**Pre-Intervention**		**Post-Intervention**		**p-value**
N = 404	N=197		N=207		
Mean % apprentice in crew	52	2.4	37	2.5	<.0001
	n	%	n	%	
Contractor size					<.0001
Small: ≤25 employees	3	4.1	24	11.6	
Medium: 26–75 employees	56	28.4	13	6.3	
Large: >75 employees	133	67.5	170	82.1	

[a] Apprentices complete a total of 8 “terms,” each combining approximately 6 months of work experience with two weeks of classroom training.

Table 2:

Linear regression models of survey results pre- and post-intervention. Changes in knowledge, crew behavior, safety climate and risk perceptions are adjusted for apprentice training term, proportion of apprentices in construction crew, contractor size, and residential construction work in the past year

	Knowledge						Crew Behavior		Safety Climate		Risk Perceptions	
	Total score (n= 1,970)		Emphasized (n=1,966)		Non-emphasized (n=1,968)		(n=1,745)		(n=1,915)		(n=1,946)	
	Estimate (SE)	**p**	**Estimate (SE)**	**p**	**Estimate (SE)**	**p**	**Estimate (SE)**	**p**	**Estimate (SE)**	**p**	**Estimate (SE)**	**p**
Pre/Post Intervention	8.0 (0.9)	<.0001	11.5 (1.2)	<.0001	2.6 (1.3)	0.05	10.5 (1.0)	<.0001	5.5 (0.9)	<.0001	2.5 (1.0)	0.009
Apprentice term	1.0 (0.2)	<.0001	0.8 (0.2)	0.001	1.1 (0.3)	<.0001	−0.5 (0.2)	0.03	−0.7 (0.2)	<.001	0.3 (0.2)	0.21
% apprentice in crew		0.86		0.89		0.56		0.03		0.02		0.06
<33.3%	0.2 (1.3)		0.2 (1.6)		0.2 (1.9)		2.6 (1.5)		3.8 (1.3)		−0.7 (1.3)	
33.3% – 66.5%	0.7 (1.0)		0.9 (1.2)		0.4 (1.4)		3.1 (1.1)		1.8 (0.9)		−1.1 (1.0)	
>=66.6%	ref		ref		ref		ref		ref		ref	
Contractor size		0.01		0.01		0.46		<.0001		<.0001		0.49
Small	−2.8 (1.0)		−3.5 (1.2)		−1.7 (1.4)		−11.8 (1.1)		−6.9 (0.9)		−1.1 (1.0)	
Medium	−2.3 (1.1)		−3.4 (1.4)		−0.7 (1.6)		−9.3 (1.2)		−5.2 (1.0)		−1.1 (1.1)	
Large	ref		ref		ref		ref		ref		ref	
≥ 3mos residential experience in past year	−0.6 (1.0)	0.6	1.7 (1.2)	0.17	−4.3 (1.4)	0.002	−5.7 (1.1)	<.0001	−5.0 (0.9)	<.0001	−3.3 (1.0)	0.001
R^2	0.06		0.06		0.02		0.16		0.10		0.02	

Table 3:

Fall safety compliance scores from worksite audit, showing differences post-intervention by contractor size and contrasting change scores between items emphasized in the revised curriculum and those not emphasized.* [SD= standard deviation]

% Compliance Score	All Audited Contractors					
	Pre-Intervention		Post-Intervention		Difference	p-value
	Mean	SD	Mean	SD		
All Sizes	N=197		N=207			
Emphasized Areas	47.9	33.8	66.8	23.1	18.9	<.0001
Non- Emphasized Areas	71.3	23.4	85.6	19.9	14.3	<.0001
Total Score	59.1	24.4	75.1	20.5	16	<.0001
Small Contractor	N=8		N=24			
Emphasized Areas	17.1	24.5	63.5	31.5	46.4	<0.01
Non- Emphasized Areas	49.1	16.3	71.9	29.2	22.8	0.02
Total Score	33.7	17.5	63.9	26.6	30.2	<0.01
Medium Contractor	N=56		N=13			
Emphasized Areas	32.3	12.2	66.0	27.5	33.7	<.001
Non- Emphasized Areas	68.6	20.8	89.3	13.8	10.9	<.001
Total Score	49.8	22.3	75.8	20.8	22.3	<.001
Large Contractor	N=133		N=170			
Emphasized Areas	56.4	32.0	67.3	27.8	10.9	<.001
Non- Emphasized Areas	73.8	24.1	87.3	17.9	13.5	<.0001
Total Score	64.6	23.7	76.6	19.2	12	<.0001

* n=197 pre-intervention and 207 post-intervention audits. Audits were conducted at multiple builds of 17 contractors in the pre-intervention period and 16 contractors in the post-intervention period; 10 of these contractors participated in audits in both periods.