

Fall Hazard Control Observed on Residential Construction Sites

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Background Falls are a leading cause of mortality and morbidity in the construction industry. This study measured fall hazards at residential construction sites.

Methods Trained carpenters administered the St. Louis Audit of Fall Risks and interviewed carpenters. The prevalence of fall prevention practices meeting safety criteria was counted and correlations explored.

Results We identified a high prevalence of fall hazards at the 197 residential sites audited. Roof sheathing met safety criteria most consistently (81%) and truss setting least consistently (28%). Use of personal fall arrest and monitoring of unguarded floor openings were rare. Safer performance on several scales was correlated. Construction sites of large-sized contractors were generally safer than smaller contractors. Apprentice carpenters were less familiar with their employers' fall prevention plan than experienced workers.

Conclusions Safety could be improved with consistent use of recognized fall prevention practices at residential construction sites. *Am. J. Ind. Med.* 52:491–499, 2009.

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INTRODUCTION

Construction workers frequently encounter work situations that place them at risk of injury or death. Workers with less experience [Salminen, 1994], including those with shorter periods of union membership [Stern et al., 1995],

those employed by smaller size contracting companies [Ringen et al., 1995], and those who perform residential construction [Lipscomb et al., 2003] are more likely to experience occupational injuries. According to the Bureau of Labor Statistics [2008], in the 3-year period between 2003 and 2006, carpenter deaths due to falls to a lower level rose 40% in the United States. In 2007 the construction industry experienced the highest number of fatalities for any industry in the private sector (1,178) and fatalities of workers constructing buildings rose 11%. Falls to a lower level accounted for 43% of the fatalities in residential building construction and 55% of the fatalities in residential framing [US Department of Labor, 2008]. In 2007, the incident rate for falls to a lower level in construction was 30.4/10,000 full time employees, the highest of all occupations [US Department of Labor, 2008].

Controlling workplace hazards to reduce the incidence of falls on the job is difficult in the residential construction industry, where the work environment changes frequently and the work crews are often small and dispersed. Many residential construction workers are younger, have less work

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experience, or are immigrants [Salminen, 1994]. These workers may be at greater risk of injury for a number of reasons, including lack of familiarity with construction methods, inadequate safety training, communication difficulties created by language barriers, or lack of appropriate equipment to name a few. On site safety professionals are a rarity in residential construction, and safety innovation has lagged behind commercial construction. New home construction is a competitive sector of the construction industry, with significant time pressures on most jobs. Some building practices described in the OSHA Construction Standards, 1926 [OSHA Construction Standards, 2006] are difficult to follow at residential construction sites; therefore, OSHA released Directive STD 3.1A, the Safety and Health Interim Residential Guidelines [Plain language revision of OSHA Construction STD 3.1, 1999]. Although these guidelines describe alternative methods to protect workers from falls from height, they do not have the same legal enforcement as regulations, decreasing the incentive for adherence.

Hazard identification and control is instrumental to worker safety in the construction industry [McConnell, 1996], where, regardless of regulations, the workers are the primary caretakers of their own safety [Ringen et al., 1995]. Perceptions of the state of safety at a particular place and time, otherwise known as the safety climate [Zhang et al., 2002], may distinguish between employers with high or low injury rates [Coyle et al., 1995]. Gillen et al. [2002] found that safety climate measures in construction “beg for improvement,” including the need to alert workers of dangerous work practices and conditions, express concern for worker safety, provide proper equipment, and conduct meaningful safety training. Several researchers have measured work practices and conditions specific to fall safety on commercial construction sites [Becker et al., 2001; Stafford and Cameron, 2004], demonstrating compliance with recommended guidelines ranging from 50% to 80%. However, we cannot assume similar controls, or even similar hazards, exist at residential sites as the building materials, construction methods, equipment, safety monitoring, and work organization are different between the two types of construction sites.

Researchers have also attempted to measure fall safety practices on residential construction sites. Bigelow et al. [1998] assessed the general safety of 195 homebuilding sites in the Denver area. The overall rate of safety compliance was 65–70%. Lipscomb et al. [2003] audited 95 unionized residential construction sites where falls occurred to assess fall prevention practices and to identify circumstances surrounding falls soon after carpenter injuries at the worksites. Warning lines to mark control access zones were rarely observed, and guardrails around openings were noted 2/3 of the time. On sites where falls had occurred from over 6 ft, two-third of the scaffolding was reported as poor or unacceptable and personal fall arrest equipment was

available at only half of these sites [Lipscomb et al., 2003].

The fall safety at non-unionized construction worksites may even be worse than at unionized worksites. Non-unionized construction workers were less likely to receive basic OSHA 10-hr training [Nissen et al., 2008] and workplace safety training [Dedobbeleer et al., 1990; Gillen et al., 2002] than unionized construction workers, and workplace safety behaviors such as use of guards on cutting tools and use of respiratory equipment were less common at non-unionized construction sites than unionized sites [Nissen et al., 2008]. Union construction workers were more likely to perceive their supervisors cared about their safety and did as much as possible regarding safety, and reported being warned about dangerous work practices and conditions more commonly than non-union workers [Gillen et al., 2002]. Union workers were also less likely than non-union workers to perceive that taking risks was a part of their job [Gillen et al., 2002].

Since falls account for the largest proportion of deaths amongst residential framing carpenters and the prevalence of specific fall hazards on residential construction has not been clearly documented, our research team developed an observational audit to systematically collect data on residential fall hazards. The audit was designed to be administered by carpenters at the worksite; the audit development process and standardized audit administration manual have been previously described in detail [Kaskutas et al., 2008]. This study reports the findings from baseline audits conducted using this tool, the St. Louis Audit of Fall Risks (SAFR), as part of a needs assessment designed to inform fall prevention intervention efforts in residential construction.

METHODS

Audit Procedure

Two trained journeymen carpenters on our research team performed audits of residential construction sites in the metropolitan St. Louis area. The construction crews on these sites consisted of journeymen and apprentice carpenters represented by the Carpenters' District Council of Greater St. Louis and Vicinity. The SAFR is a 52-item observational instrument consisting of nine domains, including general safety, floor joist installation, wall openings, floor openings/edges, roof truss installation, roof sheathing, scaffolds, ladders, and personal fall arrest [Kaskutas et al., 2008]. All but one of the items on the SAFR are based on OSHA's construction standards or residential guidelines, therefore worksites that meet the audit criteria also meet OSHA's criteria for fall safety. The SAFR is scored dichotomously, with “meets criteria” marked if all observations for an item meet the safety criteria, and “does not meet criteria” marked

if at least one of the observations of the task does not meet the safety criteria. Tasks not observed at the time of the audit are marked “not observed.” Some domains of the audit can only be completed if a particular phase of construction is occurring at the time of observation (floor joist installation, truss installation, and roof sheathing) and some items within a domain are dependent upon the type of equipment in use (ladders, scaffold, and personal fall arrest) or home design (roof sheathing and truss setting). Inter-rater reliability of the SAFR was excellent among trained journeymen carpenters from a pilot study [Kaskutas et al., 2008]. The SAFR instrument and administration manual are available at the Electronic Library of Construction Occupational Safety and Health [<http://www.cdc.gov/elcosh/docs/d0800/d000854/d000854.pdf>, <http://www.cdc.gov/elcosh/docs/d0800/d000853/d000853.pdf>].

The journeymen carpenter auditors contacted residential contracting companies that employ union carpenters and explained the research project. After receiving approval, the auditor was provided with the location of worksites to visit. Occasionally a company representative accompanied the auditor to the worksites, but usually the auditor visited the worksite alone. Most crews were not aware of the audit before the journeyman carpenter arrived. After explaining the procedure to the foreman and inquiring about applicable safety rules, the auditor entered the worksite and observed the crewmembers at work. The auditor stood in a safe location and did not climb ladders or scaffolds. Since our aim was to observe the actual working conditions, the auditor did not interrupt the normal work tasks, ask individuals to repeat tasks, or mock up tasks that were not occurring at the time of the audit. Work tasks and environmental conditions that occurred during the audit were scored according to detailed directions in the SAFR administration manual. After the journeyman auditors coded the observed items of the audit, a brief interview was administered to each available carpenter who consented. Interview questions included age, position (foreman, journeyman, or apprentice), time in the trade, in the union, and with the current contractor, frequency of on-the-job safety and fall prevention training, whether familiar with the contractor’s fall prevention plan, and if personal fall arrest equipment was available at the worksite. The Institutional Review Board at Washington University School of Medicine approved all research procedures, including the SAFR instrument and informed consent procedures.

Analyses

Descriptive statistics measured frequencies for categorical variables and central tendencies for continuous variables on the audit and brief interview. The number of items meeting the safety criteria within each audit domain was summed and divided by the total number of items

observed in that category to compute a safety compliance percentile for that category. Cronbach’s alpha was computed within these domains to assess intra-scale reliability. To identify if there was a correlation between safety compliance during various phases of the home construction process, associations between audit domains with acceptable intra-scale reliability were explored using Spearman’s rank correlation coefficient. Other analyses used standard parametric and non-parametric statistics.

Contractors were categorized by size as small (<25 carpenters employed), medium (26–75 carpenters), or large (>75 carpenters) to explore the effect of contractor size on both audit and interview findings. We used analysis of variance and the Kruskal–Wallis test to compare audit and interview results by contractor size. SPSS (version 16.0) was used for all statistical analyses.

RESULTS

Audit

The audit was performed at 197 residential worksites over a 1-year period. Our sample was primarily framing crews (82%) constructing new (96%), single-family homes (74%), in multi-site developments (93%). The primary phases of construction observed included first floor framing (25%), second floor framing (23%), roof sheathing (9%), and siding installation (9%). The median cycle time to frame a residential dwelling was 3 weeks. The mean number of carpenters observed on individual worksites was 4.2 (range 1–31). Audits were conducted at 65% large, 31% medium, and 4% small size contractors.

Table I outlines the frequency of observation and percent compliance for each observed audit item and the nine domains of the audit: general safety climate/housekeeping, floor joist/sub-floor installation, floor openings/edges, wall openings (window/door), truss setting, roof sheathing, ladders, scaffolds, and personal fall arrest. Since the ability to observe audit items was dependent upon the phase of construction occurring at the time of the audit, the number and type of audit items observed varied widely between sites. Compliance with some generic items could be observed at all worksites (hard hat use); whereas others could be observed at only a few sites (scaffolds and truss setting). Work tasks that were performed for a brief period of time during only one construction phase (such as installing the first two trusses) were observed less often than tasks performed for a longer duration that are common in multiple phases of construction (such as step ladder set-up). The rate of observation for the nine domains of the audit ranged from 5% for personal fall arrest to 99% for general safety climate/housekeeping. The average rate of observation on all items of the audit was 23.6%.

TABLE I. St. Louis Audit of Fall Risks Domains and Items, Frequency of Observations and Observations That Met the Safety Criteria (n = 197 Worksites)

Domains/items	Item observed at audit	Observation met safety criteria
General safety climate and housekeeping	586/591 (99%) ^a	376/586 (64%) ^a
All workers wear hard hats	197/197 (100%)	142/197 (72%)
All workers wear safety glasses/eye protection	195/197 (99%)	109/195 (56%)
Pathways/access point free of materials/debris	194/197 (98%)	125/194 (64%)
Floor joist and sub-floor installation	37/591 (6%) ^a	18/37 (49%) ^a
Floor joists are set/secured from ladder/ground/scaffold, not beam/top plate	22/197 (11%)	4/22 (18%)
First sheet of sub-floor installed from ground/ladder/scaffold, not joist	3/197 (2%)	2/3 (67%)
Workers install subsequent sub-flooring standing on established deck, not joist	12/197 (6%)	12/12 (100%)
Floor openings and edges	479/1,182 (41%) ^a	206/479 (43%) ^a
Walking surfaces >6' (ft) above lower level are protected by guardrail or erected wall	129/197 (65%)	65/129 (50%)
All walking surfaces >6' (ft) above lower level that are not protected by guardrail or wall are identified with a warning line painted 6" from leading edge	68/197 (35%)	12/68 (18%)
All areas with unprotected walking surfaces are designated control access zones; boundary is clearly marked, workers monitored, and access restricted	56/197 (28%)	1/56 (2%)
Guardrails protecting openings are constructed sturdily (200# force) with 2 × 4's, top rail 42", mid-rail 21"	95/197 (48%)	62/95 (65%)
Holes >6' (ft) above lower levels are covered; a hole is a gap >2" in a pathway commonly accessed	41/197 (21%)	24/41 (59%)
Stairwell has sturdy handrail on at least one side	90/197 (46%)	42/90 (59%)
Wall openings (window/door)	174/304 (44%) ^a	94/174 (54%) ^a
Walls >6' (ft) above lower levels that have openings with bottom edge <39" from floor are protected by guardrails	97/197 (49%)	48/97 (50%)
For walls >6' (ft) above lower levels, guardrails are constructed sturdily (200# force) with 2 × 4's, top rail 42", mid-rail or lower wall at 21" from ground	77/197 (39%)	46/77 (60%)
Truss setting	61/1,182 (5%) ^a	17/61 (28%) ^a
Lay out for trusses is performed from sub-floor or ladder, not from top plate	6/197 (3%)	1/6 (17%)
For walls up to 8' (ft), trusses are installed from ladder or scaffold along interior wall	9/197 (5%)	0/9 (0%)
For walls >8' (ft), first two trusses are set from ladder or scaffold along interior wall	6/197 (3%)	0/6 (0%)
For walls >8' (ft), common trusses are set and secured from ladder, scaffold, or interior top plate using stable truss for support; not standing on exterior top plate	14/197 (7%)	1/14 (7%)
Worker removes chain/webbing from truss while standing on ladder/secure truss	12/197 (6%)	4/12 (33%)
Workers lift boards/stand trusses only when using stable truss for support	14/197 (7%)	11/14 (79%)
Roof sheathing	266/1,379 (19%) ^a	111/137 (81%) ^a
Bottom row of roof sheathing installed from truss web, ladder, or scaffold	9/197 (5%)	6/9 (67%)
Workers install slide guard on first row of sheathing before installing next row	15/197 (8%)	13/15 (87%)
Slide guards are ≥2 × 4 boards, bottom guard is perpendicular to sheathing	27/197 (14%)	25/27 (93%)
Slide guard intervals: pitch up to 9 in 12 at 13' (ft) intervals, >9 in 12 at 4' (ft) intervals	26/197 (13%)	21/26 (81%)
Slide guards are installed across full width of the roof and on all sides of roof	27/197 (14%)	19/27 (70%)
Roof is clear of sawdust, debris, and dew/snow/ice if workers are on roof	27/197 (14%)	25/27 (93%)
If slide guards are not used, fall arrest is properly used by all workers on roof	6/197 (3%)	2/6 (33%)
Ladders	687/1,970 (35%) ^a	463/687 (67%) ^a
Straight, free of cracks/broken parts, free of mud/ice, side locks on step ladder	141/197 (72%)	138/141 (98%)
Set up on level and solid base, securely set at the bottom	109/197 (55%)	73/109 (67%)
Extension and job-built ladders are secured at the top in appropriate manner	65/197 (33%)	12/65 (22%)
Step ladders fully opened and side locks engage, not leaned on structure like straight ladder	88/197 (45%)	45/88 (51%)
Extension and job-built ladders are set at correct angle of 1:4 ratio (palms of hands reach side rails if toes at base)	64/197 (33%)	46/64 (72%)
Extension and job-built ladders extend 3' (ft) past upper landing surface	56/197 (28%)	31/56 (55%)
Workers do not work from top three rungs of extension and job-built ladders and top rung or platform of step ladder	52/197 (26%)	39/52 (75%)

(Continued)

TABLE I. (Continued)

Domains/items	Item observed at audit	Observation met safety criteria
Workers maintain three points of contact while climbing ladders and do not carry supplies while climbing ladder	58/197 (29%)	37/58 (64%)
Workers always keep belt buckle region within side rails and both feet on ladder	54/197 (27%)	42/54 (78%)
Workers drag excess mud off of shoes before climbing ladder	0/197 (0%)	0/0
Scaffolds	107/2,561 (4%) ^a	81/107 (76%) ^a
<i>All scaffolds:</i> Fall protection used if >10' (ft) tall (personal fall arrest/guardrail/net)	9/197 (5%)	6/9 (67%)
<i>Ladder jack:</i> Ladders are safely secured at both the top and bottom	10/197 (5%)	7/10 (70%)
<i>Ladder jack:</i> Maximum height is 20' (ft)	10/197 (5%)	9/10 (90%)
<i>Ladder jack:</i> Walk board is 12" wide	10/197 (5%)	10/10 (100%)
<i>Ladder jack:</i> Third ladder present to access if walk board is outside of ladders	1/197 (0.5%)	0/1 (0%)
<i>Ladder jack:</i> If access ladder is present, it extends 3' (ft) above walk board	3/197 (2%)	2/3 (67%)
<i>Pump jack:</i> Set on secure/stable base	5/197 (3%)	4/5 (80%)
<i>Pump jack:</i> 4 × 4 posts are properly braced and secured to building	5/197 (3%)	5/5 (100%)
<i>Pump jack:</i> Maximum height is 50' (ft)	5/197 (3%)	5/5 (100%)
<i>Pump jack:</i> Workers only disengage one brake at a time	3/197 (2%)	3/3 (100%)
<i>Job built:</i> Set up on level, stable footing	16/197 (8%)	15/16 (94%)
<i>Job built:</i> Platform is secure and stable	15/197 (8%)	10/15 (67%)
<i>Job built:</i> Platform is 18" wide	15/197 (8%)	5/15 (33%)
Personal fall arrest	18/394 (5%) ^a	16/18 (89%) ^a
Workers wearing fall arrest use approved harness that is worn properly	9/197 (5%)	9/9 (100%)
Lanyard is properly attached to secure anchorage point/lanyard length is correct	9/197 (5%)	7/9 (78%)
Overall SAFR	2,415/10,244 (24%) ^b	1,382/2,286 (60%) ^b

^aRepresents all items within the corresponding scale.

^bRepresents all items on the SAFR.

The second column of Table I shows how frequently the items met safety criteria when the item was observed. Performance of the items and domains of the audit varied widely. Some items met audit safety criteria on 100% of observations, such as sub-floor installed from decking, and personal fall arrest harness worn properly. Other items never met audit criteria, including installing trusses on walls 8' (ft) tall or less from ladder/scaffold, and installing the first two trusses on walls over 8' (ft) from ladder/scaffold and not from the top plate. Of the 68 unprotected walking surfaces over 6' (ft) above a lower level observed during the audits, only 12 (18%) had a warning line painted 6" from the leading edge to warn workers of the hazard, and only 1 of these sites monitored carpenters working beyond this warning line as is required by OSHA residential guidelines. Many workers were observed walking on the exterior top plate, a "3½" board on the top of the outside wall of the home, during truss installation. When exploring the audit domains we found that safety compliance ranged from 28% to 89%. Roof sheathing met the audit safety criteria at 81% of the worksites; whereas truss installation met safety criteria for only 28% of observations. The overall prevalence of audit items that met safety criteria was 60% (Table I).

Scale reliability was excellent for seven of the nine audit domains (Cronbach's alpha 0.78–0.96). To summarize results when exploring associations we used the domain scores for the truss installation, roof sheathing, scaffolds, ladders, personal fall arrest, wall openings, floor openings/edges, and floor joist domains, but used individual items from the general safety/housekeeping domain due to low reliability of this domain (Cronbach's alpha 0.06).

Several of the domains were correlated. The floor openings/edges domain was correlated with the wall openings domain (Spearman's rank correlation coefficient = 0.72) and scaffolding domains (Spearman's rank correlation coefficient = 0.67). The roof-sheathing domain correlated with the wall openings domain (Spearman's rank correlation coefficient = 0.66), and the ladders domain (Spearman's rank 0.60). Statistically higher domain scores were noted for the floor openings/edges domain at sites where hard hats or safety glasses were worn, and for the wall opening and roof sheathing domains at sites where safety glasses were worn. When exploring differences among the sample based upon employer size, we found significant differences on the wall openings, floor openings/edges, and roof-sheathing domains, and for the use of safety glasses and hard hats, with

TABLE II. Proportion of Worksites That Met Audit Safety Criteria for Domains^a and General Safety Items by Contractor Size (n = 197^b)

	Small (%)	Medium (%)	Large (%)
Floor joist/sub-floor domain	100 ^c	25	47
Floor openings/edges domain*	12	29	59
Wall openings domain*	0	34	61
Truss setting domain	Not observed	29	27
Roof-sheathing domain*	0 ^c	69	90
Ladder domain	56	71	70
Scaffold domain	54	78	77
Personal fall arrest domain	Not observed	50 ^c	94
General safety domain*	43	58	68
Hard hat use*	14	69	77
Use of safety glasses*	14	41	65
Pathways free of material/debris	100	66	62

^aCriteria were based on number of items within each domain that were observed.

^bReflects number of sites observed for hard hat use (7 small, 61 medium, 129 large), numbers differed for each domain as all domains were not observed at each site.

^cObserved on one site.

* $P \leq 0.05$, Kruskal–Wallis test.

performance scores improving as the size of the contractor increased (Table II). Safety glasses and hard hats were rarely used by workers employed by small contractors. Safety glasses were used at 41% of the medium-sized contractors and 65% of the large contractors. Hard hat use was common at medium and large contractors audited.

Brief Interviews

We observed 778 carpenters at 197 worksites while performing the audits and conducted 506 interviews at 157 of these worksites. No interviews were conducted if the carpenter was working on an elevated work surface inaccessible to the auditor like a roof or scaffold, if the crew was performing a time-sensitive task such as setting trusses using a crane, or if there was an abrupt change in weather conditions. Four foremen refused the interview for their crews (total of 16 carpenters), and another eight individual carpenters refused the interview. Of those asked for interviews, the participation rate was 95.5%.

The average number of interviews per site was 3.2. The median age of our cohort was 28 years. Although race and gender were not collected, the vast majority of apprentices in this union are white males. Median time in carpentry trade was 7 years, time in union 5 years, and time with contractor 3 years. Our sample was 58% journeyman and 42% apprentices; 30% of those interviewed were foremen (normally journeymen). The apprentice participants were fairly evenly distributed across the 4 years of the apprenticeship program. The median number of times respondents reported receiving safety training in the past year was 13, and

fall protection training was 7. Fall arrest equipment was reported to be available by 81% of the respondents, and 85% said that the contractor's fall prevention plan had been communicated to them.

Various measures of the safety climate were positively correlated. Frequency of safety to fall protection training was closely correlated (Spearman's rho = 0.70). Longer employment time with the contractor was associated with a positive response to all variables of the interview; such as knowledge of contractor's fall prevention plan and greater amount of fall prevention training. Knowledge of the contractors' fall prevention plan was associated with greater amount of safety training, journeyman status, and foreman status. Foremen were more likely to report knowing their employers' fall prevention plan than non-foremen (94% vs. 81%) and journeymen were more likely than apprentices to know this plan (90% vs. 79%). Carpenters familiar with their contractors' fall prevention plan reported three times more fall prevention training and two times more safety training sessions/year than those not familiar with their contractors fall prevention plan. Although not a statistically significant finding, 96% of the foremen knew if personal fall arrest systems were available at their worksite, compared to 88% of the non-foremen, 93% of journeymen, and 85% of apprentices. We did not find a statistically significant difference between the amount of safety and fall prevention training reported by the more experienced carpenters when compared to the less experienced carpenters (apprentices, less time in the trade/union/with employer) (Table III).

Carpenters employed by large-sized contractors reported more safety training sessions on average per year

TABLE III. Comparisons by Contractor Size for Interview Results (n = 506 Workers)

Interview results	Small ^a (n = 20 ^b)	Medium ^a (n = 34 ^b)	Large ^a (n = 452 ^b)
Median age (in years)	30	25	28
Median years in trade	7	5	7
Median years in union	4	4	5
Median years with employer*	0.8	2	3
Median number of safety training sessions/year*	4	12	16
Median number of fall prevention training sessions/year*	3	11	6
Percentage with positive response			
Know contractors' fall prevention plan**	43%	94%	79%
Report personal fall arrest is available**	19%	94%	81%

^aSmall: <25 carpenters employed, medium: 26–75 carpenters, large: >75 carpenters.

^bReflects number of respondents for median age, slight variation for other variables was noted.

* $P \leq 0.05$, ANOVA.

** $P < 0.05$, Kruskal–Wallis test.

than those employed by smaller sized contractors (4 for small contractors, 12 for medium, and 16 for large) and longer time working for the contractor (0.8 years small, 2.0 years medium, 3.0 years large). Carpenters employed by medium- and large-sized contractors were also more likely than those employed by small-sized contractors to report that personal fall arrest systems were available at the worksite (19% small, 94% medium, 81% large) and to know their employers' fall prevention plan (43% small, 94% medium, 79% large).

DISCUSSION

These worksite observations provide information about the actual behaviors and work practices of construction workers in residential construction. We identified a high prevalence for many fall hazards at the 197 unionized residential construction sites we audited. The age-old practice of construction workers standing on narrow wood boards used for floor and roof trusses and the top plate of walls continues to be common in residential construction. We observed extended periods of worker exposure to unprotected floor openings over 6' (ft) above a lower level. Frequently these openings were not marked to alert workers of the fall hazard and rarely were workers in these zones monitored, which is required in controlled access zones according to the OSHA residential guidelines.

Many of our results point to the importance of the contractors in maintaining a safe work site. Workers with longer seniority with their contractor were better prepared to handle the fall hazards at the workplace. Larger sized contractors demonstrated greater compliance on several audit domains, including floor openings/edges, wall openings, and roof sheathing, and for use of hard hats and safety glasses. Carpenters working for larger contractors also reported greater frequency of safety training, greater

availability of personal fall arrest equipment, and greater familiarity with the contractors' fall protection. Our findings of greater safety compliance and training in large contractors appear to be in concert with Ringen et al. [1995], who found higher rates of injuries among smaller sized contractors. It is likely that larger contractors have more safety professionals or financial resources to provide safety training, equipment, monitoring, and enforcement.

The mean rate of safety compliance of 60% that we found during these residential audits is similar to that documented by researchers at both commercial sites (50–80%) [Becker et al., 2001; Stafford and Cameron, 2004] and residential sites (75–80%) [Bigelow et al., 1998; Lipscomb et al., 2003]. Given the large number of workers in the construction trade, nearly 1.5 million carpenters alone [Occupational Information Network, 2008], and the prevalence of unsafe work practices and conditions noted at the construction sites that have been researched, it is easy to understand why so many carpenter have lost their lives due to falls in the United States. We agree with Gillen et al. [2002] that this situation “begs for improvement.”

We were able to overcome many of the barriers to performing field research in construction to access a large number of journeymen and apprentice carpenters working for various sized residential contracting companies to measure safety compliance among these populations. We did this through a close collaboration between the academic team, carpenters' union and their membership, and affiliated homebuilders. Use of journeymen carpenters with safety and research training and experience as auditors/interviewers ensured validity of the observations and may have improved our rates of participation by both the contractors and carpenters.

Use of safety criteria that comply with federal construction standards and guidelines in audit items ensures

that sites meeting the safety criteria measured by the SAFR should also comply with nationwide safety standards and guidelines. Strong correlations between several scales of the audit suggest that fall safety in some domains predicts performance in other areas. It may be possible to predict performance on some phases of the construction process with a short cycle time by observing other operations that occur more commonly, such as ladder use and protection of openings, though this question needs to be explored further. Our research findings reflect the fall safety of residential construction sites that employ unionized carpenters in the St. Louis area. Because the St. Louis carpenters' union requires school-based safety training for apprentices and annual safety training for journeymen, the fall prevention behaviors observed in St. Louis may not reflect those seen in other regions where residential construction workers are not typically union members and safety-training requirements differ or do not exist. Since our sample was mostly drawn from large-sized employers, further assessment at small- and medium-sized contractors is needed. We were not able to view all fall safety behaviors at each site due to the cross-sectional nature of the study and variability of construction work. Continued use of the SAFR will give us the opportunity to show how the cross-sectional audits relate to safety across the full spectrum of a home build. Repeated audits at a single build would allow comparisons of safety results at different time points. We were unable to interview all workers at the observed sites. Many of the limitations of our study were due to the barriers encountered when performing field-based research with residential construction workers.

We saw many opportunities to decrease fall risks and improve worker behaviors through use of fall arrest equipment and building technologies, training to increase worker awareness of fall risks, contractor required practices to address these risks, and enforcement of existing company safety policies and federal guidelines. Some of these interventions can be delivered through apprenticeship classroom training; however, others must be administered at the work site. It is the contractors' responsibility to inform all workers of their fall prevention plan and ensure that appropriate equipment and materials are provided. We are especially concerned about apprentice carpenters. Inexperienced workers in our sample were less likely to know their employers' fall prevention plan and did not participate in more on-the-job safety training sessions than experienced workers, suggesting that apprentices are not receiving enough training and role modeling to formulate an effective safety attitude early in their careers. Since inexperienced workers sustain more work injuries than experienced workers [Salminen, 1994], it is especially important for apprentices to understand their contractors' fall prevention plan and receive explicit mentorship in methods to implement this plan with both routine and non-routine tasks.

Our work suggests that worker safety during truss installation must be improved. Truss installation methods outlined in OSHA's residential guidelines were rarely used at sites we visited, possibly due to difficulty interpreting these guidelines or the time required to use these work practices. Methods and equipment to install roof trusses that are safe and efficient must be identified and put into widespread practice. Worker safety around unprotected floor openings and edges is another area, which needs to be addressed. Workers were not consistently monitored or alerted to their proximity to these unprotected floor openings. Methods described in OSHA's residential guidelines should be implemented and enforced, or alternative methods identified to ensure worker safety around unprotected floor openings. A campaign to increase construction professionals' and contractors' awareness and understanding of the residential guidelines may be warranted, including widespread dissemination, training, and application of these guidelines at the worksite.

We found that many measures of the safety climate measured by the audit and interview correlated closely, suggesting that the safety climate at the worksite drives the fall safety of the workers. Since construction managers, such as foremen, superintendents, and owners, have been found to be instrumental in defining and implementing safety practices and providing role modeling for their work crews [Gillen et al., 2004, 2004], interventions to affect managers may be a likely place to implement changes to improve the safety climate.

Our team will use these findings to prioritize intervention efforts to construction phases and equipment that are consistently used in an unsafe manner at the worksite. We plan to use the SAFR as an outcome measure to determine the effect of our educational intervention on the fall safety behaviors of construction workers. Since falls account for most of the construction worker deaths in residential framing, it is important to identify the prevalence of risky behaviors and unsafe working conditions in these environments, and design interventions to decrease worker exposure and ultimately decrease falls from elevated work surfaces.

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