Original article

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Work-related falls from ladders – a follow-back study of US emergency department cases

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Objectives Ladder falls comprise 16% of all US workplace fall-related fatalities, and ladder use may be particularly hazardous among older workers. This follow-back study of injured workers from a nationally representative sample of US emergency departments (ED) focused on factors related to ladder falls in three domains of the work environment: work equipment, work practices, and worker-related factors. Risk factors for fractures, the most frequent and severe outcome, were also evaluated.

Methods Workers injured from a ladder fall, treated in one of the 65 participating ED in the occupational National Electronic Injury Surveillance System (NEISS) were asked to participate. The questionnaire included worker demographics, injury, ladder and work equipment and environment characteristics, work tasks, and activities. Multivariate logistic regression models estimated odds ratios and 95% confidence intervals of a work-related fracture.

Results Three-hundred and six workers experiencing an injury from an – on average – 7.5-foot-fall from a step, extension, or straight ladder were interviewed primarily from construction, installation, maintenance, and repair professions. Injuries were most frequently to the arm, elbow or shoulder; head, neck, or face with diagnoses were primarily fracture, strain, sprain, contusion or abrasion. Workers were most frequently standing or sitting on the ladder while installing, hanging an item, or performing a repair when they fell. Ladder movement was the mechanism in 40% of falls. Environmental conditions played a role in <10% of cases. There was a significant association between fracture risk and fall height while working on the ladder that was also influenced by older work age.

Conclusions This study advances knowledge of falls from ladders to support those who specify means and methods, select equipment, and plan, supervise, or manage the performance of employees working at heights.

Key terms construction; epidemiology; fracture; injury; safety.

According to data published by the Center for Construction Research and Training (CPWR), more than 20 000 US workers are injured each year from ladder falls (1). However, when both occupational and non-occupational falls are combined, the burden of ladder related-injuries is much greater. A study of all ladder falls in the US over a 16-year period, resulting in a visit to the emergency department (ED) (2), estimated 136 118 ladder falls annually (4.95 falls per 10 000 persons) with the frequency of occurrence increasing by more than 50% from 1990 to 2005. Regarding the disability from these falls, one study of ED-treated ladder-fall injuries (3) reported that a majority led to lost workdays (68%) with an average duration of disability of 24 days, while another (4) reported that 18% of all ladder falls required hospital admission with a median hospital stay of one week and duration of disability and unemployment of six weeks. Ladder falls are also estimated to comprise 16% of all workplace fall-related fatalities (5, 6). In the US labor force in 2004, there were 133 fatal ladder-related falls (7).

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As the US population and associated workforce continues to shift to an older age distribution, prevention of ladder falls is emerging as a workplace safety priority (6, 8, 9). A study by Diggs et al (8) reported that 47% of all patients hospitalized for a ladder fall (work and non-work) were >55 years of age, compared to only 16% of patients who fell from other structures (eg, building, window etc) or scaffolding. Another study of 9826 ladder-fall injuries over a one year period (1.8% of all injury claims) from workers' compensation claims (9), reported that 7% of all cases resulted in fractures while workers aged ≥45 were at greater risk of fractures than other injuries. In a study that evaluated the impact of age on the relative risk of mortality from work-related ladder falls relative to other types of occupational injuries in the US (6), risks for falls for older workers were much greater for ladders when compared to other fatal injuries, including other falls from elevation.

Falls in industries such as construction are most common (10); these workers accounted for an estimated 37% of all fatalities due to falls in the US in 2007. In a study of union carpenters, ladders were involved in 21% of all falls from heights (11, 12). Working on ladders has also been shown to be hazardous in agricultural work; a study of Washington state orchard workers' compensation claims reported ladders to be the highest incidence among all causes of injury [30/1000 fulltime equivalent (FTE) years], accounting for 31% of all injuries (13).

Despite the potential for a broad range of adverse outcomes resulting from a ladder fall, there are few peer-reviewed published studies describing the activities, mechanisms, tasks, and conditions surrounding ladder falls. There have also been a limited number of studies on ladder safety in the safety engineering literature; however, most focus on straight, portable ladders (14, 15, 16). Although Häkkinen and colleagues (16) reported that straight ladders were involved in 70% of the most serious work-related ladder injuries, and sliding at the base was the most common (50%) preceding event for an injury, the circumstances and relative contribution of straight versus step ladder falls remain unclear.

This follow-back study was conducted to identify the proximal factors (work environment, equipment, and worker-related) among injured workers who fell from a ladder and were treated in a nationally representative sample of US ED. Secondarily, we evaluated the risk factors for the most frequent and severe outcome from these ladder falls (fractures) as a function of several variables collected during the interview. The risk of fracture was evaluated as a function of work environment, equipment, and worker-related factors.

Methods

Interview

Ladder fall injury cases for this study were identified and recruited through the National Electronic Injury Surveillance System (NEISS). NEISS is a stratified random sample of all ED visits in the USA and provides a representative sample of all injuries treated therein (17). Persons who were injured at work and later visited one of the 65 participating ED in the occupational NEISS sample were included in the sampling for this study. The Liberty Mutual Research Institute for Safety and the Harvard School of Public Health Human Subjects Committees reviewed and approved the study.

Case definition

Cases in this study were defined as persons injured at work due specifically to a fall from a ladder. Other ladder-related injuries such as those from carrying, lifting, or being struck by a ladder were excluded. NEISS has developed approaches for identifying specific cases such as ladder falls, however, the primary ED records do not identify the occupation and industry or address the exact type of ladder involved. Thus, an inclusive approach was utilized to collect occupational cases where the industry and occupation were ascertained from participants during the case interview phase.

Questionnaire design

To understand the potential exposures for ladder falls prior to designing the study questionnaire, we conducted an analysis of workers compensation claims identifying ladder fall scenarios from a review of coded data and free text narratives (9). These scenarios provided insights into the likely common tasks and activities involved in falls from ladders. An expert panel was then convened that included noted ladder experts and industry representatives to review the research priorities for the study. The primary areas of discussion included mechanical ladder, human factor, and worksite issues. Finally, three separate focus groups were conducted with 5–7 construction workers who frequently worked with ladders to understand the common scenarios and worker-related factors that may precipitate a ladder fall and to pilot test the questionnaire (including cognitive interviews) to evaluate if the questions would capture the desired information. Participants for these sessions were identified in cooperation with the Associated General Contractors of Massachusetts. The final questionnaire contained 167 items (including branching) and included sections on worker demographics, injury characteristics, ladder and work equipment characteristics, work tasks and activities, and attributes of the work environment.

Participant interviews

The use of the NEISS enabled the opportunity for follow-back interviews of injured persons relatively soon after the injury had occurred. The procedures from the NEISS were originally designed for the Consumer Product Safety Commission (CPSC) to do in-depth interviews to follow up on specific product-related injuries that are the target of their current investigations. This system was further developed by the National Institute for Occupational Safety and Health (NIOSH) and CPSC to collect information on occupational injuries treated in their sample of ED.

Cases of ladder falls at work were identified from the occupational injury component of NEISS. At the end of each day, cases from participating ED meeting the inclusion/exclusion criteria were sent to the CPSC. Cases meeting the criteria were enrolled over a 27-month period from September 2006 through October 2008, and individuals were interviewed via structured phone interview that lasted approximately 20–25 minutes. To minimize error due to recall, the goal was to interview cases for follow up by telephone as soon as possible after their injury. CPSC has an ongoing arrangement with the participating ED to conduct follow-back interviews and is a Health Insurance Portability and Accountability Action (HIPAA) covered entity. Injury diagnosis and body part were coded to NEISS 2-digit coding definitions using the attending physician's diagnosis to determine the nature of an injury.

Once a case meeting the selection criteria was identified by CPSC, the contact tracing information was sent to the trained interviewers under contract to CPSC who then contacted the patient directly to conduct the interview. As part of our data monitoring, any unusual delays in interview time were reported back to CPSC. NIOSH has had previous success in completing follow-back telephone interviews of occupational injury cases identified through the NEISS, for example in describing work-related exposures to blood-borne pathogens (18) and obtaining descriptive data on injuries to older workers (19). The NEISS is also an important component of the NIOSH national occupational injury surveillance program.

Data analysis

Descriptive statistics [eg, frequencies, column percentages, means, and standard error of the mean (SEM)] were calculated for all demographic, occupational, and injury related variables (eg, age, body part) by type of ladder. Frequencies and percentages are presented for the variables related to the activity, source, and mechanism of the ladder fall.

Unconditional multivariate logistic-regression models were used to estimate odds ratios (OR) and the associated 95% confidence intervals (95% CI) of a work-related fracture (binomial variable) as a function of the type of ladder being used, the reported height of the worker at the time of the fall, the task and stage of ladder work at the time, the ladder surface and setup, age, gender, and body mass index. To determine those factors with independent predictive value, the final multivariate model declares statistical significance at a level of 0.05. Interactions were also evaluated for several pairs of variables (eg, ladder type and height) using a hierarchically well-formulated logistic regression model (20) approach that includes both lower order terms of the two-way higher order interaction. All analyzes were performed using the SAS system version 9.1 (SAS Institute, Inc, Cary, NC, USA).

Results

Worker characteristics

Of those who reported to one of the ED in the NEISS sample, 306 workers with a ladder-fall injury were professionally interviewed over a 27-month period (August 2006 through October 2008) with a median lag time between injury and interview of 34 days. The 306 workers accounted for 49.3% (of 629) of all potential cases that were contacted for a telephone interview. There were 319 refusals to participate. The average age of the workers was 38.8 years (SEM 0.8) and 86.0% were male; approximately 12% were ≥55 years of age (see supplemental table A, www.sjweh.fi/data_repository.php). With respect to race/ethnicity, 71.5% were caucasian, 11.1% were hispanic, and 9.2% were black. The majority (85.1%) of workers had a high school, technical school or higher level of education. Occupations were diverse with the three most common occupational groups of injured workers in this study being construction (39.7%); installation, maintenance, and repair (20.7%); and sales and related fields (10.0%). With regards to job characteristics and ladder type (see supplemental table B www.sjweh.fi/data_repository.php), of the 306 ladder falls, 51.0% (N=156) occurred when using step or trestle ladders, 40.2% (N=123) when using extension or straight ladders, and 8.8% (N=27) while using other ladder types (eg, rolling). Fifty-percent of the workers had <3 years of job experience; however 30.9% had >10 years. Company sizes were often small with <25 employees (50.2%) and mostly non-unionized workers (85.0%).

Injury characteristics

The body part(s) injured from the ladder fall were distributed across the body; however among all ladder falls, most frequently injured (see supplemental table

C, www.sjweh.fi/data_repository.php) were the arm, elbow, or shoulder (21.6%), followed by the head, neck, or face (17.1%), lower trunk (13.8%), ankle, foot, or toe (12.8%), leg or knee (12.5%), wrist, hand or finger (11.2%) and the upper trunk (10.5%). This distribution was generally consistent across ladder types; however head, neck or face and lower trunk injuries were more frequent among those falling from step/trestle ladders than extension/straight ladders. Injury diagnoses were also broadly distributed across fractures (28.4%), followed by strains or sprains (26.1%), and contusions or abrasions (23.5%), and were generally consistent across ladder types.

Ladder conditions

With regards to their characteristics (see table 1), ladders were constructed primarily from aluminum or metal (55.9%), followed by fiberglass (34.6%) and wood (9.5%). The mean and median fall height among all injured cases was 7.5 (SEM 0.33) and 6.0 feet, respectively – however, 5% of injured cases fell from heights >20 feet. When heights were categorized, 35.3% of falls were ≤4 feet, 35.7% from 5–9 feet, and 29.0% from heights ≥10 feet. The greatest proportion of falls from the highest levels (eg, ≥10 feet) occurred when using extension or straight ladders (57.0%). With respect to the environmental conditions on and or around the ladder at the time of the fall, most frequently, the ladder was neither wet nor slippery (92%), the ladder was stable (92.7%) and on a level (93.3%) and hard supporting base (96.7%). These self-reported conditions varied little by ladder type.

Table 1. Ladder characteristics and conditions. [SEM=standard error of the mean.]

Characteristic or condition	Step/trestle (N=156)		Extension/ straight (N=123)		Rolling/ wheeled (N=27)		Total (N=306)	
	N	%	N	%	N	%	N	%
Material								
Aluminum/metal	80	51.28	71	57.72	20	74.07	171	55.88
Fiberglass	65	41.67	40	32.52	1	3.70	106	34.64
Wood	11	7.05	12	9.76	6	22.22	29	9.48
Fall height [a]								
≤4 feet	76	49.67	19	15.57	11	44.00	106	35.33
5–9 feet	66	43.14	34	27.87	7	28.00	107	35.67
≥10 feet	11	7.19	69	56.96	7	28.00	87	29.00
Wetness								
Wet	9	5.81	13	10.66	2	7.41	24	7.89
Dry	146	94.19	109	89.34	25	92.59	280	92.11
Slipperiness								
Slippery	10	6.45	12	9.84	1	3.70	23	7.57
Not slippery	145	93.55	110	90.16	26	96.30	281	92.43
Stability								
Stable	145	93.55	112	92.56	23	88.46	280	92.72
Unstable	10	6.45	9	7.44	3	11.54	22	7.28
Supporting base								
Hard	152	98.7	114	94.21	24	96.00	290	96.67
Soft or not hard	2	1.30	7	5.79	1	4.00	10	3.33
Base support								
Level	144	93.51	110	91.67	25	100	279	93.31
Not level	10	6.49	10	8.33	0	0.00	20	6.69

[a] Step/trestle mean=4.90 (SEM 0.22); extension/straight mean=10.97 (SEM 0.61); rolling/wheeled mean=10.97 (SEM 0.61); total mean=7.50 (SEM 0.33).

Activity and task on the ladder

Work activity on the ladder at the time of the fall is presented in table 2. Most often, falls occurred when work was performed while standing or sitting on the ladder (51.3%) versus climbing down (27.8%), climbing up (11.4%), or getting on or off the ladder (6.9%). In comparing step or trestle to extension or straight ladders, the distribution of activity was similar; however, workers were more often injured while climbing up an extension or straight ladder (15.5 versus 7.7%).

The most frequent tasks at the time of the fall were diverse, but approximately a third of workers indicated performing no action other than using the ladder (34.3%). High frequency-specific tasks included installing or hanging an item (15.0%), repairing or doing maintenance (7.5%), stocking or retrieving from a shelf (7.2%), performing electrical work (6.9%), painting (6.2%), or reaching, pushing, or pulling (4.9%). In comparing extension/straight ladders to step/trestle, workers were more often installing or hanging items (23.6 versus 8.3%) and doing painting work (10.9 versus 3.9%) on extension or straight ladders; whereas step/trestle ladders were more often used for electrical work (9.0 versus 4.9%), stocking or retrieving from shelves (7.7 versus 4.9%), reaching or pulling (6.4 versus 2.4%), and carrying or operating a tool (4.5 versus 1.6%).

Mechanism of ladder fall

Fall mechanisms varied by ladder type (figure 1), and were most often due to ladder movement. With respect to step or trestle types (N=156), ladder movement was most frequent and occurred in 33.3% of cases. Movement was typically at the base or bottom (15.4%) or the ladder fell sideways (12.2%). Workers lost their balance more often from this type of ladder (27.6%) than from straight/extension ladders (7.4%). Other notable mechanisms for falls from step/trestle ladders included slip or miss of the foot on a rung (23.1%) and malfunctioning ladders (broken, collapsed or folded) (3.2%). For extension/straight ladders, the ladder moved in 53.7% of cases – primarily, at the base or bottom (40.5%). Other notable mechanisms included a slip or miss of the foot on a rung (21.5%) and ladder malfunction (broken, collapsed or folded) (5.0%).

Table 2. Activity and task at the time of the ladder fall.

	Step/trestle (N=156)		Extension/straight (N=123)		Rolling/wheeled (N=27)		Total (N=306)	
	N	%	N	%	N	%	N	%
Activity on ladder								
Standing/sitting and working from ladder	90	57.69	64	52.03	3	11.11	157	51.31
Climbing down the ladder	42	26.92	29	23.58	14	51.85	85	27.78
Climbing up the ladder	12	7.69	19	15.45	4	14.81	35	11.44
Getting on/off the ladder	9	5.77	7	5.69	5	18.52	21	6.86
Other [a]	3	1.92	4	3.25	0	0.00	7	2.29
Don't know	0	0.00	0	0.00	1	3.70	1	0.33
Tasks								
Using ladder only, no other action	57	36.54	36	29.27	12	44.44	105	34.31
Installing/hanging item	13	8.33	29	23.58	4	14.81	46	15.03
Repairing and maintenance	13	8.33	10	8.13	0	0.00	23	7.52
Stocking/retrieving shelves	12	7.69	6	4.88	4	14.81	22	7.19
Electric work	14	8.97	6	4.88	1	3.70	21	6.86
Painting work	6	3.85	13	10.87	0	0.00	19	6.21
Reaching/pushing/pulling	10	6.41	3	2.44	2	7.41	15	4.90
Cleaning/washing	5	3.21	3	2.44	1	3.70	9	2.94
Carrying/lifting/operating tool	7	4.49	2	1.63	0	0.00	9	2.94
Changing/replacing bulb or item	5	3.21	3	2.44	0	0.00	8	2.61
Cutting/breaking item/tree work	4	2.56	3	2.44	0	0.00	7	2.29
Inspecting	2	1.28	2	1.63	1	3.70	5	1.63
Welding	2	1.28	0	0.00	0	0.00	2	0.65
Other [b]/ unknown task	6	3.85	7	5.69	2	7.41	15	4.90
Total	156	100	123	100	27	100	306	100

[a] Other: Putting ladder up or down, preparation work.
[b] Other: carpentry, trimming, and casing.

Risk factors for fractures

The injury diagnosis most frequently resulting from a ladder fall in this study was fractures, occurring in 87 of 306 cases (28%). Based on the multivariate logistic regression model (table 3), we found a statistically significant ($P<0.05$) monotonic association between an increased risk of fracture with increasing fall height and increasing worker age. The activity of the worker while working on the ladder was marginally significant ($P=0.067$); workers who fell while standing, sitting, or working on the ladder were more likely to experience a fracture (OR 1.66) compared to workers who were climbing up or down. Gender, body mass index, ladder placement, slipperiness and stability, and ladder type were not significantly related to fracture risk.

Discussion

Few studies provide comparable nationally representative data for facilitating the development of ladder-fall prevention strategies for straight and portable ladders, where the sample of workers is from a broad range of occupations and both male and female. Among published studies that have provided some data on ladder-fall injury circumstances, most have also reported that the majority of falls occur while the victim is working on the ladder, ascending, or descending (14, 15, 16). This finding is consistent with ours where workers were most often standing or sitting while performing work directly from the ladder (51.3%), or climbing down (27.8%) or up the ladder (11.4%) at the time of their fall.

We also reported that fractures were the most common injury diagnosis in 28.4% of cases (87 of the 306 cases). This percentage is consistent with the findings of Faergemann & Larsen (21), in a case-series of 1462 patients aged ≥15 years with *non-occupational* fall injuries from ladders and scaffolds in which they reported about one third of all cases to be either fractures or dislocations. In evaluating the significant risk factors associated with a fracture outcome, we found a monotonic relationship between increasing fall height and fracture risk that was also influenced by an increase in worker age and by working on the ladder as compared to climbing up or down. Although fractures have been previously reported as an outcome in ladder falls, there are few published studies that have evaluated a broader range of risk factors for fracture. The increased risk with age observed here is consistent with the findings of Smith et al (9) of 9826 ladder-fall injuries reported to a larger workers compensation system, where 7% of all cases resulted in fractures, and older persons (age ≥45 years) were found to be at a greater risk of fractures than other less serious injuries.

The results of this study should be viewed in light of its strengths and limitations. An important strength

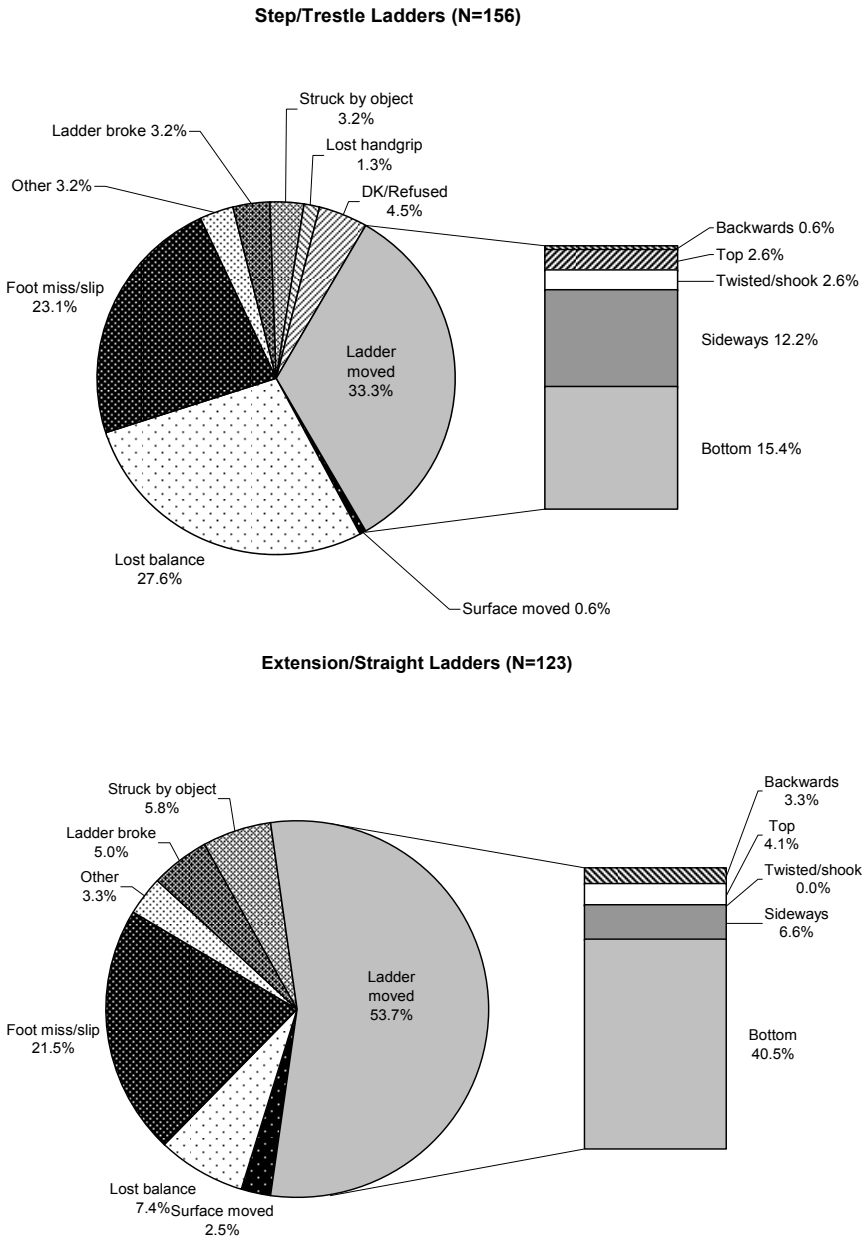

Figure 1. Mechanism leading to the fall by ladder type.

Table 3. Adjusted multivariate logistic regression model. Odds ratio (OR) estimates for risk of fracture from ladder fall. Variables not statistically significant include gender, body mass index, placement, slipperiness, and stability of ladder, and ladder type. [SEM=standard error of the mean; 95% CI=95% confidence interval.]

Parameter	Estimate	SEM	P-value [a]	OR	95% CI
Intercept	-2.72	0.526	<0.0001	.	..
Age	0.026	0.011	0.013	1.026	1.005–1.048
Activity on ladder					
Climbing up or down	reference	.	.	.	..
Standing, sitting or working	0.508	0.276	0.066	1.662	0.967–2.857
Height position of worker at fall					
<5 feet	reference	.	.	.	..
5–9.9 feet	0.345	0.340	0.310	1.413	0.726–2.750
≥10 feet	1.073	0.350	0.002	2.923	1.487–5.747

[a] Wald chi-square test.

of this follow-back study is the systematic approach to case-ascertainment and representativeness of the NEISS US ED sample (17), with timely follow-back interviews of the ladder-fall victims. Limitations of this study include the potential for information bias since all case interviews were conducted retrospectively. However, it is unlikely that the responses made among ladder types would be systematically biased. We were able to interview 49% of those whom we successfully contacted, but have no further information to describe the 51% that were not interviewed. No further information was available for those cases who declined to be interviewed, thus it is possible that there are differences in ladder fall circumstances in these cases compared to those who were interviewed.

Implications for prevention

In this study, we sought to identify important areas that need to be targeted to reduce risks for work-related ladder fall injuries. The problem is not a new one but the level of its impact could increase, especially in light of the aging workforce.

This study was the first to combine sampling from a nationally representative data system with the collection of information on a broad range of potential contributing factors. As such, the findings may be generalized more than those of previous published studies. Future research should address the potential influence of fixed and transient contributing factors identified here in the etiology of ladder-fall injuries and effective approaches to intervention.

This study advances knowledge of fall-from-ladder incidents to better inform decisions by those that specify work means and methods, select equipment to work at heights, and plan/supervise/manage performance of all workers who work at heights. The findings suggest that potential targets for intervention include (i) task selection and design (high reported frequency of tasks potentially involving less than three points of contact with the ladder) and (ii) work practices particularly involving ladder set-up (high prevalence of ladder movement as a contributing factor) such as anchoring or tying off the top of the ladder. Sitting, facing away from the ladder rungs/steps, was an important contributing factor, as was descending from the working position. Best practices include using three points of contact at all times on the ladder, pausing for several seconds with the head in a neutral position before starting descent from the working position to help restore balance, looking at the next lower step/rung before moving the foot that will be placed on it, and facing the ladder at all times keeping the center line (belt buckle) between the side rails. Manufacturer recommendations on the maximum working height of equipment (eg, ascend no higher than the third step from the top) should always be followed.

Workplace safety audits that measure the presence of fall hazards (19) can be useful in identifying and assessing these prevention targets. However, such audits typically devote relatively limited attention to ladder-specific safety issues. Readers may find recently published guidelines for extension (22) and portable step (23) ladder audits useful in addressing these two aspects of safe ladder use. Employers with work-at-height needs should always consider the demands of each task, the capabilities of the workers involved, and the proper selection of work-at-heights access equipment (eg, mechanical lifts, scaffolding, ladders) to be used when planning such operations.

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