Is Renovation Riskier Than New Construction? An Observational Comparison of Risk Factors for Stepladder-Related Falls

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Background *Stepladder-related injuries at construction sites have increased in recent years. We aimed to quantify the prevalence of stepladder-related fall hazards in general construction and to compare the risks on renovation worksites to new construction build sites.*
Methods *Eighteen worksites were visited, resulting in the observation of 771 stepladders. Eight of the sites were new builds and ten were renovation projects.*
Results *High compliance with best practices was not observed for several factors, including having hands free while climbing (46%) and using minimum forces (72%). There was a notable trend toward more hazards on renovation build projects than on new construction sites; however, these differences were not statistically significant.*
Conclusions *There was not sufficient evidence to show that stepladder fall hazards are more prevalent on renovation projects than on new build projects. Having hands free while climbing and using minimum forces were two practices needing more wide-scale adoption regardless of construction job type.* Am. J. Ind. Med. 54:579–585, 2011. *© 2011 Wiley-Liss, Inc.*

KEY WORDS: construction; safety; ladders; cluster analysis; occupational epidemiology

INTRODUCTION

Construction leads the American private industry sector in number of fatalities. The number of deaths in general construction increased by 11% in 2007 relative to 2006 [Bureau of Labor Statistics, 2009a]. Falls, a leading cause of fatalities, have increased in incidence by 39% since the inception of the Census of Fatal Occupational Injuries in 1992 [Bureau of Labor Statistics, 2008]. While fatality rates due to falls in construction declined 20% in 2008, the decline resulted from reduced workforce and fewer hours worked rather than a broad adoption of safer work practices [Bureau of Labor Statistics, 2008]. Ladders, specifically, accounted for 32% of fatal construction falls in 2008 [Bureau of Labor Statistics, 2009b]. Additionally, 24.2% of non-fatal occupational falls in 2005 were from ladders [CPWR, 2008]. Non-fatal ladder fall injuries commonly cause a fracture of the extremities that can result in over $5,000 in direct medical costs per case [Partridge et al., 1998; Smith et al., 2006]. Thus, ladders pose a significant safety risk to construction workers.

The recent economic recession has disproportionately affected the construction industry. Decreases in cash flow and credit availability have diminished the number of new

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Cooperative Agreement Sponsor: CPWR The Center for Construction Research and Training, Cooperative agreement sponsor number: U54 0H008307.
Contract grant sponsor: NIOSH Training Grant; Contract grant number: T42 0H008416.
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Accepted 17 March 2011
DOI 10.1002/ajim.20956. Published online 22 April 2011 in Wiley Online Library (wileyonlinelibrary.com).

construction projects. Accordingly, the sector has needed to focus more on renovation projects as a leading revenue source [Bureau of Labor Statistics, 2010]. These projects may have smaller working environments with hard-to-reach tasks, causing workers to set up stepladders in cluttered areas and contort themselves to reach work areas at height. These features of renovation projects may cause stepladder setups and worker behavior while using them to be more hazardous than on new construction builds.

Although preventable, ladder falls remain a major contributor to the burden of injury and mortality in the United States. To assess possible targets for intervention, this study assessed the prevalence of several types of working at height tools (ladders, lifts, scaffolding, etc.) and stepladder-related fall hazards in general construction, with specific attention at comparing renovation projects to new build projects. Stepladder condition, setup, workers' movements, and completion of tasks are thought to contribute to an unsafe environment; therefore, these categories were studied independently as specific outcomes of interest for comparison across worksites [Cohen and Lin, 1991a; Björnstig and Johnsson, 1992; ANSI, 2000; Dennerlein et al., 2008].

MATERIALS AND METHODS

Site Visits

Stepladders and ladder alternatives (e.g., portable scaffolding, lifts, etc.) were observed at construction sites in Massachusetts from October to December 2007. This equipment was observed at 18 different sites, selected by convenience sampling, encompassing eight general construction companies. A partnership with the Associated General Contractors (AGC) of Massachusetts allowed access to their network of general contractors. The general contractors may be considered construction management firms in that they oversaw the build, but subcontracted the work. Company safety managers were recruited at AGC meetings. If a company had at least two ongoing sites with ladder usage, and were willing to participate, their sites were included in the study. A site was considered a renovation if the main structure of the building was pre-existing; this information was provided by a company representative. Each company contributed two or three sites, but not necessarily one of each site type.

In the field, the researchers were either accompanied by a safety manager, superintendent, or company engineer, or were unaccompanied. All observed equipment was scored for compliance with generally accepted best practices using an established assessment tool with known reliability [Dennerlein et al., 2008]. Questions compiled from standards and guidelines, and reviewed with safety professionals and researchers, denoted best practices. See Dennerlein et al. [2008] for a complete description of the tool, its development, and validation. The assessment tool was implemented on a hand-held computer. The two researchers that conducted the field investigations were trained through an interactive training session and were provided with a user manual. The user manual described the questions in detail, providing explanations and relevant definitions for each of the questions. The interactive training program consisted of a discussion-based class that included group exercises where the attendees practiced applying the tool.

The tool assessed four categories of stepladder safety: condition (i.e., structural soundness), setup, climbing, and work being performed. Each category was made up of questions relating to best practices, and each question had a possible response of yes, no, or unknown. A response of "no" denoted a fall hazard. For example, when a researcher observed a worker climbing down a stepladder, the researcher answered the set of questions in the climbing, setup, and condition categories. Non-compliance with any best practice question resulted in a "no" input. The set of questions on working from the stepladder was skipped, because the worker did not complete any task while being observed on the stepladder. Workers on or near stepladders were observed for a few minutes to determine their stepladder use practices.

Statistical Analyses

The data were stratified into the four categories of stepladder safety: condition, setup, movements, and completion of tasks at height. The first two categories were based on observations of stepladders. The latter two categories of stepladder safety were observations of workers on stepladders. The number of "no" responses to the questions within these categories was used to demonstrate the hazard level of a site. The count of hazards observed in the four categories of stepladder safety was used as the outcome to compare renovation projects to new build projects.

The count data followed a Poisson distribution, and to first compare the site types, standard Poisson regression was used. Poisson regression models were fit for each stepladder safety category. Incident rate ratios (β) of stepladder-related fall hazards on renovations relative to new builds were approximated using maximum likelihood estimation.

This modeling approach may not be appropriate because observations may be correlated within companies and worksites. For example, hazard counts on Company A's first site may be more similar to the other Company A site than to sites of the other companies. The companies' hiring policies and safety programs may affect hazard prevalence rates differentially. Similarly, each site may provide its own constraints related to supervisors, site safety presence, owner mandates, and various other attributes that could lead to some hazards being more or less common than at other sites. Consequently, the observed data ought not be assumed independent. Correlation of the data within the levels such as worksite and company is known as clustering [Fitzmaurice et al., 2004].

To address the potential clustering limitations from using standard Poisson regression in this instance, random-intercept multilevel Poisson regression was used. Random intercepts allow the intercept to vary by observation. This fluctuation accounts for the unmeasured individual characteristics of—depending on the category—a ladder or worker [Rabe-Hesketh and Skrondal, 2008]. The inclusion of random effects accounted for the intra-cluster correlations [Fitzmaurice et al., 2004; Rabe-Hesketh and Skrondal, 2008]. These random effects are assumed to be normally distributed [Stata, 2010a]. In this case, the random effects of company and worksite levels were estimated to better describe the fixed effects of stepladder observations for the quality and setup categories. Fixed effects of worker observations were estimated for the climbing and working-from-stepladder categories.

To test whether the company and worksite levels should be included in the final model, random effects models for worksite and company levels were individually tested against the standard Poisson model for each category of stepladder safety. The worksite level was first added to each category model. A likelihood ratio test (LRT) was used to compare the multilevel model to the standard Poisson model. The LRT determined if the multilevel model was a better fit of the data than the standard Poisson model. If the *P*-value of the LRT was less than 0.05, worksite random effects were kept in the model. The same procedure was used to test if company level random effects should be kept in the category-specific models.

Individual best practice questions within each category were also analyzed to compare potential differences between new builds and renovation projects. The dichotomous yes/no responses for each question were used as the outcome variable in standard and multilevel logistic regression models. In multilevel logistic regression, the random effects are assumed normally distributed [Stata, 2010b]. In a similar manner to the stepladder safety category comparisons, LRTs were used to compare question-specific multilevel logistic models to the standard logistic regression best-practice-specific models. The final model estimated the odds ratios of stepladder-related fall hazards on renovation projects relative to new builds.

For both multilevel Poisson and logistic regression, coefficients were estimated through maximizing the respective likelihood functions. Using the resulting beta coefficients and covariance matrix, confidence intervals were calculated. Multilevel regression analyses were conducted using Stata 11 software. Other analyses, such as frequency calculations, were conducted using SAS software (9.2, SAS Institute, Inc, Cary, NC).

RESULTS

The types of facilities being constructed as well as phases of each build varied; 10 were renovations of existing structures, 8 were brand new sites. Facilities included residential apartment complexes, office buildings, and many others typical to general construction. Most build sites had extensive stepladder usage, but one, in particular, was in the excavation stage and did not use many stepladders ($n = 5$). Overall, 1,148 devices were observed and scored. Sixty-seven (67%) percent ($n = 771$) were stepladders, 4.5% (50) were extension ladders, 2.5% (28) were job-made ladders, and 1 ladder jack was observed. The remaining 26% were ladder alternatives; 167 portable scaffolds (including bakers), 68 scissor lifts, 37 aerial buckets, and 26 scaffolding setups were observed. There were 92 portable scaffolds at the new builds and 74 at the renovation worksites. The new builds had 51 scissor lifts on site while there were only 17 observed at renovations. The most prevalent extension ladder length was 24ft (32%). Forty-four percent of stepladders were 6ft in length, 28% were 8ft in length, and 12% were 10ft long.

Overall, stepladder quality was satisfactory with almost all stepladders being rated Type I (96.4%) and free of defects (95.6%; Table I). The majority of the set up stepladders were done in compliance with best practices (Table I). Most were placed on a flat, stable surface (91%). Spreaders were locked on 94% of observed setups. However, there was a significant proportion of stepladders in which the bottoms were not clear of tripping hazards (12.5%). Most of the risks related to moving on a stepladder were not high in prevalence (Table I), although some exceptions were observed. Only 72.2% of workers maintained three points of contact (e.g., two hands and one foot on the ladder rungs, or two feet and one hand), and 46.4% kept hands free while climbing up and down the stepladders. Similarly, the observed prevalence of hazards for workers completing tasks on stepladders demonstrated a lack of compliance with some best practices (Table I). Only 69.4% of the workers faced the ladder and 71.9% used minimum forces. A moderate percentage (11.9%) of the stepladders were not tall enough to allow workers to safely reach the job task. Finally, the ‘‘belt buckle rule,’’ meaning the worker is not supposed to lean outside the horizontal support of the ladder, was not followed in 13.8% of the observations.

TABLE I. Prevalence of Hazards [% (n)] Related to the Quality of Stepladders (n = 771), Their Setup, and Use

	% (n)		
Best practice	**Yes[a]**	**No[b]**	**Unknown**
Stepladder condition			
Rated Type I	96.4 (744)	1.0 (8)	2.6 (20)
Free of defects	95.6 (738)	3.6 (28)	0.8 (6)
Has labels	84.3 (651)	14.7 (113)	1.0 (8)
Stepladder setup			
Clear of electrical hazards	98.8 (396)	0.7 (3)	0.5 (2)
Clean and dry	95.5 (383)	3.5 (14)	1.0 (4)
Spreaders were locked	94.0 (377)	5.3 (21)	0.7 (3)
On a flat/stable surface	91.0 (365)	9.0 (36)	0.0 (0)
Bottom clear of trip hazards	87.0 (349)	12.5 (50)	0.5 (2)
Climbing a stepladder			
One person on the ladder	99.3 (139)	0.7 (1)	0.0 (0)
Gets on/off the bottom of the ladder only	96.4 (135)	3.6 (5)	0.0 (0)
Stays off the top two steps	94.3 (132)	5.7 (8)	0.0 (0)
Keeps center of mass within ladder's support	94.3 (132)	5.7 (8)	0.0 (0)
Moves slowly	87.1 (122)	12.9 (18)	0.0 (0)
Faces the ladder	86.4 (121)	13.6 (19)	0.0 (0)
Checks stability of setup and ladder before climbing	80.0 (112)	12.1 (17)	7.9 (11)
Maintains three points of contact	72.2 (101)	27.1 (38)	0.7 (1)
Hands are free of objects while climbing	46.4 (65)	51.4 (72)	2.2 (3)
Working from a stepladder			
One person on the ladder	99.4 (159)	0.6 (1)	0.0 (0)
Is holding only one tool	97.5 (156)	1.9 (3)	0.6 (1)
Stays off the top two steps	91.3 (146)	8.8 (14)	0.0 (0)
Ladder is the proper length for the task	88.1 (141)	11.9 (19)	0.0 (0)
Keeps center of mass within ladder's support	86.3 (138)	13.8 (22)	0.0 (0)
Uses minimum forces	71.9 (115)	22.5 (36)	5.6 (9)
Faces the ladder	69.4 (111)	30.6 (49)	0.0 (0)

[a]"Yes" denotes compliance with the best practice.
[b]"No" relates to non-compliance with the best practice.

When stepladders on renovation worksites were compared to those on new builds, no significant differences were observed (Tables II and III). Category-specific comparisons demonstrated a general trend of more hazards being observed on renovation sites (Table II). For example, taking worksite random effects into account, stepladders were 53% more likely to have a higher condition score on the sites undergoing a renovation compared to the new builds, however this was not statistically significant. Similarly, question-specific comparisons consistently estimated odds ratios to be greater than one (Table III). The set of questions on setup, including not having spreaders locked, unstable surface, and tripping hazards, all indicated a trend toward higher hazard prevalence on renovation worksites than on new builds.

DISCUSSION

Our main goal was to compare the prevalence of stepladder-related fall hazards on renovation build sites to new build sites in the general construction environment. The results from the category-specific Poisson regression incidence rate ratios demonstrated that there were not statistically significant differences between renovation worksites and new worksites. Although not significant, the trend consistently showed renovations to have more hazards. Similarly, upon comparing specific best practices, results were not significant, but trended toward the renovations having lower compliance with best practices.

It was hypothesized that workers on renovation projects would set up stepladders in cluttered areas and contort themselves to reach work areas at height because

TABLE II. Comparison of Stepladder Hazards on Renovation Worksites to New Construction Sites (Reference Group) in Four Categories of Stepladder Safety

Category	IRR[a]	*P*-Value	95%CI
Stepladder condition[b]	1.53	0.09	0.94, 2.50
Stepladder setup[c]	1.67	0.14	0.84, 3.32
Climbing a stepladder[c]	1.57	0.18	0.81, 3.05
Working from a stepladder[c]	1.13	0.71	0.60, 2.11

[a]Incident rate ratio (IRR) of hazards on renovation worksites relative to new build worksites.
[b]Multilevel Poisson regression model included worksite level random effects.
[c]Multilevel Poisson regression model included worksite level and company level random effects.

of the greater potential for the renovation projects to have smaller working environments with hard-to-reach areas. These features of renovation projects were hypothesized to result in stepladder setups and worker behavior while using them to be more hazardous relative to new construction projects. Specifically, we expected to observe differences between the worksite types for the ‘‘bottom clear of tripping hazards,’’ ‘‘faces the ladder,’’ and ‘‘keeps center

TABLE III. Comparison of Stepladder Hazards on Renovation Worksites to New Construction Sites (Reference Group)

Best practice	OR	*P*-Value	95%CI
Stepladder condition ($n = 771$)			
Rated Type I	—		
Free of defects[a]	3.16	0.07	0.92, 10.9
Has labels[b]	1.08	0.70	0.72, 1.62
Stepladder setup ($n = 401$)			
Clear of electrical hazards	—		
Clean and dry[a]	0.42	0.34	0.07, 2.51
Spreaders were locked[b]	1.87	0.17	0.77, 4.55
On a flat/stable surface[b]	1.40	0.34	0.71, 2.78
Bottom clear of trip hazards[c]	2.58	0.17	0.67, 9.92
Climbing on a stepladder ($n = 140$)			
One person	—		
Gets on/off the bottom of the ladder only[b]	0.52	0.48	0.084, 3.20
Stays off the top two steps[b]	0.78	0.74	0.19, 3.27
Keeps center of mass within ladder's support[b]	0.78	0.74	0.19, 3.27
Moves slowly[c]	2.63	0.30	0.42, 16.4
Faces the ladder[c]	1.41	0.75	0.16, 12.2
Checks stability of setup and ladder before climbing[b]	1.16	0.78	0.41, 3.23
Maintains three points of contact[c]	1.62	0.62	0.36, 7.31
Hands are free of objects while climbing[b]	1.40	0.33	0.72, 2.73
Working from a stepladder ($n = 160$)			
One person on the ladder	—		
Is holding only one tool[b]	0.43	0.50	0.039, 4.89
Stays off the top two steps[b]	2.37	0.16	0.71, 7.89
Keeps center of mass within ladder's support[c]	1.40	0.69	0.26, 7.51
Ladder is the proper length for the task[c]	2.42	0.40	0.31, 18.6
Uses minimum forces[b]	0.98	0.96	0.47, 2.07
Faces the ladder[a]	1.08	0.89	0.38, 3.07

[a]Multilevel logistic regression model included worksite level random effects.
[b]Standard logistic regression did not include any random effects.
[c]Multilevel logistic regression model included worksite level and company level random effects.

of mass within ladder's support'' best practices. However, non-compliance with these best practices on the observed construction sites was not found to be statistically significant. There was a trend that renovation worksites had a greater rate of non-compliance with these best-practice questions, but the associated confidence intervals were quite large. For example, the odds of a worker on a renovation worksite not keeping their center of mass within the ladder's support while working from a stepladder was 40% higher than the odds of a worker on a new build worksite (95%CI: 0.26, 7.51).

For the overall prevalence of stepladder-related fall hazards on the eighteen sites, the condition and setup of ladders were typically satisfactory; however, workers' movements and completion of tasks on stepladders illustrated where hazards were often present. It is important to keep in mind that prevalence may not equal risk. Tripping hazards at the bottom of a stepladder, for example, may pose greater risk to workers than not having hands free while climbing up and down a stepladder; even though the former is less common.

The lack of significant difference between new construction and renovation sites may be real, but may be attributable to limitations in our methods. Misclassification of build type could explain the lack of difference in that the definition of renovation may have been too broad. As new builds progress, they begin to take on characteristics of a renovation. For example, when sheetrock walling has been installed, but HVAC, pipefitting, and electrical work are still ongoing at a new build, the work environment is likely small, crowded, and may have material cluttering the ground. There may be few differences in hazards at new build sites with these attributes compared to renovation projects. For this study, a narrower definition of site type may have better represented the true distinctions between site types. Classifying sites by work environment size, stage, and other constraints may have yielded clearer results. Using a narrower definition was not attempted due to sample size limitations. Incorporating more companies and sites into the study may have helped increase power through greater sample and cluster sizes, and may add more precision to the effect estimates.

Several attempts were made to minimize the influence of observers on the workers, commonly known as the Hawthorne Effect [Wickström and Bendix, 2000]. To the best of our knowledge, site visits were not announced to workers in advance, although regional union officials approved the overall timeline in advance of the project and knew during what month the observations would be conducted. In several instances workers seemed to believe the observers were engineers. The site walk-throughs were either solo or accompanied by a safety manager (site-specific or regional), engineer, or by the superintendent. The majority of sites did not have a site-specific safety manager. When the regional manager was on site and accompanying the research team, work behavior may have changed in response to our presence. This observational influence would likely result in underestimates in the overall prevalence of stepladder hazards and overestimates of best practices; however, these effects would likely be similar by build type and not systematically vary between new build and renovation worksites.

Planning of a construction project is a complex and intensive job with general contractors overseeing the construction, but subcontracting the work to multiple vendors. The general contractors in our study hired numerous companies to do the plumbing, ironwork, electrical work, and several other specialty jobs. Almost all the observed workers were subcontractors and members of a trade union. Most of the general contractors did employ some laborers that kept the site relatively clean for safety purposes and commonly built guardrails and job-made ladders. These laborers were most likely not observed on stepladders.

Each site was in a unique phase of construction that led to different working environments and uses of stepladders and ladder alternatives between sites and companies. Stepladders were found in greatest proportion relative to others tools used to reach height. Yet, as subcontractors typically provide their own ladders and other safety equipment, many stepladders were being stored on site and were tied to a pillar or stacked on the ground. Regardless, because ladders were on site, there was the opportunity for use. In contrast, in some instances, a single working area with a few workers had numerous stepladder setups to allow easy access for a multi-area task, such as pulling cables. In these scenarios, we observed several workers using these ladders. As a result, many setups were not being climbed or worked on when they were observed and scored. Also, the observations were conducted so that worker's movements and working behaviors while on a stepladder were scored once. If he or she moved several times or worked on various stepladders, a single score was assigned to the movement or work, respectively.

The prevalent hazards observed on our site assessments may further explain and be supported by the results others have found while studying ladder falls. Lombardi et al. [unpublished work], found that, of occupational ladder falls resulting in emergency room visits, 50.3% of workers fell while performing standing work directly from ladders, 27.8% were climbing down ladders, and 11.4% were climbing up ladders [Lombardi et al., unpublished work]. Risks associated with these tasks, such as not having hands free, not maintaining three points of contact, and not facing the ladder, limit a worker's ability to stabilize themselves. Similarly, Cohen and Lin concluded that over-reaching was the most common cause of occupational ladder falls [Cohen and Lin, 1991a]. Not facing the ladder and not following the belt buckle rule can sometimes be classified as over-reaching and should therefore be targeted during site inspections and training. Furthermore, Axelsson and Carter [1995] found that ladders tipping sideways resulted in the most falls in construction falls attributable to portable ladders. Not using minimum forces and not following the belt buckle rule may lead to the unbalancing of ladders. Poor setups may also lead to ladders tipping. The prevalent hazards found on our site assessments may be associated with the incidences Lombardi et al. [unpublished work], Cohen and Lin [1991a], and Axelsson and Carter [1995] studied. Interventions may be more effective if targeting these hazards.

The inventory of equipment demonstrates that several alternatives to stepladders are readily available on construction sites. Portable scaffolding, scissor lifts, and other types of lifts were common and may be safer than ladders [Cohen and Lin, 1991b]. Many of the most prevalent hazards, such as climbing without hands free and not facing the stepladder, may be mitigated with the use of such devices. These ladder alternatives were seen less often at renovation sites than new builds. This disparity is potentially due to constraints in the work environment such as smaller rooms and passageways. Further, indoor lift use requires the flooring to be capable of handling the weight of such lifts. Cost may also be an issue with renovation projects, as they typically have smaller budgets than new builds. Proper planning of project flow and progress may make these tools available for trades, such as electricians, that are more apt to use ladders. Still, ladder alternatives pose their own fall risks to workers [Rivara and Thompson, 2000]. These risks should be considered and preventative measures taken.

Our assessments of 18 general construction sites show that most sites had stepladders of good quality and setups were regularly safe. However, full compliance with best practices was not seen for several factors, including having hands free while climbing, facing the ladder, maintaining three points of contact, and using minimum forces while working from stepladders. Interventions targeting these behaviors may better prevent injuries in the general construction environment. No significant differences in stepladder-related fall risks were found between renovation projects and new builds.

ACKNOWLEDGMENTS

The authors thank Dave Powell and Chris Ziegler of the Associated General Contractors of Massachusetts for their support and vital assistance; Jason Edic of Harvard University, Christopher Brunette of the Liberty Mutual Research Institute, and Jae Young Kim of the Harvard School of Public Health for their expertise; and the contractors who participated and gave needed input during the study design period.

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