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Falls:

An Interdisciplinary Annotated Bibliography

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Falls: An Interdisciplinary Annotated Bibliography

Ahn, C. R., et al. (2019). "Wearable Sensing Technology Applications in Construction Safety and Health." Journal of Construction Engineering and Management 145(11): 03119007.

The advent of wearable sensing technologies has produced unprecedented opportunities for the near real-time collection and analysis of workers' safety and health data. To encourage the proactive safety management these opportunities present, extensive research efforts have explored using various wearable sensing technologies—including motion sensors (e.g., inertial measurement units) and physiological sensors (e.g., heart-rate sensors, electrodermal-activity sensors, skin-temperature sensors, eye trackers, and brainwave monitors)—to detect potential safety hazards and to continuously monitor a worker's health on a construction jobsite. However, these efforts tend to be piecemeal or fragmented, which presents a challenge for both the practitioners and the researchers who wish to fully understand the current developments in this area. In this context, this paper provides a critical review of the state of the art of wearable applications in construction safety and health. The review first identifies five general applications within the literature: preventing musculoskeletal disorders, preventing falls, assessing physical workload and fatigue, evaluating hazard-recognition abilities, and monitoring workers' mental status. Second, this study identifies the challenges impeding further development and deployment of wearable applications, specifically, signal artifacts and noise in wearable-sensors' field measurements, variable standards for personal safety and health risks in construction, users' resistance to technology adoption, and uncertainty regarding the return on investment. Lastly, this paper recommends future research opportunities for advancing the field, especially in terms of conducting sensor fusion for wearable applications, developing a business case, and engaging wearables in risk assessment and post-injury compensability assessment.

Al-Bayati, A. J. and D. D. York (2018). "Fatal injuries among Hispanic workers in the U.S. construction industry: Findings from FACE investigation reports." J Safety Res 67: 117-123.

INTRODUCTION: Identifying and understanding the characteristics of workplace accidents can provide vital information required to clarify their causes and prevent similar accidents from happening in the future. The Hispanic workforce represents a significant segment of the U.S. construction labor force that is projected to continue increasing in population. The government statistical data show higher rates of fatalities among Hispanic workers when compared to other ethnic groups. METHOD: This study aims to provide details about the trends of fatal injuries among Hispanic workers. The study examined 92 government investigation reports to reveal the general trends, then an examination of fatal fall injuries within the study sample was conducted since falling is the predominant cause of fatal injuries. RESULTS: The findings suggest differences in accident characteristics between Hispanic workers and all workers, which could indicate a need for different interventions to improve the overall site safety. The study also revealed the dire need to propose revised investigation procedures that would help identify the root causes of accidents, which in turn leads to better recommendations and interventions.

Albert, A., et al. (2020). "Focus on the fatal-four: Implications for construction hazard recognition." Safety science 128: 104774.

Much effort has been devoted to improving hazard recognition in the construction industry. One such effort is the training outreach program pioneered and promoted by the Occupational Safety and Health Administration (OSHA) – commonly known as the Construction Focus Four or the Construction Fatal Four program. This program which is integrated in much of the training efforts offered in the construction industry seeks to promote hazard recognition and management by focusing on the four leading causes of fatal incidents – namely falls, caught-in/between, struck-by, and electrocution (i.e., fatal-four) hazards. Given the emphasis of these hazards in most training efforts, the objective of the current research was to explore if there are any performance disparities among workers in recognizing hazards that fall under the fatal-four and the non-fatal-four hazard categories. To accomplish this research goal, more than 280 workers were recruited from 57 construction workplaces in the United States to participate in a hazard recognition activity. The results of the study reveal that workers fail to recognize a disproportionate number of safety hazards in both the fatal-four and the non-fatal-four hazard categories. However, workers are relatively more proficient in recognizing hazards in the fatal-four hazard category than the non-fatal-four hazard category. More specifically, on average, the participating workers roughly recognized 57% of the fatal-four safety hazards while only recognizing 18% of the non-fatal-four safety hazards. Collectively, these findings suggest that apart from focusing on the fatal-four hazards, training efforts must also focus on the non-fatal-four safety hazards – given the relative poor performance.

Armstrong, T., et al. (2008). "Development of Design Interventions for Preventing Falls from Fixed Ladders (CPWR Report)."

Beavers, J., et al. (2009). "Steel erection fatalities in the construction industry." Journal of Construction Engineering and Management 135(3): 227-234.

Construction fatalities continue to occur during steel erection. Using 166 case files resulting from Occupational Safety and Heath Administration (OSHA) investigations of steel erection fatalities during the years 2000–2005, the writers examined the data to determine the proximal causes and contributing physical factors. Of the 166 fatal events, results showed proximal cause “falls” represented 125 of the fatal events, “crushed/struck/hit by object” represented 40, and one was caused by electrocution. The rate of fatalities tended to reduce from 2000 to 2005. As a result, OSHA may be reaching one of its goals established following the introduction of the new steel standards in 2002, an annual reduction of 30 fatalities. The results of this study indicate that employer compliance with OSHA’s fall protection standards and instructing employees in recognition and avoidance of unsafe conditions could save lives.

Becker, P., et al. (2001). "Use of a handheld computer to audit construction fall prevention effectiveness." International Journal of Computer Integrated Design and Construction 3(1): 16-24.

Becker, P., et al. (2001). "Prevention of construction falls by organizational intervention." Inj Prev 7 Suppl 1: i64-67.

OBJECTIVES: Determine if a university based (third party) intervention can improve construction contractor organizational performance to increase use of fall prevention practices and technologies. SETTING: Falls are the leading cause of worker injury and death in the construction industry. Equipment and practices that can prevent falls are often not used

appropriately in the dynamic construction work environment. METHODS: A contractual partnership between a university and construction contractors created management systems to ensure use of fall protection measures. Audits by university faculty provided accountability for implementing the fall prevention system. Evaluation was conducted by quasiexperimental methodology comparing changes in audit score from baseline to fifth quarter from baseline for intervention and control contractors. RESULTS: Audit scores improvement was greater for intervention than for control contractor group. CONCLUSION: A third party intervention can improve contractor fall prevention performance.

Behm, M. (2012). "Safe design suggestions for vegetated roofs." Journal of Construction Engineering and Management 138(8): 999-1003.

Rooftop vegetation is becoming increasingly popular because of its environmental benefits and its ability to earn green-building certification credits. With the exception of one international guideline, there is little mention of worker safety and health in vegetated-roof codes and literature. Observations and field investigations of 19 vegetated roofs in the United States revealed unsafe access for workers and equipment, a lack of fall-protection measures, and other site-specific hazards. Design for safety strategies and the integration of life-cycle safety thinking with green-building credits systems are the preferred methods to reduce risk to workers on vegetated roofs. Design suggestions have been developed to add to the body of knowledge. The findings complement several National Institute for Occupational Safety and Health (NIOSH) construction and prevention through design (PtD) goals and are congruent with NIOSH's Safe Green Jobs initiative. Organizations that install and maintain vegetated roofs can utilize the findings to understand hazards, take precautions, and incorporate safety into their bids. © 2012 American Society of Civil Engineers.

Bethancourt, J. and M. Cannon (2015). "Fall protection structural efficacy of residential structures for fall protection systems." Professional Safety 60(05): 58-64.

Bobick, T. G., et al. (2010). "Evaluation of guardrail systems for preventing falls through roof and floor holes." J Safety Res 41(3): 203-211.

INTRODUCTION: Fall-related occupational injuries and fatalities are serious problems in the U.S. construction industry, especially incidents related to unguarded holes. The National Institute for Occupational Safety and Health, Division of Safety Research, Morgantown, WV conducted a project to evaluate the effectiveness of guardrail systems to prevent falls through roof and floor holes. METHODS: Two commercial edge-protection products were evaluated when used as perimeter guarding around a roof hole. Installations of the commercial products were compared to job-built guardrails constructed of 2(")x4(") construction-grade lumber. Occupational Safety and Health Administration (OSHA) regulations require that "a force of at least 200 pounds" must be supported by the top rail of a guardrail system "in any outward or downward direction at any point along the top edge." A laboratory testing system was developed to evaluate this requirement. A dynamic 200-lb force was generated against the top rail using a weighted manikin mounted on a hinged steel frame. Nine construction workers, who served as test subjects, each built five different guardrail configurations. RESULTS: All 45 configurations met the 200-lb OSHA requirement. Installation time for one commercial product was 32% quicker than the job-built configuration (25.6 min vs. 37.9 min). IMPACT ON INDUSTRY: This study: (a) indicates that the two edge-protection products can be used as

perimeter guarding; (b) highlights the importance of using proper materials and fasteners to construct guardrails to protect workers from falling into unguarded roof and floor holes; and (c) discusses an overall-strength-testing methodology that can be used by fall-protection researchers.

Borjan, M., et al. (2016). "Assessing barriers to the use of fall protection in small residential construction companies in New Jersey." New Solut 26(1): 40-54.

Three focus groups were conducted with residential construction workers from local New Jersey labor organizations to characterize barriers to fall protection use among residential construction contractors who work for companies with fewer than ten employees. Thirty-six residential construction workers volunteered to participate, the average age was thirty-nine years, and twenty-four (67%) were of Hispanic origin. Twelve (33%) of the participants reported having fallen from greater than 6 ft at work and twenty (56%) of the participants had known someone who has fallen from greater than 6 ft. Sixteen (44%) had not been provided with fall protection equipment by their employer and eighteen (50%) reported their current employer had not provided workplace safety training. Factors that created barriers to use of fall protection equipment such as equipment availability, employee/employer relationships, cultural differences, and company size were identified. Results from this study confirm that falls remain a concern among residential construction workers in small companies.

Breloff, S. P., et al. (2020). "Inclination angles during cross-slope roof walking." Saf Sci 132.

Residential roofers have the highest rate of falls in the construction sector with injuries and fatalities costing billions of dollars annually. The sloped roof surface is the most predominant component within the residential roof work environment. Postural stability on a sloped work environment is not well studied. Calculating inclination angles (IAs) using the lateral ankle marker could be a quality measure to determine how cross-slope roof walking will influence stability. Will cross-slope roof-walking effect anterior-posterior (AP) and medial-lateral (ML) IAs in adult males? Eleven adult males participated in two testing sessions-level and cross-slope roof gait session on a 6/12 pitched roof segment. Changes in AP and ML IAs between conditions were compared at: heel strike (HS) and toe off (TO). Legs were analyzed separately due to the cross-slope walking. The left foot was 'higher' on the sloped roof and the right was 'lower.' Significant increases ($p </= 0.006$) in IAs were observed due to the sloped roof in all conditions except the AP 'lower' leg ($p = 0.136$). Increases in IA suggest a decrease in postural stability as the body will result in greater sway compared to a natural posture. Increases in AP IAs may cause slipping in the anterior or posterior direction as the normal force will decrease during HS and TO. In the ML direction, fall risk is increased and more stress is placed on the hip abductors in order to reduce falling. Thus traversing a sloped roof surface reduces stability of healthy workers and escalates injury/fall risk factors.

Breloff, S. P., et al. (2022). "Spatiotemporal gait parameters while cross-slope residential roof walking." Int J Ind Ergon 87.

Falls from residential roofs account for 80% of roofing industry fatalities. Furthermore, roofing work represents 44.7% of work in residual construction specialty trades and residential roofers count for 2.1% of overall workers in construction, with an anticipated growth in roofers of 14.9% by 2024. The purpose of the study was to evaluate the alterations in spatiotemporal gait parameters while traversing along a 6/12 pitched residential roof segment. Eighteen of the

nineteen calculated spatiotemporal variables were statistically, significantly changed by walking across a 6/12 pitched simulated residential roof. The study clearly demonstrates that spatiotemporal gait variables increase and decrease while traversing across a residential roof. The changes in spatiotemporal parameters might suggest alterations to a person's balance system resulting in an increased risk of falling. The knowledge generated in the current study will be relevant to the residential roofing industry when it can be used in educational materials to increase awareness of how a roofer's altered gait while working on a pitched roof may increase their falling risk.

Breloff, S. P., et al. (2019). "Lower extremity kinematics of cross-slope roof walking." Appl Ergon 75: 134-142.

Working conditions of residential roofers expose them to a unique sloped environment. The purpose of this study is to determine in what way traversing across a sloped/roof surface alters lower extremity kinematics of the upslope and downslope legs compared to level walking. College aged males negotiated across a pitched (26 degrees) roof segment during which lower extremity three-dimensional kinematics were calculated. One foot was higher on the slope and one was lower for the duration of cross slope walking. Overall, cross-slope walking on a 26 degree roof significantly altered 77% of the measured lower extremity variables compared to level self-selected pace walking. The data suggest that roof pitch incite significant differences in crossslope walking of the kinematics in the lower extremity between the upslope and down slope limbs when compared to level surface walking. These alterations could temporarily alter proprioception which may in turn lead to increased falls and musculoskeletal injury, though further study is needed.

Brown, S., et al. (2021). "Injury inequalities among U.S. construction workers." J Occup Environ Hyg 18(4-5): 159-168.

This study explores racial/ethnic inequalities in work-related injuries among U.S. construction workers. Data from the 2004-2017 National Health Interview Survey were used to estimate work-related injuries by race/ethnicity in construction. Disparities in demographic, socioeconomic, and injury status among construction workers were examined by race/ethnicity. Injury differences were also evaluated in multiple logistic regression analyses controlling for potential confounders. Compared to white, non-Hispanic workers, minority workers were more likely to have lower socioeconomic statuses (e.g., lower educational attainment, lack of health insurance coverage, and family income below the poverty level), which considerably increased the likelihood of work-related injuries. The odds of work-related injuries were 70% higher among racial/ethnic minorities than white, non-Hispanics in construction. Injuries were also more severe among minorities than white, non-Hispanic workers. Among workers with a work-related injury, nearly 85% of Hispanics reported missing at least one workday due to injury, 45.6% higher than the proportion of 57.9% for their white, non-Hispanic counterparts. After adjusting for major demographic and socioeconomic factors, the work-related injury difference between race/ethnicity was no longer statistically significant. However, the odds of work-related injury remained significantly higher among workers who were younger (35-54 years vs. >/= 55 years: aOR = 2.2, 95% CI: 1.3-3.6); male (aOR = 5.3, 95% CI: 2.9-9.8); not college-educated (aOR = 1.5, 95% CI: 1.0-2.2); had a family income below the poverty threshold (aOR = 1.8, 95% CI: 1.2-2.8); or held a blue-collar occupation (aOR = 2.0, 95% CI: 1.2-3.4). These findings suggest that the injury differences between race/ethnicity were strongly associated with

demographics and socioeconomic inequalities in these worker groups. The identified injury disparities should be reduced or eliminated, following the hierarchy of controls paradigm.

Bunn, T. L., et al. (2007). "Data linkage of inpatient hospitalization and workers' claims data sets to characterize occupational falls." J Ky Med Assoc 105(7): 313-320.

PROBLEM: The identification of industry, occupation, and associated injury costs for worker falls in Kentucky have not been fully examined. The purpose of this study was to determine the associations between industry and occupation and 1) hospitalization length of stay; 2) hospitalization charges; and 3) workers' claims costs in workers suffering falls, using linked inpatient hospitalization discharge and workers' claims data sets. METHODS: Hospitalization cases were selected with ICD-9-CM external cause of injury codes for falls and payer code of workers' claims for years 2000-2004. Selection criteria for workers'claims cases were International Association of Industrial Accident Boards and Commissions Electronic Data Interchange Nature (IAIABCEDIN) injuries coded as falls and/or slips. Common data variables between the two data sets such as date of birth, gender, date of injury, and hospital admission date were used to perform probabilistic data linkage using LinkSolv software. Statistical analysis was performed with non-parametric tests. RESULTS: Construction falls were the most prevalent for male workers and incurred the highest hospitalization and workers' compensation costs, whereas most female worker falls occurred in the services industry. The largest percentage of male worker falls was from one level to another, while the largest percentage of females experienced a fall, slip, or trip (not otherwise classified). When male construction worker falls were further analyzed, laborers and helpers had longer hospital stays as well as higher total charges when the worker fell from one level to another. CONCLUSIONS: Data linkage of hospitalization and workers' claims falls data provides additional information on industry, occupation, and costs that are not available when examining either data set alone.

Bunting, J., et al. (2017). "A national safety stand-down to reduce construction worker falls." J Safety Res 60: 103-111.

INTRODUCTION: Falls are the leading cause of death and third leading cause of non-fatal injuries in construction. In an effort to combat these numbers, The National Campaign to Prevent Falls in Construction began in April 2012. As the campaign gained momentum, a week called the National Safety Stand-Down to Prevent Falls was launched to draw attention to the campaign and its goals. The purpose of this paper is to examine the reach of the Stand-Down and lessons learned from its implementation. METHODS: The Occupational Safety & Health Administration offered a certificate of participation during the Stand-Down. To print the certificate, respondents provided information about their company and stand-down event. CPWR - The Center for Construction Research and Training conducted analyses on the data collected to assess reach and extent of participation. RESULTS: In 2014, 4,882 stand-downs were reported. The total number reported in 2015 was 3,759. The number of participants, however, increased from 770,193 in 2014 to 1,041,307 in 2015. DISCUSSION: The Stand-Down successfully reached the construction industry and beyond. Respondents were enthusiastic and participated nationally and internationally in variety of activities. They also provided significant feedback that will be influential in future campaign planning. CONCLUSION: Numbers of Stand-Downs and participants for both years are estimated to be substantially higher than the data recorded from the certificate database. While we cannot determine impact, the reach of the Stand-Down has surpassed expectations. PRACTICAL

APPLICATIONS: The data gathered provide support for the continuation of the Stand-Down. Campaign planners incorporated findings into future Stand-Down planning, materials creation, and promotion. This analysis also provides insight on how organizations can partner to create targeted national campaigns that include activities stakeholders in the construction industry respond to, and can be used to replicate our efforts for other safety and health initiatives in construction and other industries.

Cakan, H., et al. (2014). "Investigation of Factors Contributing to Fatal and Nonfatal Roofer Fall Accidents." International Journal of Construction Education and Research 10(4): 300-317.

Roofers continue to suffer frequent fall-related injuries and fatalities. The objectives of this research were (a) identifying the factors affecting roofer fall accidents; (b) investigating the frequency distributions of these factors; (c) examining the relationships between the factors; and (d) developing a statistical model for fatal and nonfatal fall outcomes. Occupational Safety & Health Administration (OSHA) accident data was analyzed using categorical variables. After establishing data demographics, cross-tabulation analysis was performed to determine factor relationships, and logistic regression modeling was done to predict accident outcomes using degree of injury as a dependent variable and the significant factors from cross-tabulation as independent variables. It was found that roofers most frequently experienced falls while working in smaller alteration/rehabilitation projects and at heights below 20 feet. Unguarded/improperly secured platforms, walkways, openings, edges and ladders, misjudgment of hazardous situation, and improper choice of equipment/process came out to be significant contributing factors. It was observed that the odds of fatality decreased when roofers were provided OSHA-compliant fall protection systems; used these systems; and received fall protection training per OSHA requirements. The model developed and validated in this study successfully predicted the fall accident outcomes in terms of fatality and nonfatal injury. © Associated Schools of Construction.

Castaneda, D. E., et al. (2013). "Evaluating an Entertainment–Education Telenovela to Promote Workplace Safety." SAGE Open 3(3): 2158244013500284.

Chen, G. X., et al. (2000). "Expanded analysis of injury mortality among unionized construction workers." Am J Ind Med 37(4): 364-373.

BACKGROUND: To evaluate the utility of expanding the number and precision of injury categories used in previous occupational mortality studies, this study reanalyzed data from four previous studies of unionized construction workers (construction laborers, ironworkers, sheet metal workers, and operating engineers), by expanding the number of injury categories from 6 to 33. METHODS: Proportionate mortality ratios (PMRs) were computed using the distribution of deaths from the National Occupational Mortality Surveillance System, a mortality surveillance system from 28 states, as a comparison. A blue collar comparison group was also used in additional analyses to adjust for socioeconomic and other factors. RESULTS: This reanalysis identified significantly elevated PMRs in at least one of the four worker groups for falls, motor vehicle crashes, machinery incidents, electrocutions, being struck by falling objects, being struck by flying objects, explosions, suffocation, and water transport incidents. Limiting the comparison population to deaths among blue collar workers did not change the results substantially. CONCLUSIONS: This study demonstrates that increasing the precision of categories of death from injury routinely used in mortality studies will provide improved

information to guide prevention. Am. J. Ind. Med. 37:364-373, 2000. Published 2000 Wiley-Liss, Inc.

Choi, S. D. and K. Carlson (2014). "Occupational safety issues in residential construction surveyed in wisconsin, United States." Ind Health 52(6): 541-547.

Residential construction is a high-risk industry in the U.S. due to the exposure to workrelated safety hazards and fall injuries. This study aimed to examine the safety training and safe work practices of construction workers within the small residential construction industry. In order to achieve the study objectives, a survey was designed and sent to approximately 200 Wisconsin based residential construction contractors. About one third of the respondents stated that they did not have any form of safety programs. The study indicated that the most common types of workrelated injuries in residential construction were slips/trips/falls and cuts/lacerations. The survey findings also suggested that the residential construction contractors needed to increase the utilization of fall protection safety equipment. Further education and subject matter expert training could provide benefits to improve occupational safety and health of the small business workforce in the residential construction industry. © 2014 by National Institute of Occupational Safety and Health.

Choi, S. D. and T. K. Fredericks (2008). "Surface slope effects on shingling frequency and postural balance in a simulated roofing task." Ergonomics 51(3): 330-344.

The purpose of this study was to investigate the influence of surface slopes (18 degrees , 26 degrees , 34 degrees) on the maximum acceptable roof shingling frequency for males performing a simulated roof-shingling task. The psychophysical roof shingling frequency was also compared to the postural sway and trunk motion values. The maximum acceptable roof shingling frequency and selected trunk motion decreased significantly with an increase in slope. Postural sway however increased significantly with an increase in slope. The study also revealed that workers were experiencing a greater postural sway at the earlier phase of task on the steeper surface. This suggests that there might be an adaptation period associated with working on a slope and the body's ability to compensate for a loss of balance. Therefore, more emphasis should be given to the workers in this adaptation period, with additional monitoring and cautionary measures. Collectively, the findings of the study could be utilized for improving work practices on roofs, while reducing the potential risks of falls in roofing construction.

Courtney, T. K., et al. (2002). "Disabling occupational injury in the US construction industry, 1996." J Occup Environ Med 44(12): 1161-1168.

In 1996 the US construction industry comprised 5.4% of the annual US employment but accounted for 7.8% of nonfatal occupational injuries and illness and 9.7% of cases involving at least a day away from work. Information in the published literature on the disability arising from construction injuries is limited. The construction claims experience (n = 35,790) of a large workers' compensation insurer with national coverage was examined. The leading types and sources of disabling occupational morbidity in 1996 in the US construction industry were identified. Disability duration was calculated from indemnity payments data using previously published methods. The average disability duration for an injured construction worker was 46 days with a median of 0 days. The most frequently occurring conditions were low back pain (14.8%), foreign body eye injuries (8.5%), and finger lacerations (4.8%). Back pain also accounted for the greatest percentage of construction claim costs (21.3%) and disability days

(25.5%). However, the conditions with the longest disability durations were sudden-onset injuries, including fractures of the ankle (median = 55 days), foot (42 days), and wrist (38 days). Same-level and elevated falls were the principal exposures for fractures of the wrist and ankle, whereas elevated falls and struck by incidents accounted for the majority of foot fractures. Manual materials handling activities were most often associated with low back pain disability. The results suggest that these most disabling injuries can be addressed by increasing primary prevention resources in slips and falls and exposures related to injuries of sudden-onset as well as in reducing manual materials handling and other exposures associated with more gradual-onset injuries.

Cruz, Y., et al. (2018). "Characterization of Foreign-Born vs. Native-Born Worker Fatalities in Kentucky, 2001-2014." J Immigr Minor Health 20(2): 448-455.

Information on foreign-born worker (FBW) and native-born worker (NBW) fatal injuries is scarce. The Kentucky Fatality Assessment and Control Evaluation program analyzed 2001-2014 worker fatality data. The Kentucky FBW fatality rate was double the US FBW and NBW rates, and 50% higher than the Kentucky NBW fatality rate. FBW average age at death was 38 years; NBW age was 47 years. FBW deaths occurred in construction (26%) and services (22%) industries, and transportation [28% (54% due to semi truck crashes)] and construction [26%(48% due to roofing, scaffolding, and ladder-related falls)] occupations; in contrast, NBW deaths occurred in services (22%), and transportation (18%) industries, and transportation (25%) and management (20%) occupations, and were due to exposures to inanimate mechanical forces (38%), and transport accidents (30%). Enhanced FBW cultural competent interventions and policies are needed to prevent FBW occupational injuries, and improve FBW workplace safety and health.

Cutlip, R., et al. (2000). "A comparison of different postures for scaffold end-frame disassembly." Appl Ergon 31(5): 507-513.

Overexertion and fall injuries comprise the largest category of nonfatal injuries among scaffold workers. This study was conducted to identify the most favourable scaffold end-frame disassembly techniques and evaluate the associated slip potential by measuring whole-body isometric strength capability and required coefficient of friction (RCOF) to reduce the incidence of injury. Forty-six male construction workers were used to study seven typical postures associated with scaffold end-frame disassembly. An analysis of variance (ANOVA) showed that the isometric forces (334.4-676.3 N) resulting from the seven postures were significantly different ($p < 0.05$). Three of the disassembly postures resulted in considerable biomechanical stress to workers. The symmetric front-lift method with hand locations at knuckle height would be the most favourable posture; at least 93% of the male construction worker population could handle the end frame with minimum overexertion risk. The static RCOF value resulting from this posture during the disassembly phase was less than 0.2, thus the likelihood of a slip should be low.

Dennerlein, J. T., et al. (2009). "Portable ladder assessment tool development and validation-quantifying best practices in the field." Safety science 47(5): 636-639.

Many causes for falls from ladders in construction are related to the user's activities; however, the extent to which users comply with ladder use best practices is unknown and has not been well quantified before. We developed and tested an audit tool that assesses compliance

with best practices guidelines for portable ladder use designed for applications in the construction industry. Implemented on a hand-held computer, the assessment tool consisted of a series of checklists categorized in four groups; ladder condition, setup, moving on a ladder, and completing tasks from a ladder. For these four observational categories, the resulting tool contained 31 and 33 questions for step and extension ladders, respectively. Three individuals trained to use the tool scored a set of photographs and videos depicting 25 ladder conditions, 20 ladder setups, 10 users moving on ladders, and 13 users completing tasks from a ladder for a total of 78 observations. The assessment tool had good agreement across and within raters. For the three raters, agreement ranged from 79% to 97% across the questions. Within one subject, kappa coefficients for the intrarater reliability ranged from 0.67 to 0.91. The tool offers a practical method to quantify best practices associated with ladder use that can ultimately inform targeted intervention efforts.

DiDomenico, A., et al. (2010). "Effects of simulated occupational task parameters on balance." Appl Ergon 41(3): 484-489.

The effects of single-handed load holding, length of the base of support, and standing surface condition (narrow and wide construction beams) on balance were investigated in twenty-three healthy men between the ages of 18 and 55 years old. Balance during quiet standing was evaluated from postural sway measurements derived from center of pressure (COP) displacement. These measurements included the range or maximal displacement of the COP in the anteroposterior (AP) and mediolateral (ML) directions, the elliptical area, and mean sway velocity. Holding a load in the hand did not significantly affect postural sway measures ($p > 0.05$), although the effect of surface condition was significant on all COP measures ($p < 0.001$). Lengthening the base of support did not affect the ranges or elliptical area, but increased the mean velocity of sway ($p = 0.001$). Changes in the dimensional characteristics of the surface condition and length of base of support affected postural sway, possibly by requiring adjustments to balance and motor control strategies. Further research is required to determine if these changes are detrimental to maintaining balance and increase the risk of falls for workers in similar environments.

DiDomenico, A., et al. (2010). "Perceptions of postural stability after transitioning to standing among construction workers." Safety science 48(2): 166-172.

Falls are a leading cause of fatal and nonfatal injuries in the construction trades. This study explored construction workers' self-reports of postural stability upon standing after working in different postures. One hundred and eighty-nine workers in 10 construction trades provided stability ratings by completing a written questionnaire. Additional data collected included age, gender, years of experience, and rating of overall balance. Construction workers rated their overall balance as high, furthermore, no difference was found between trades or age groups. Significant differences in stability ratings were provided for the various postures. The most commonly used non-erect postures (bent over at waist, squatting, and forward kneeling) resulted in the largest self-reports of instability. Sitting on elevated surface and sitting on level surface resulted in the highest levels of self-reported stability and are recommended when maintaining balance is a concern. Differences associated with construction trade and age were also found, but were thought to be attributed to differences in tasks performed since no differences were found when each posture was analyzed separately. The results suggest that the working posture used to complete a task affects the postural stability upon standing regardless

of construction trade and age of worker. Findings may lead to recommendations for redesign of tasks or tools to reduce the use of certain working postures, particularly in high-risk environments such as construction.

Dong, R. G., et al. (2021). "An alternative method for analyzing the slip potential of workers on sloped surfaces." Saf Sci 133.

Slips and falls on sloped roof surfaces remain an important safety issue among construction workers. The slip potential has been conventionally analyzed and assessed primarily based on ground reaction forces, which cannot differentiate the specific roles of each of the force factors (e.g., workers' motions-induced dynamic forces and slope-induced static forces) contributing to the slip potential. Their differentiation may enhance the understanding of the slip mechanisms on the sloped roof surfaces and help develop effective walking and working strategies/tactics to minimize the dangerous slips on the elevated roofs. Hence, the objective of this study is to develop a biodynamic method as an additional tool for analyzing the slip potential of a worker walking or working on sloped roof surfaces. A whole-body biodynamic model is proposed and used to develop the alternative method, in which the slip potential is expressed as an analytical function of its major controlling factors including coefficient of friction, slope angle, and biodynamic forces. Some experimental data available in the literature are used to demonstrate the application of the proposed method. The results suggest that the slope may not change the basic trends of the biodynamic forces, but the slope may affect their magnitudes, which can be explained using the system's energy equation also derived from the whole-body biodynamic model. The analytical results suggest that reducing the body acceleration in uphill direction or the deceleration in downhill direction can reduce the slip potential. 'Zigging' and 'zagging' walking on a sloped surface may also reduce the slip potential, as it reduces the effective slope angle. The proposed biodynamic theory can be used to enhance the safety guidelines not only for roofers but also for people walking on ramps, inclined walkways, and mountain terrains.

Dong, X., et al. (2014). "Fatalities in the construction industry: findings from a revision of the BLS Occupational Injury and Illness Classification System." Monthly Lab. Rev. 137: 1.

Dong, X. S., et al. (2013). "Fatal falls from roofs among US construction workers." J Safety Res 44: 17-24.

This study examined trends and patterns of fatal falls from roofs in the U.S. construction industry over an 18-year period (1992–2009), with detailed analysis for 2003–2009. Roof fatalities accounted for one-third of fatal falls in construction in 1992–2009. A disproportionately high percentage (67%) of deaths from roof falls occurred in small construction establishments (1–10 employees). Roofers, ironworkers, workers employed with roofing contractors, or working at residential construction sites, had a higher risk of roof fatalities. A higher rate of roof fatalities was also found among younger (< 20 years) and older (> 44 years) workers, Hispanics, and immigrant workers.

Dong, X. S., et al. (2009). "Fatal falls among Hispanic construction workers." Accid Anal Prev 41(5): 1047-1052.

This study evaluated occupational deaths resulting from fall injuries among Hispanic construction workers using data from the Census of Fatal Occupational Injuries and the Current

Population Survey. The demographics and characteristics of fatal falls among Hispanic workers were examined and compared with that of their white, non-Hispanic counterparts. The results show that fatal injuries among Hispanic construction workers were more likely to be caused by a fall than their white, non-Hispanic counterparts (OR=1.48, 95% CI: 1.05-2.10) after controlling for possible confounders. The rate of fatal falls for foreign-born Hispanic construction workers was 5.5 per 100,000 FTE, which is significantly higher than 4.1 per 100,000 FTE for Hispanic workers who were born in the U.S. (OR=1.36, 95% CI: 1.08-1.67). The disparities in fatal injuries from falls were found in age groups, job tenure, occupations, and types of construction projects. This study also found that about every two of three fatal falls in construction occurred in establishments with 10 or fewer employees. More prevention, intervention, and training measures must be applied to Hispanic workers, especially those who are new immigrants. OSHA enforcements should target small construction establishments in order to lower overall fatality rates, costs, and unnecessary losses of life.

Dong, X. S., et al. (2017). "Fatal falls and PFAS use in the construction industry: Findings from the NIOSH FACE reports." Accid Anal Prev 102: 136-143.

This study analyzed the Construction FACE Database (CFD), a quantitative database developed from reports of the Fatality Assessment and Control Evaluation (FACE) program conducted by the National Institute for Occupational Safety and Health (NIOSH). The CFD contains detailed data on 768 fatalities in the construction industry reported by NIOSH and individual states from 1982 through June 30, 2015. The results show that falls accounted for 42% (325) of the 768 fatalities included in the CFD. Personal fall arrest systems (PFAS) were not available to more than half of the fall decedents (54%); nearly one in four fall decedents (23%) had access to PFAS, but were not using it at the time of the fall. Lack of access to PFAS was particularly high among residential building contractors as well as roofing, siding, and sheet metal industry sectors (~70%). Although the findings may not represent the entire construction industry today, they do provide strong evidence in favor of fall protection requirements by the Occupational Safety and Health Administration (OSHA). In addition to stronger enforcement, educating employers and workers about the importance and effectiveness of fall protection is crucial for compliance and fall prevention. © 2017 Elsevier Ltd

Dong, X. S., et al. (2014). "Risks of a lifetime in construction Part I: Traumatic injuries." Am J Ind Med 57(9): 973-983.

Background: Estimates of occupational risk are typically computed on an annual basis. In contrast, this article provides estimates of lifetime risks for fatal and nonfatal injuries among construction workers. A companion paper presents lifetime risks for occupational illnesses. Methods: Using 2003-2007 data from three large data sources, lifetime risk was computed based on the number of fatal and nonfatal injuries per 100 FTEs for a working lifespan of 45 years. Results: For a working life in construction, the risk of fatal injuries were approximately one death per 200 FTE, and the leading causes were falls and transportation incidents. For nonfatal injuries resulting in days away from work, the adjusted lifetime risk was approximately 78 per 100 FTEs, and the leading causes were contact with objects/equipment, overexertion, and falls to a lower level. Conclusions: Lifetime risk estimates help inform both workers and policymakers. Despite improvements over the past decades, risks in construction remain high. Am. J. Ind. Med. 57:973-983, 2014. © 2014 Wiley Periodicals, Inc.

Dong, X. S., et al. (2012). "Fatal falls among older construction workers." Hum Factors 54(3): 303-315.

OBJECTIVE: This study examines recent trends and patterns in fall fatalities in the U.S. construction industry to determine whether fatal falls among older workers are different from younger workers in this industry. BACKGROUND: Falls are the leading cause of fatalities in the U.S. construction industry. Given the increasingly aging workforce in construction, it is important to assess the risk of falls among older construction workers. METHODS: Fatality data were obtained from the Census of Fatal Occupational Injuries for the years 1992 through 2008. Denominators for death rates were estimated from the Current Population Survey. Stratified and multivariate analyses were performed to examine whether there are differences in fatal falls between older workers (> or = 55 years) and younger workers (16-54 years). Fatal falls in nonconstruction industries were excluded from this study. RESULTS: Older workers had higher rates of fatal falls than younger workers; results were significant in 11 of 14 construction occupations. Regression analysis indicated that older decedents had a higher likelihood that work-related death was caused by a fall, after controlling for major demographic and employment factors (odds ratio = 1.50, confidence interval [1.30, 1.72]). Falls from roofs accounted for one third of construction fatal falls, but falls from ladders caused a larger proportion of deadly falls in older decedents than in younger decedents. CONCLUSION: Older workers have a higher likelihood of dying from a fall. Roofs and ladders are particularly risky for older construction workers. APPLICATION: As the construction workforce ages, there is an urgent need to enhance fall prevention efforts, provide work accommodations, and match work capabilities to job duties.

Dong, X. S., et al. (2014). "Fatal falls in the U.S. residential construction industry." Am J Ind Med 57(9): 992-1000.

Background: Falls from heights remain the most common cause of workplace fatalities among residential construction workers in the United States. Methods: This paper examines patterns and trends of fall fatalities in U.S. residential construction between 2003 and 2010 by analyzing two large national datasets. Results: Almost half of the fatalities in residential construction were from falls. In the residential roofing industry, 80% of fatalities were from falls. In addition, about one-third of fatal falls in residential construction were among self-employed workers. Workers who were older than 55 years, were Hispanic foreign-born, or employed in small establishments (1-10 employees) also had higher proportions of fatal falls in residential construction compared to those in nonresidential construction. Conclusions: The findings suggest that fall safety within the residential construction industry lags behind commercial construction and industrial settings. Fall prevention in residential construction should be enhanced to better protect construction workers in this sector. Am. J. Ind. Med. 57:992-1000, 2014. © 2014 Wiley Periodicals, Inc.

Ehrnthaller, C. and F. Gebhard (2014). "35 m Vertical Free Fall: How Impact Surface Influences Survival." Case Rep Orthop 2014: 805213.

We describe the accidental free fall of a 23-year-old construction worker, who fell 13 stories (approximately 35 meters) from a false work landing on a toilet container. On impact he broke through the roof of the container, which attenuated his fall and made his survival possible. The patient sustained a central spleen rupture, liver laceration, subdural hematoma, blunt thoracic trauma with a left-sided hematothorax and right-sided pneumothorax with serial

bilateral rib fractures, and an unstable fracture of the 10th thoracic vertebra. Two thoracic drainages were inserted in the emergency department before the patient underwent emergency surgery for the management of his intra-abdominal injuries. On the third day after trauma the unstable fracture of the 10th thoracic vertebra was stabilized with an internal fixator. Following extubation on day 8 after trauma the patient did not show any peripheral neurological deficits but cerebral affection with a general slowdown. After only 21 days, the patient was discharged from the hospital to a rehabilitation center where work specific rehabilitation was started. Although the patient is not suffering from physical afflictions from the injury his daily life abilities are still limited due to cerebral damage.

Eiris, R., et al. (2018). "PARS: Using Augmented 360-Degree Panoramas of Reality for Construction Safety Training." Int J Environ Res Public Health 15(11).

Improving the hazard-identification skills of construction workers is a vital step towards preventing accidents in the increasingly complex working conditions of construction jobsites. Training the construction workforce to recognize hazards therefore plays a central role in preparing workers to actively understand safety-related risks and make assertive safety decisions. Considering the inadequacies of traditional safety-training methods (e.g., passive lectures, videos, demonstrations), researchers have employed advanced visualization techniques such as virtual reality technologies to enable users to actively improve their hazard-identification skills in a safe and controlled environment. However, current virtual reality techniques sacrifice realism and demand high computational costs to reproduce real environments. Augmented 360-degree panoramas of reality offers an innovative alternative that creates low-cost, simple-to-capture, true-to-reality representations of the actual construction jobsite within which trainees may practice identifying hazards. This proof-of-concept study developed and evaluated a platform using augmented 360-degree panoramas of reality (PARS) for safety-training applications to enhance trainees' hazard-identification skills for four types of sample hazards. Thirty subjects participated in a usability test that evaluated the PARS training platform and its augmented 360-degree images captured from real construction jobsites. The usability reviews demonstrate that the trainees found the platform and augmentations advantageously to learning hazard identification. The results of this study will foreseeably help researchers in developing engaging training platforms to improve the hazard-identification skills of workers.

English, W. and W. Marletta (1995). "An Investigation of Surface Slip Resistance On Structural Steel (CPWR Report)."

Evanoff, B., et al. (2016). "Results of a fall prevention educational intervention for residential construction." Safety science 89: 301-307.

Falls from height remain the leading cause of fatalities in residential construction. We used results from a comprehensive needs assessment to guide changes in fall prevention training in a joint union-contractor carpenter apprenticeship program; including surveys of 1018 apprentice carpenter and observational audits at 197 residential construction sites. The revised training utilized hands-on, participatory training methods preferred by the learners to address the safety gaps in the curriculum; including ladder use, leading edge work, truss setting, and use of scaffolding and personal fall arrest. We compared apprentice surveys (n = 1273) and residential worksite audits (n = 207) 1–2 years post-training with baseline measures.

Apprentices working residential construction were more likely to fall from heights (OR = 2.26, 95% CI 1.59–3.21) than those working commercial construction. The revised training resulted in improved fall safety knowledge, self-reported worksite behaviors, risk perceptions, and safety climate, even after adjusting for temporal trends. We also observed significant improvements in fall safety compliance in most domains of the worksite audit, with larger changes observed in areas emphasized in the training, demonstrating specificity of the effect. Greater effects were noted in small and medium-sized contractors, who often have limited resources to devote to safety. Self-reported falls fell from 18.2 to 14.5 per 100 person-years of work. This research supports growing evidence that worksite safety can be improved by training. This curriculum could be readily adapted to other union apprenticeship programs. Fall safety of inexperienced residential construction workers' should remain a focus of future research. © 2016 Elsevier Ltd

Evanoff, B., et al. (2012). "Outcomes of a revised apprentice carpenter fall prevention training curriculum." Work 41 Suppl 1: 3806-3808.

Falls from heights are a leading cause of morbidity and mortality among construction workers, especially inexperienced workers and those performing residential construction. This research reports changes in fall prevention behaviors following revision of fall prevention training in a union-based carpenters' apprenticeship program. We used a comprehensive needs assessment to identify gaps in apprentice carpenters' preparation to work at heights, used these results to guide a school-based fall prevention curriculum to fill these gaps, and measured the effects of the revised curriculum on knowledge, beliefs, and fall prevention behaviors.

Fernandez-Esquer, M. E., et al. (2020). "Documenting and Understanding Workplace Injuries Among Latino Day Laborers." J Health Care Poor Underserved 31(2): 791-809.

BACKGROUND: Latino day laborers face substantial injuries at work. We present a comprehensive assessment of their injury experience and explore the predictors of selfreported injuries. METHODS: Worker and injury characteristics were collected from 331 day laborers using an innnovative injury assessment tool. The odds of injury were estimated using a logistic regression. RESULTS: Participants were foreign-born, Spanish monolingual, and employed in construction. Sixty-seven individuals reported 88 past-year injuries, mostly involving the upper or lower extremities. Injuries were caused by moving heavy objects, falling, or being struck an object. Of the documented injuries, 24% were not reported at work due to fear of being fired; 64.4% resulted in missed workdays, 54.0% in temporary incapacitation, and 34.5% in permanent incapacitation. Being married significantly reduced the odds of reporting an injury. DISCUSSION: Better documentation can inform the development of better policy protections that ameliorate injuries experienced by Latino day laborers at the workplace.

Frames, C., et al. (2013). "Assessment of postural stability using inertial measurement unit on inclined surfaces in healthy adults." Biomedical Sciences Instrumentation 49: 234-242.

Fatal and nonfatal falls in the construction domain remain a significant issue in today's workforce. The roofing industry in particular, annually ranks amongst the highest in all industries. Exposure to an inclined surface, such as an inclined roof surface, has been reported to have adverse effects on postural stability. The purpose of this preliminary study was to investigate the intra-individual differences in stability parameters on both inclined and level surfaces. Postural Stability (PS) and Limit of Stability (LOS) were assessed in seven healthy

subjects (aged 25-35 years) on inclined and level surfaces using embedded force plates and an Inertial Measurement Unit (IMU). Four 90-second trials were collected on the inclined surface in distinctive positions: (1) Toes raised 20° above heel; (2) Heels raised 20° above toes (3); Transverse direction with dominant foot inverted at a lower height; (4) Transverse direction with non-dominant foot inverted at a lower height. Limit of Stability was evaluated by the two measurement devices in all four directions and margin of safety was quantified for each individual on both surfaces. The results reveal significant differences in postural stability between the flat surface condition and the inclined surface condition when subject was positioned perpendicular to the surface slope with one foot descended below the other; specifically, a significant increase was identified when visual support was interrupted. The findings lend support to the literature and will assist in future research regarding early detection of postural imbalance and preventative measures to reduce fall risks in professions where workers are consistently exposed to inclined surfaces. © 2013.

Grant, A. and J. Hinze (2014). "Construction worker fatalities related to trusses: An analysis of the OSHA fatality and catastrophic incident database." Safety science 65: 54-62.

This study was conducted to gain a better understanding of the risks associated with truss installation in building projects. The Occupational Safety and Health Administration (OSHA) fatality and catastrophic incident database was analyzed for the years inclusive of 1990-2009. The database includes over 15,000 incidents, 211 of which pertain to trusses. The incidents were analyzed as to the number of fatalities per incident, the type of truss, the truss material, the activity taking place at the time of the accident, the release of the hoisting equipment, the initiation of the accident, the presence of bracing materials, the type of construction, the length of the trusses, the location of the incident, the type of accident (fall, caught-in/between, struck by, or electrocution), and the year the fatality occurred. Many of the accidents occurred at elevation and were initiated in large part by moving or falling objects. The study recommends that further research should focus on the stabilization of incomplete roof structures and the implementation of best practices for fall protection while performing truss-related work. © 2014 Elsevier Ltd.

Halperin, K. M. and M. McCann (2004). "An evaluation of scaffold safety at construction sites." J Safety Res 35(2): 141-150.

PROBLEM: This study evaluated common scaffold safety practices in construction. METHOD: A 150-point checklist was used to evaluate supported scaffold safety practices at 113 scaffolds in nine areas of the eastern United States. RESULTS: Thirty-six scaffolds (31.9%) were either in danger of collapse or missing planking, guardrails, or adequate access. There was a strong statistical correlation between structural flaws and fall protection hazards, and between proper scaffold safety practice and (a) competent persons with scaffold safety training, (b) use of separate scaffold erection contractors, and (c) scaffolds that were not simple frame types. A slightly weaker correlation was found with union status of the scaffold erector, and no correlation was found with geography, site size, number of scaffold users, and trade working on the scaffold. DISCUSSION: Recommendations are made for safer scaffold practice, including a simple four-factor scaffold inspection method. IMPACT ON INDUSTRY: Implementation of the four-factor method could result in a cost-effective way to identify unsafe scaffolds.

Hatipkarasulu, Y. (2010). "Project level analysis of special trade contractor fatalities using accident investigation reports." J Safety Res 41(5): 451-457.

INTRODUCTION: Construction is among the most dangerous industries in the United States accounting for thousands of fatalities every year. Although there is data available on high risk work types and areas, the project-level detail is not readily available. METHOD: This paper uses the accident investigation reports to categorize project types and presents project level analysis of 350 fatal accidents for special trade contractors. RESULTS: The results showed that Residential and Commercial projects lead the fatalities where Falls are observed as the leading cause. However, when the fatality causes and project categories are analyzed for each work type, the results showed different fatality cause proportions for each project type. IMPACT ON INDUSTRY: Project level analysis approach has a direct impact on identifying high risk work types and areas for special trade contractors by making it possible to focus the prevention and intervention efforts more accurately, while highlighting training and education needs.

Hindman, D. P., et al. (2014). "Bracing of wood composite I-joists to resist lateral buckling from walking loads." Journal of Construction Engineering and Management 140(9).

Lateral buckling of unbraced beams during construction may be an important cause of fatalities and injuries. Temporary bracing to restrict lateral buckling is a potential preventive approach, but has received little study. Lateral acceleration, lateral displacement, and rotation of wood composite I-joists were measured under different bracing conditions while participants traversed the joists. Five different bracing stiffnesses and two different bracing placements were examined. Lateral displacement and rotation increased near the midspan of the joist, while acceleration remained consistent. Greater lateral displacement and rotation were found with increasing participant weight and lack of construction experience. Construction experience was found to be a significant factor in the amount of joist motion. A safety platform similar to the testing methods discussed may have potential as a training tool to expose workers to partially braced joists. The relationship of lateral displacement and rotation with bracing stiffness was nonlinear. Bracing placement had little effect upon lateral displacement and rotation. Increased bracing stiffness reduced lateral displacement and rotation at a decreasing rate, indicating that bracing stiffness can be optimized to reduce cost. © 2014 American Society of Civil Engineers.

Hindman, D. P., et al. (2017). "Simulating Loads on a Roof Structure Caused by a Worker Falling from a Roof Edge." Journal of Architectural Engineering 23(1).

Changes in the Occupational Safety and Health Administration (OSHA) fall-protection guidelines for residential construction since late 2011 have required the use of fall-protection and fall-arrest systems for workers past a certain height. Evaluation of fall-arrest anchor capacity depends on placement within a structure and includes strength of connections, truss/rafter elements, and bracing. The purpose of this study was to explore the use of a displacement-rate test for evaluating the strength and stability of fall-arrest anchors connected to truss assemblies as a supplement to currently used drop-test methods. A two-truss assembly with bracing was used for comparison. A range of displacement rates from 254 mm/min (10 in./min) to 381 mm/min (15 in./min) was recommended for evaluating the capacity of truss assemblies. A comparison of truss-assembly failures found similar results for the displacement-rate test and the drop test. The addition of the displacement-rate test can provide valuable information about truss performance, including an estimation of maximum load on structures,

the ability to identify individual truss/bracing element failures, and the measurement of individual member deflection. © 2016 American Society of Civil Engineers.

Hsiao, H., et al. (2005). "Human responses to augmented virtual scaffolding models." Ergonomics 48(10): 1223-1242.

This study investigated the effect of adding real planks, in virtual scaffolding models of elevation, on human performance in a surround-screen virtual reality (SSVR) system. Twenty-four construction workers and 24 inexperienced controls performed walking tasks on real and virtual planks at three virtual heights (0, 6 m, 12 m) and two scaffolding-platform-width conditions (30, 60 cm). Gait patterns, walking instability measurements and cardiovascular reactivity were assessed. The results showed differences in human responses to real vs. virtual planks in walking patterns, instability score and heart-rate inter-beat intervals; it appeared that adding real planks in the SSVR virtual scaffolding model enhanced the quality of SSVR as a human - environment interface research tool. In addition, there were significant differences in performance between construction workers and the control group. The inexperienced participants were more unstable as compared to construction workers. Both groups increased their stride length with repetitions of the task, indicating a possibly confidence- or habit-related learning effect. The practical implications of this study are in the adoption of augmented virtual models of elevated construction environments for injury prevention research, and the development of programme for balance-control training to reduce the risk of falls at elevation before workers enter a construction job.

Hsiao, H., et al. (2012). "Impact of harness fit on suspension tolerance." Hum Factors 54(3): 346-357.

Objective: This study investigated the effect of body size and shape and harness fit on suspension tolerance time. Background: Fall victims may develop suspension trauma, a potentially fatal reduction of return blood flow from legs to the heart and brain, after a successfully arrested fall if they are not rescued quickly or the harness does not fit them well.Method: For this study, 20 men and 17 women with construction experience were suspended from the dorsal D-ring of a full-body fall-arrest harness. Their suspension tolerance time, physical characteristics, and harness fit levels were assessed.Results: Body characteristics (i.e., weight, stature, upper- and lower-torso depths) were associated with decreased suspension tolerance time . In addition, harness fit affected suspension tolerance time; workers with a torso angle of suspension greater than 35-¦, a thigh strap angle greater than 50-¦, or a poorly fitting harness size had shorter suspension tolerance time (mean differences = 14, 11, and 9.8 min, respectively).Conclusion: Body size and harness fit were predictors of suspension tolerance time. Selecting well-fit harnesses and establishing a 9-min rescue plan are suggested to ensure that no more than 5% of workers would experience suspension trauma.Applications: The study provides a basis for harness designers, standards writers, and manufacturers to improve harness configurations and testing requirements for better worker protection against suspension trauma.

Hsiao, H., et al. (2009). "Harness sizing and strap length configurations." Hum Factors 51(4): 497-518.

Objective: This article describes the derivation of strap lengths and adjustments to fall-arrest harnesses and the development of harness size configurations. Background: Updated harness sizing configurations are needed to accommodate diverse populations in the current

workforce. Method: Three-dimensional torso anthropometric data from 243 women and 258 men were incorporated into eight validated equations to develop a cost-effective harness sizing plan and to define strap lengths. Results: To met strap adjustable range goals and to accommodate 95% to 98% of the estimated population, two sizing options were identified. Conclusion: Study outcomes suggest system improvement with three to four sizes for women and three to four sizes for men, on which the adjustment ranges of the torso straps were within 15 to 17 cm and within 20 to 23 cm on thigh and hip straps. Application: This research provided harness sizing and cut-length information for harness design to reduce the risk of worker injury that results from poor fit or improper size selection.

Hung, Y.-H., et al. (2013). "Identifying fall-protection training needs for residential roofing subcontractors." Appl Ergon 44(3): 372-380.

Falls remain the leading cause of injuries and fatalities in the small residential roofing industry and analogous investigations are underrepresented in the literature. To address this issue, fall-protection training needs were explored through 29 semi-structured interviews among residential roofing subcontractors with respect to recommendations for the design of fall-protection training. Content analysis using grounded theory was conducted to analyze participants' responses. Results of the analysis revealed six themes related to the design of current fall-protection training: (1) barriers to safety training; (2) problems of formal safety-training programs; (3) recommendations for training implementation; (4) important areas for fall-protection training; (5) training delivery means; and (6) design features of training materials. Results of the study suggest the need for informal jobsite safety training to complement what had been covered in formalized safety training. This work also provides recommendations for the design of a more likely adopted fall-protection training program.

Hurtado, D., et al. (2020). "Does Experiencing an Injury Claim Impact Small Construction Company Leaders' Participation in a Fall Protection Survey?" Ann Work Expo Health 64(8): 897-902.

OBJECTIVES: Workers in small and medium residential construction companies (</=50 employees) have a high risk of fall-related fatality or disability. However, little is known about effective ways to engage with this subsector for research and training. We tested whether insurance-documented fall-related claims during the past 12 months and lower familiarity with equipment motivated companies' representatives to engage with a fall protection survey. METHODS: Oregon's largest workers compensation insurer drew a random anonymous sample of small and medium residential construction that did (n = 197) and did not (n = 195) have a recent fall-related claim. Samples were stratified by size, trade, and region. Company representatives were emailed a 34-item questionnaire about equipment familiarity to enter a raffle to win fall-prevention equipment. We coded survey engagement binarily, indicating whether a participant completed at least half of the survey. Familiarity with 10 pieces of equipment was measured with a scale from 0 (never seen it) to 3 (use it frequently) points. RESULTS: The survey was initiated by 88 out of 392 representatives (22.4% response rate). Of those, 63 representatives provided the company identifier which was needed to establish claim status. Survey engagement was higher among representatives from companies with claims compared with those without (57.6 versus 42.4%, P = 0.16). Equipment familiarity was lower among company representatives with lower survey engagement (1.15 versus 1.56, P < 0.05). CONCLUSIONS: The survey had a relatively encouraging response rate for a hard-to-reach

sector. The large but not statistically significant difference in survey engagement rates suggests that adverse events motivate companies to engage with fall protection research. Low equipment familiarity in the sample substantiates the need to identify effective engagement methods for fall protection practices.

Husberg, B. J., et al. (2005). "Hospitalized nonfatal injuries in the Alaskan construction industry." Am J Ind Med 47(5): 428-433.

BACKGROUND: Construction industry workers are exposed to many hazards leading to fatal and nonfatal injuries. Information for nonfatal work-related injury surveillance may be vague and come from a variety of sources. METHODS: The Alaska Trauma Registry (ATR) is used as an injury surveillance tool to focus on hospitalized nonfatal injuries in the Alaskan construction industry. RESULTS: During 1991-1999, 717 workers in the Alaskan construction industry were hospitalized due to occupational injuries, with an average annual injury rate of 0.39 injuries/100 workers. Leading causes of injury included falls (48%) and machinery (15%). Thirty-four percent of the falls were from a building or structure, followed by falls from a ladder (24%). A fractured bone was the most common type of injury (57%). CONCLUSIONS: Information on hospitalized patients from the ATR focuses on the more severe and debilitating injuries, and provides valuable information for prioritizing injury prevention efforts in Alaska.

Irizarry, J., et al. (2005). "Effect of safety and environmental variables on task durations in steel erection." Journal of Construction Engineering and Management 131(12): 1310-1319.

In spite of the efforts by government agencies, labor organizations, and researchers in the field of health and safety, injuries and fatalities continue to affect the construction industry. In 2002 the construction industry had the undesirable distinction of having two of the most dangerous occupations in the United States, with fatalities among structural steel workers at 58.2 per 100,000 workers (fourth highest rate) and among construction laborers at 27.7 per 100,000 workers (ninth highest rate). Costs associated with construction accidents, such as increased insurance premiums and medical expenses, and loss of productivity are also concerns in the industry. It has not been demonstrated how unsafe working conditions affect worker performance, and the impact of unsafe work practices on worker performance has not been quantified. This paper describes a methodology that included direct observation of steel erection activities and statistical analysis of task duration data. The data collected at steel erection sites included safety conditions such as the use of personal protective equipment (PPE), elevation of the work area, environmental conditions such as temperature and humidity, and worker performance in the form of task durations. Analysis of variance (ANOVA) analysis of 186 of steel erection task durations collected over a six-month period showed that the use of personal protective equipment (PPE), the time of day during which the operation was being performed, the elevation at which the work was being performed, and the presence of decking below the work area had statistically significant effects on the durations of steel erection tasks.

Jackson, S. A. and D. Loomis (2002). "Fatal occupational injuries in the North Carolina construction industry, 1978-1994." Appl Occup Environ Hyg 17(1): 27-33.

Occupational injury is a major public health problem and the cause of high rates of fatalities. The construction industry is one of the leading industries for on-the-job fatalities. The North Carolina Medical Examiner's system was used to identify all fatal unintentional injuries that occurred on the job in the state's construction industry between 1978 and 1994. The

populations at risk were estimated from the 1980 and 1990 U.S. censuses. There were 525 identified deaths. All except two decedents were male, and the majority were Caucasian (79.2%). The mean age of decedents was 39 years. Death rates were higher among older workers. The crude fatality rate for the overall study period was 15.4 per 100,000 worker-years, with higher rates found among African-Americans (22.9) than among Caucasians (14.5). Occupations within the industry with the highest rates were laborers (49.5), truck drivers (43.2), operating engineers (37.2), roofers (32.8), and electricians (29.0). Falls (26.7%), electrocutions (20.4%), and motor vehicle accidents (18.9%) were found to be the leading causes of death. These findings suggest a need for continued attention to the hazards of heights and electric currents and a need for occupational safety standards for motor vehicles. This study also suggests that the hazards facing construction laborers require further investigation.

Jebelli, H., et al. (2016). "Comprehensive Fall-Risk Assessment of Construction Workers Using Inertial Measurement Units: Validation of the Gait-Stability Metric to Assess the Fall Risk of Iron Workers." Journal of Computing in Civil Engineering 30(3).

In construction worksites, slips, trips, and falls are major causes of fatal injuries. This fact demonstrates the need for a safety assessment method that provides a comprehensive fall-risk analysis inclusive of the effects of physiological characteristics of construction workers. In this context, this research tests the usefulness of the maximum Lyapunov exponents (Max LE) as a metric to assess construction workers' comprehensive fall risk. Max LE, one of the gait-stability metrics established in clinical settings, estimates how the stability of a construction worker reacts to very small disruptions. In order to validate the use of Max LE, a laboratory experiment that asked a group of subjects to simulate iron workers' walking tasks on an I-beam was designed and conducted. These tasks were designed to showcase various fall-risk profiles: walking with a comfortable walking speed presented a low fall-risk profile; carrying a one-sided load and walking at a faster speed on the I-beam both presented high fall-risk profiles. Inertial measurement unit (IMU) sensors were attached to the right ankle of participants' bodies to collect kinematic data for the calculation of Max LE. The results showed that Max LE offers adequate distinguishing power for characterizing the fall risk of various construction workers' tasks, and the introduced approach to compute the gait stability from IMU sensor data captured from human bodies could provide a valuable analysis of the safety-related risks present in construction workers' motions. © 2015 American Society of Civil Engineers.

Jebelli, H., et al. (2016). "Fall risk analysis of construction workers using inertial measurement units: Validating the usefulness of the postural stability metrics in construction." Safety science 84: 161-170.

Fall accidents are a leading cause of fatalities and injuries in the construction industry, and the loss of bodily stability is one of the primary factors contributing to such falls. Body stability can be analyzed by studying dynamic and postural stability, the assessment of which can ultimately improve worker safety on the job sites. Previous studies have introduced a method for assessing construction workers' gait stability, but there remains a need for a comprehensive method that can analyze the fall-risk of construction workers' in stationary postures. This study aims to test the usefulness of two metrics-velocity of the bodily center of pressure (COPv) and the resultant accelerometer (rAcc)-as predictors with which to measure workers' fall risk in stationary postures. A laboratory experiment was designed and conducted to gather IMU data and compare the resulting stability metrics (I-COPv and rAcc) with the

postural stability observed while conducting the same activities on a forceplate (F-COPv). The experiment evaluated stationary-posture tasks with various fall-risk profiles: standing and squatting in different situations (e.g. wearing a loaded harness with a symmetric and an asymmetric load, and holding a toolbox). The analysis's results demonstrated a significant difference in I-COPv and rAcc values across different postures and tasks and also showed considerable correlations between the metrics from both the force plate and the IMU sensors. The results showed the distinguishing power of I-COPv and rAcc in measuring the fall risk of different construction workers' tasks in the stationary posture. © 2015 Elsevier Ltd.

Jensen, R. C. and C. J. Holland (2020). "Ladder Safety: A Taxonomy of Limb-Movement Patterns for Three Points of Control." Int J Environ Res Public Health 17(8).

Traditional guidance on ladder safety emphasizes training workers on the use of three points of contact. More recent guidance is to train workers to use three points of control. What is lacking is empirical information about what limb-movement patterns effectively support the use of three points of control. This project was conducted to establish a taxonomy of possible limb-movement patterns and a means for comparing relative safety. Prior to the experiment, a taxonomy of six possible limb-movement patterns was established. A sample of 20 undergraduate students performed four tasks each without any instructions on limb-movement pattern. The tasks were ascending and descending a straight ladder and a portable ladder, once each, while being videotaped. Out of 80 observed tasks, 59 of the subjects were using rungs rather than rails. Analysis of rung users identified the use of all six patterns. An innovative measure of safe performance was developed and used to compare the patterns. Statistical analysis did not find significant differences in the patterns based on the safety performance measure.

Kaskutas, V. (2014). "Fall Protection Resources for New Home Construction (CPWR Report)."

Kaskutas, V., et al. (2016). "Foremen's intervention to prevent falls and increase safety communication at residential construction sites." Am J Ind Med 59(10): 823-831.

Background: This research aimed to improve residential construction foremen's communication skills and safety behaviors of their crewmembers when working at heights. Methods: Eighty-four residential construction foremen participated in the 8-hr fall prevention and safety communication training. We compared pre- and post-intervention surveys from foremen and their crewmembers to measure the effect of training. Results: Foremen and crewmembers' ratings showed improvements in fall prevention knowledge, behaviors, and safety communication and were sustained 6-months post-training, with emphasized areas demonstrating larger increases. Ratings were similar between foremen and crewmembers, suggesting that the foremen effectively taught their crew and assigned accurate ratings. Based upon associations between safety behaviors and reported falls observed in prior research, we would expect a 16.6% decrease in the one year cumulative incidence of self-reported falls post-intervention. Conclusions: This intervention improved safety knowledge and behaviors of a large number of workers by training construction foremen in fall prevention and safety communication skills. Am. J. Ind. Med. 59:823–831, 2016. © 2016 Wiley Periodicals, Inc. © 2016 Wiley Periodicals, Inc.

Kaskutas, V., et al. (2013). "Fall prevention and safety communication training for foremen: Report of a pilot project designed to improve residential construction safety." J Safety Res 44: 111-118.

PROBLEM: Falls from heights account for 64% of residential construction worker fatalities and 20% of missed work days. We hypothesized that worker safety would improve with foremen training in fall prevention and safety communication. METHOD: Training priorities identified through foreman and apprentice focus groups and surveys were integrated into an 8-hour training. We piloted the training with ten foremen employed by a residential builder. Carpenter trainers contrasted proper methods to protect workers from falls with methods observed at the foremen's worksites. Trainers presented methods to deliver toolbox talks and safety messages. Results from worksite observational audits (n=29) and foremen/crewmember surveys (n=97) administered before and after training were compared. RESULTS: We found that inexperienced workers are exposed to many fall hazards that they are often not prepared to negotiate. Fall protection is used inconsistently and worksite mentorship is often inadequate. Foremen feel pressured to meet productivity demands and some are unsure of the fall protection requirements. After the training, the frequency of daily mentoring and toolbox talks increased, and these talks became more interactive and focused on hazardous daily work tasks. Foremen observed their worksites for fall hazards more often. We observed increased compliance with fall protection and decreased unsafe behaviors during worksite audits. DISCUSSION: Designing the training to meet both foremen's and crewmembers' needs ensured the training was learner-centered and contextually-relevant. This pilot suggests that training residential foremen can increase use of fall protection, improve safety behaviors, and enhance on-the-job training and safety communication at their worksites. IMPACT ON INDUSTRY: Construction workers' training should target safety communication and mentoring skills with workers who will lead work crews. Interventions at multiple levels are necessary to increase safety compliance in residential construction and decrease falls from heights.

Kaskutas, V., et al. (2010). "Fall prevention among apprentice carpenters." Scand J Work Environ Health 36(3): 258-265.

OBJECTIVES: Falls from heights are a leading cause of mortality and morbidity in the construction industry, especially among inexperienced workers. We surveyed apprentice carpenters to identify individual and organizational factors associated with falls from heights. METHODS: We developed a 72-item survey on fall prevention with multiple domains including fall experience, fall-prevention knowledge, risk perceptions, confidence in ability to prevent falls, training experience, and perceptions of the safety climate and crew safety behaviors. We administered the questionnaire to apprentice carpenters in this cross-sectional study. RESULTS: Of the 1025 respondents, 51% knew someone who had fallen from a height at work and 16% had personally fallen in the past year, with ladders accounting for most of the falls. Despite participation in school-based and on-the-job training, fall-prevention knowledge was poor. Ladders were perceived as low risk and ladder training was rare. Apprentices reported high levels of unsafe, fall-related behaviors on their work crews. Apprentices in residential construction were more likely to fall than those in commercial construction, as were apprentices working on crews with fewer senior carpenters to provide mentorship, and those reporting more unsafe behaviors among fellow workers. CONCLUSIONS: Despite participation in a formal apprenticeship program, many apprentices work at heights without adequate preparation and subsequently experience falls. Apprenticeship programs can improve the timing and content of

fall-prevention training. This study suggests that organizational changes in building practices, mentorship, and safety practices are also necessary to decrease worker falls from heights.

Kaskutas, V., et al. (2010). "Changes in fall prevention training for apprentice carpenters based on a comprehensive needs assessment." J Safety Res 41(3): 221-227.

PROBLEM: Falls from heights in residential construction are common, especially among inexperienced workers. METHODS: We conducted a comprehensive needs assessment to determine gaps in the school-based apprentice carpenters' fall prevention training. A team of carpenter instructors and researchers revised the fall prevention training to fill these gaps. Apprentice evaluation and feedback guided ongoing curricular improvements. RESULTS: Most apprentice carpenters performed work tasks at heights prior to training and fall protection techniques were not commonly used at residential construction sites. Priorities of the revised school-based training included safe ladder habits, truss setting, scaffold use, guarding floor openings, and using personal fall arrest systems. New apprentices were targeted to ensure training prior to exposure at the workplace. We used adult learning principles to emphasize hands-on experiences. A framed portion of a residential construction site was fabricated to practice fall protection behaviors in a realistic setting. The revised curriculum has been delivered consistently and apprentice feedback has been very favorable. CONCLUSIONS: Integration of needs assessment results was invaluable in revising the school-based carpenters apprentice fall prevention curriculum. Working closely with the instructors to tailor learning experiences has provided preliminary positive results. IMPACT ON INDUSTRY: The fall safety of the residential construction industry continues to lag behind commercial construction and industrial settings. The National Occupational Research Agenda includes a Strategic Goal to strengthen and extend the reach of quality training and education in the construction industry via mechanisms such as construction safety and health training needs assessments. This study demonstrates how a structured process can be used to identify and remedy gaps and improve training effectiveness. We encourage others to take steps to assess and increase the impact of training efforts directed at all residential construction professionals; including both union and non-union workers. The implications are even greater in the non-union sector where most U.S. residential work is done.

Kaskutas, V., et al. (2009). "Fall hazard control observed on residential construction sites." Am J Ind Med 52(6): 491-499.

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.

Kaskutas, V., et al. (2013). "Fall prevention on residential construction sites." Professional Safety 58(7): 36.

Kaskutas, V. and K. Hunsberger (2013). "Residential fall protection case study: Habitat for Humanity St. Louis." Wood Design Focus.

Kaskutas, V. K., et al. (2008). "Development of the St. Louis audit of fall risks at residential construction sites." Int J Occup Environ Health 14(4): 243-249.

We describe the development and pilot testing of the St. Louis Assessment of Fall Risks, a worksite audit to assess fall prevention safety practices on residential construction sites. Surveillance data and feedback from carpenters and safety instructors regarding work tasks associated with falls from heights were used to develop the audit instrument. The audit focuses on the framing process, including general safety climate/housekeeping, floor joist/sub-floor installation, walking surfaces/edges, wall openings, truss setting, roof sheathing, ladders, scaffolds, and personal fall arrest equipment. The audit was tested at sixteen residential construction sites, documenting excellent inter-rater reliability (kappa = 0.93). Results suggest that the audit has good face and content validity and is a reliable instrument for measuring fall safety risks at residential construction sites. It is practical, easy, and safe to administer, making it a potentially useful instrument for field research as well as regular safety monitoring by foremen and crew.

Kazan, E. and M. A. Usmen (2018). "Worker safety and injury severity analysis of earthmoving equipment accidents." J Safety Res 65: 73-81.

INTRODUCTION: Research on construction worker safety associated with construction equipment has mostly focused on accident type rather than injury severity and the embedded factor relationships. Significant variables and their effects on the degree of injury are examined for earthmoving equipment using data from OSHA. Four types of equipment, backhoe, bulldozer, excavator, and scraper are included in the study. Accidents involving on-foot workers and equipment operators are investigated collectively, as well as separately. METHODS: Cross tabulation analysis was conducted to establish the associations between selected categorical variables, using degree of injury as a dichotomous dependent variable (fatal vs. nonfatal) and a number of independent variables having different values. Odds ratios were calculated to determine how much a certain variable/factor increases the odds of fatality in an accident, and the odds ratios were ranked to determine the relative impact of a given factor. RESULTS: It was found that twelve variables were significantly associated with injury severity. Rankings based on odds ratios showed that inadequate safety training (2.54), missing equipment protective system (2.38), being a non-union worker (2.26), being an equipment operator (1.93), and being on or around inadequately maintained equipment (1.58) produced higher odds for fatality. CONCLUSION: A majority of the earthmoving equipment accidents resulted in fatality. Backhoes were the most common equipment involved in accidents and fatalities. Struck-by accidents were the most prevalent and most fatal. Non-OSHA compliant safety training, missing seatbelt, operator not using seatbelt, malfunctioning back-up alarms, and poorly maintained equipment were factors contributing to accidents and fatalities. On-foot workers experienced a higher number of accidents than operators, while fatality odds were higher for the operators. Practical applications: Safety professionals should benefit from our

findings in planning and delivering training and providing oversight to workers in earthmoving equipment operations.

Kidd, P., et al. (2004). "Overcoming recruitment challenges in construction safety intervention research." Am J Ind Med 45(3): 297-304.

BACKGROUND: Recruiting workers in small construction companies and securing their participation in voluntary safety programs or safety research poses unique challenges. Worker turnover and worksite changes contribute to difficulties in locating and enrolling participants. Economic pressures and time demands potentially threaten ongoing participation. METHODS: Six simulation exercises designed to reduce back and fall injuries in small construction companies were developed based on data from focus groups of workers and company owners. Working with a workers' compensation insurer, we had access to owner-operators of general, heavy, and special trade construction companies reporting less than $10,000 in payroll expenses. Recruitment methods included a participation incentive, mailed invitations followed by phone contacts, and follow-up reminders. RESULTS: Despite using recruitment methods recommended in the literature, participation rates were low over a 2-year intervention period. Because of these difficulties, factors affecting participation or nonparticipation became an additional research focus. Owners' perceptions of already having a good safety record and of the time demands of participation were the most commonly cited reasons for not participating. CONCLUSIONS: Literature on recruitment emphasizes processes and procedures under investigator control rather than understanding potential participants' judgments about the adequacy of their existing practices and the potential benefits of intervention participation relative to potential time and productivity trade-offs. Greater attention to such judgments may enhance recruitment and participation in under-studied and difficult to access populations.

Konda, S., et al. (2020). "Workers' compensation claims for traumatic brain injuries among private employers-Ohio, 2001-2011." Am J Ind Med 63(2): 156-169.

BACKGROUND: The purpose of this analysis was to identify and prioritize high-risk industry groups for traumatic brain injury (TBI) prevention efforts. METHODS: Workers with TBI from 2001 to 2011 were identified from the Ohio Bureau of Workers' Compensation data. To prioritize industry groups by claim type (lost-time (>/=8 days away from work) and total claims) and injury event categories, we used a prevention index (PI) that averaged TBI counts and rate ranks (PI = (count rank + rate rank)/2). TBI rates per 10 000 estimated full-time equivalent (FTE = 2000 h/y) workers were calculated. RESULTS: From 2001 to 2011, 12 891 TBIs were identified among private employers, resulting in a rate of 5.1 TBIs per 10 000 FTEs. Of these, 40% (n = 5171) were lost-time TBIs, at a rate of 2.0 per 10 000 FTEs. Spectator Sports had the highest lost-time TBI rate (13.5 per 10 000 FTEs), whereas General Freight Trucking had the greatest number of lost-time TBIs (n = 293). Based on PIs, General Freight Trucking ranked first for lost-time TBIs for all injury events combined. Several industry groups within Construction, General and Specialized Freight Trucking, Services to Building and Dwellings, Employment Services, and Restaurants and Other Eating Places ranked high across multiple injury event categories for lost-time TBIs. CONCLUSIONS: The high-ranking industry groups identified from our study can be used to effectively direct occupational TBI prevention efforts.

Konda, S., et al. (2016). "Fatal traumatic brain injuries in the construction industry, 2003-2010." Am J Ind Med 59(3): 212-220.

Background: Research on fatal work-related traumatic brain injuries (TBIs) is limited. This study describes fatal TBIs in the US construction industry. Methods: Fatal TBIs were extracted from the Bureau of Labor Statistics Census of Fatal Occupational Injuries. Results: From 2003 to 2010, 2,210 fatal TBIs occurred in construction at a rate of 2.6 per 100,000 full-time equivalent (FTE) workers. Workers aged 65 years and older had the highest fatal TBI rates among all workers (7.9 per 100,000 FTE workers). Falls were the most frequent injury event (n=1,269, 57%). Structural iron and steel workers and roofers had the highest fatal TBI rate per 100,000 FTE workers (13.7 and 11.2, respectively). Fall-related TBIs were the leading cause of death in these occupations. Conclusions: A large percentage of TBIs in the construction industry were due to falls. Emphasis on safety interventions is needed to reduce these fall-related TBIs, especially among vulnerable workers. Am. J. Ind. Med. 59:212-220, 2016. Published 2016. This article is a U.S. Government work and is in the public domain in the USA. © 2016 Wiley Periodicals, Inc.

Lee, H. W., et al. (2017). "Applying Prevention through Design (PtD) to Solar Systems in Small Buildings (CPWR Report)."

Lee, S. and T. Armstrong (2014). "Field Tool for On-Site Biomechanical Analysis During Ladder Climbing (CPWR Report)."

LeMasters, G., et al. (2006). "Functional impairment and quality of life in retired workers of the construction trades." Exp Aging Res 32(2): 227-242.

This cross-sectional study compared the quality of life and physical health of retirees from the construction industry to that of retirees from more sedentary occupations. The feasibility of cooperation from the unions and their retirees for a larger health study was also examined. The mailed health survey assessed current physical functioning, role limitations as a result of poor health, pain, and past and current problems with falls and injuries. The survey was completed by 77 construction and 174 nonconstruction retirees. Results were striking with 42.1% of the construction retirees, compared to 12.9% of the male and 14.3% of female nonconstruction retirees reporting significantly poorer health. A multiple regression analysis comparing male construction to male nonconstruction retirees showed male construction retirees were almost five times more likely to report their health as being fair or poor. Further, significantly more male construction, versus male nonconstruction retirees, reported that their physical health reduced the time they were able to spend on daily activities. Almost one in five (19.4%) construction retirees described themselves as having severe to very severe pain versus 3.1% of the male nonconstruction retirees. Construction retirees reported significantly greater problems with their vision, neck and shoulders, hands and wrists, hips, knees, and ankle/feet joints. These findings suggest that with our rapidly aging population, there will be enormous physical, emotional, and financial costs related to construction work and that prevention and intervention measures are needed for current employees in this profession.

Lin, K.-Y., et al. (2018). "Training of Low-Literacy and Low-English-Proficiency Hispanic Workers on Construction Fall Fatality." Journal of Management in Engineering 34(2): 05017009.

The construction industry has made extensive efforts to improve the safety of its labor force through various approaches, including training. However, many construction workers in the United States are recent immigrants who lack English proficiency and do not possess sufficient literacy levels in their own language for training comprehension. This reduces the effectiveness of traditional text-dominated translated training materials, which depend on both literacy and proficiency in a language. Thus, in this study, the authors used three-dimensional (3D) visualization to overcome the communication barriers that hinder effective safety training for low-literacy (LL) and low-English-proficiency (LEP) construction workers. This article summarizes the contributions of a study sponsored by the Occupational Safety and Health Administration (OSHA) Susan Harwood Training Grant Program; it describes the methodology to develop scenario-based 3D training materials on fall safety for LL and LEP workers and to validate the effectiveness of the materials. The results show that 3D training materials improve interaction between trainer and trainee during safety training, facilitate learning processes, and can overcome some of the communication barriers that hinder effective safety training.

Lipscomb, H. J., et al. (2008). "Challenges in residential fall prevention: insight from apprentice carpenters." Am J Ind Med 51(1): 60-68.

BACKGROUND: Falls remain a serious source of morbidity and mortality in residential construction despite considerable knowledge of risk factors and prevention strategies. While training is universally viewed as positive, we know little about its effectiveness in preventing residential falls. METHODS: A series of focus groups were conducted with union apprentice carpenters (n = 36) at varied levels of training to elicit input on factors that might influence the effectiveness of residential fall prevention training, including hazard awareness, timing of elements of formal instruction, jobsite mentoring, and workplace norms. RESULTS: While apprentices identified many residential fall hazards, they voiced little concern about work near unprotected vertical or horizontal openings such as stairwells, window openings or leading edges. On residential jobs, apprentices worked at heights immediately and were often exposed to hazards they had not yet been trained to handle. The quality of mentoring varied tremendously, and things they had been taught in school were often not the norm on these small worksites. Use of fall arrest equipment was uncommon. Job insecurity in this fast-paced work environment influenced behaviors even when apprentices reported knowledge of safe procedures; this was more of a problem for less experienced apprentices. CONCLUSIONS: These data provide compelling evidence that apprentices often do not apply safety principles they have been taught in school in the actual work environment, illuminating how attempts to empower workers through training alone can fall short. The findings have policy implications and demonstrate the importance of measuring more than knowledge when evaluating effectiveness of training.

Lipscomb, H. J., et al. (2003). "Falls in residential carpentry and drywall installation: findings from active injury surveillance with union carpenters." J Occup Environ Med 45(8): 881-890.

Active injury surveillance was conducted with a large, unionized workforce of residential and drywall carpenters over a 3-year period. Injured carpenters were interviewed by trained carpenter investigators and sites were visited where falls occurred. Qualitative information was collected on exposures, risk perception, training, and mentoring. Falls accounted for 20% of injuries. Same-level falls were often related to weather, carrying objects-sometimes with an obstructed view-housekeeping, terrain of the lot, and speed of work. Falls

from height occurred from a variety of work surfaces and involved ladders, scaffolding, roofs, work on other unsecured surfaces, unprotected openings, speed, and weather conditions. Recognized fall protection strategies, such as guardrails, toe boards, tying off to appropriate anchors, and guarding openings, would have prevented many of these falls; these practices were not the norm on many sites.

Lipscomb, H. J., et al. (2004). "Analysis of text from injury reports improves understanding of construction falls." J Occup Environ Med 46(11): 1166-1173.

OBJECTIVE: We combined payroll data, coded workers' compensation (WC) data, and text descriptions of injuries from the construction of Denver International Airport to create a more comprehensive picture of falls from height (FFH) than is typically available from WC data. Text descriptions were coded to identify circumstances surrounding falls. Slips/trips preceded one third of FFH, often involving motor vehicles or heavy equipment. Another third involved movement or collapse of work surfaces, usually ladders or scaffolds. CONCLUSIONS: The significant contribution of motor vehicles and heavy equipment to FFH, particularly those preceded by slips/trips, was not apparent from coded data. Heavy equipment engineering modifications are called for and workers in street/roadway construction/site development need fall protection training. Text analyses allow exploration of factors not identified at the time of data collection and better understanding of the context in which injuries occur.

Lipscomb, H. J., et al. (2006). "Injuries from slips and trips in construction." Appl Ergon 37(3): 267-274.

Construction injuries preceded by a slip or trip were documented using data from the building of the Denver International Airport (Denver, Colorado, USA), the largest construction project in the world at the time. Slips and trips occurred at a rate of 5/200,000 h worked accounting for 18% of all injuries and 25% of workers' compensation payments, or more than $10 million. Slips contributed to the vast majority (85%) of same-level falls and over 30% of falls from height, as well as a significant number of musculoskeletal injures sustained after slipping or tripping but without falling. The injury burden would have been under-recognized in analyses of most coded compensation records. In contrast to other types of injuries, the most common contributing factors were environmental in nature including conditions of walking and working surfaces, terrain and weather. Due to the very dynamic nature of construction work, reducing slips and trips will require a focus on environmental and organizational solutions that evolve as the site changes and the construction project evolves.

Lipscomb, H. J., et al. (2014). "How well are we controlling falls from height in construction? Experiences of union carpenters in Washington State, 1989-2008." Am J Ind Med 57(1): 69-77.

Background: Falls from height (FFH) continue to cause significant morbidity and mortality across the construction industry. Methods: By linking data on work hours with workers' compensation records, rates of work-related injuries resulting from FFH and associated days away from work were evaluated among a large cohort (n=24,830) of union carpenters in Washington State from 1989 to 2008. Using Poisson regression we assessed rates of FFH over the 20-year period while adjusting for temporal trend in other work-related injuries. Patterns of paid lost days (PLDs) were assessed with negative binomial regression. Results: Crude rates of FFH decreased 82% over the 20-year period. Reductions were more

modest and without demonstrable change since 1996 when adjusting for the temporal reduction in other injuries. Younger workers had higher injury rates; older workers lost more days following falls. Rates of PLDs associated with falls decreased over time, but there was not a consistent decline in mean lost days per fall. Conclusion: These patterns are consistent with decreased FFH for several years surrounding state (1991) and then federal (1994) fall standards; the decline during this time period exceeded those seen in injury rates overall in this cohort. While crude rates of FFH have continued to decline, the decline is not as substantial as that seen for other types of injuries. This could reflect a variety of things including more global efforts designed to control risk (site planning, safety accountability) and changes in reporting practices. Am. J. Ind. Med. 57:69-77, 2014. © 2013 Wiley Periodicals, Inc.

Lipscomb, H. J., et al. (2014). "Twenty years of workers' compensation costs due to falls from height among union carpenters, Washington State." Am J Ind Med 57(9): 984-991.

Background: Falls from height (FFH) are a longstanding, serious problem in construction. Methods: We report workers' compensation (WC) payments associated with FFH among a cohort (n=24,830; 1989-2008) of carpenters. Mean/median payments, cost rates, and adjusted rate ratios based on hours worked were calculated using negative-binomial regression. Results: Over the 20-year period FFH accounted for $66.6 million in WC payments or $700 per year for each fulltime equivalent (2,000hr of work). FFH were responsible for 5.5% of injuries but 15.1% of costs. Cost declines were observed, but not monotonically. Reductions were more pronounced for indemnity than medical care. Mean costs were 2.3 times greater among carpenters over 50 than those under 30; cost rates were only modestly higher. Conclusions: Significant progress has been made in reducing WC payments associated with FFH in this cohort particularly through 1996; primary gains reflect reduction in frequency of falls. FFH that occur remain costly. Am. J. Ind. Med. 57:984-991, 2014. © 2014 Wiley Periodicals, Inc.

Lipscomb, H. J., et al. (2010). "Nonfatal tool- or equipment-related injuries treated in US emergency departments among workers in the construction industry, 1998-2005." Am J Ind Med 53(6): 581-587.

BACKGROUND: Individuals in the construction industry are exposed to a variety of tools and pieces of equipment as they work. METHODS: Data from the National Institute for Occupational Safety and Health (NIOSH) occupational supplement to the National Electronic Injury Surveillance System (NEISS-Work) were used to characterize tool- and equipment-related injuries among workers in the construction industry that were treated in US emergency departments between 1998 and 2005. Based on a national stratified probability sample of US hospitals with 24 hr emergency services, NEISS-Work allows calculation of national injury estimates. RESULTS: Over the 8-year period between 1998 and 2005, we estimated 786,900 (95% CI 546,600-1,027,200) ED-treated tool- or equipment-related injuries identified by the primary or secondary source of injury code. These injuries accounted for a quarter of all ED-treated construction industry injuries. Although over 100 different tools or pieces of equipment were responsible for these injuries, seven were responsible for over 65% of the injury burden: ladders, nail guns, power saws, hammers, knives, power drills, and welding tools in decreasing order. CONCLUSIONS: Current injury estimates and their severity, marked by the proportion of cases that were not released after ED treatment, indicate interventions are particularly needed to prevent injuries associated with use of ladders as well as nail guns and power saws. Attention should focus on design and guarding to more efficiently prevent these injuries rather than

simply calling for the training of workers in how to safely use a dangerous tool or piece of equipment.

Lombardi, D. A., et al. (2011). "Work-related falls from ladders--a follow-back study of US emergency department cases." Scand J Work Environ Health 37(6): 525-532.

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.

Macario, E., et al. (2015). "Preventing falls in residential construction: Effectiveness of engaging partners for a national social marketing campaign." Am J Ind Med 58(8): 809-823.

Marin, L. S. and C. Roelofs (2018). "Engaging Small Residential Construction Contractors in Community-Based Participatory Research to Promote Safety." Ann Work Expo Health 62(suppl_1): S72-S80.

Construction is a large employment sector with a high prevalence of small businesses. Despite the high injury rates reported for employees of small construction firms, these firms are under-represented in occupational safety research studies. Such studies are needed to understand barriers experienced by these firms and to examine ways to overcome them. However, challenges accessing and recruiting this hard-to-reach population are frequently reported. Traditional approaches of recruiting through unions or workers' compensation insurers may not be appropriate or effective for small construction businesses. Previous studies have demonstrated the value of academic collaborations with community-based organizations for recruiting participants from hard-to-reach populations for research studies. In accordance with the principles of Community-Based Participatory Research (CBPR), we formed a recruitment team comprised of staff from a local union, a community organization, and a community outreach team to recruit small construction contractors in Lawrence, MA. Media marketing

strategies, participation in community events, exploring neighborhoods in search of ongoing residential projects, and partnership with vocational training institutions and building trade associations were some of the strategies implemented during this project. We recruited 118 contractors, supervisors, and foremen from more than 50 construction firms across the Greater Lawrence area to participate in an intervention project to reduce falls and silica exposure. The CBPR approach facilitated the development and implementation of recruitment strategies that resulted in the participation of a significant number of hard-to-reach small construction contractors.

Marín, L. S. and C. Roelofs (2017). "Promoting Construction Supervisors' Safety-Efficacy to Improve Safety Climate: Training Intervention Trial." Journal of Construction Engineering and Management 143(8): 04017037.

Hispanic workers may be more likely to experience a deficient safety climate on construction worksites and it may account for their disproportionate injury rates. As part of a large study, the authors developed and implemented a 5-h training program to improve construction supervisors' safety-efficacy, in order to enhance the safety climate on construction worksites. The training program covered fall prevention, silica exposure, leadership, communication, and safety planning. This study evaluated pretraining and posttraining changes and safety-efficacy six months posttraining. A total of 118 supervisors, contractors, and workers from more than 50 construction firms in Massachusetts attended the training. Statistically significant improvements were observed in participants' safety knowledge, skills, and attitudes. Six-months postintervention, 58% of supervisors, contractors, or both, perceived that the training contributed "a lot" to their ability to communicate effectively with Spanish-speaking workers, to take on a safety leadership role (52%), and to conduct effective training (62%). This study determined that when supervisors perceive that they have the knowledge, skills, and confidence to make changes, they may better fulfill their role as a safety leader. Construction supervisor training courses might be revised to include leadership and effective communication topics. - See more at: http://ascelibrary.org/doi/full/10.1061/%28ASCE%29CO.1943-7862.0001330#sthash.bOwqmOhn.dpuf

McCann, M. (2003). "Deaths in construction related to personnel lifts, 1992-1999." J Safety Res 34(5): 507-514.

PROBLEM: This study examined deaths of construction workers due to personnel lifts (boom-supported and scissor lifts, suspended scaffolds, and crane platforms). METHODS: Deaths of construction workers for 1992-1999 were examined using data from the Census of Fatal Occupational Injuries, a Bureau of Labor Statistics database. RESULTS: The study identified 339 deaths: 42% from boom-supported lifts; 26% from suspended scaffolds; 19% from scissor lifts; 5% from crane platforms; and 7% from unapproved lifts (e.g., forklift platforms). The main causes of death were falls (36%), collapses/tipovers (29%), and electrocutions (21%). DISCUSSION: Recommendations include: following OSHA regulations, wearing personal fall protection equipment, adequate maintenance, inspection before use, and training on the model of lift used. Precautions are also needed to prevent contact with overhead power lines. IMPACT ON INDUSTRY: The increasing popularity of boom-supported lifts and scissor lifts, both in construction and other industries, make their safety an important issue.

McDonald, M. A., et al. (2009). ""Safety is everyone's job:" the key to safety on a large university construction site." J Safety Res 40(1): 53-61.

PROBLEM: Construction risk management is challenging. METHOD: We combined data on injuries, costs, and hours worked, obtained through a Rolling Owner-Controlled Insurance Program (ROCIP), with data from focus groups, interviews, and field observations, to prospectively study injuries and hazard control on a large university construction project. RESULTS: Lost-time injury rates (1.0/200,000 hours worked) were considerably lower than reported for the industry, and there were no serious falls from height. Safety was considered in the awarding of contracts and project timeline development; hazard management was iterative. A top-down management commitment to safety was clearly communicated to, and embraced by, workers throughout the site. DISCUSSION AND IMPACT: A better understanding of how contracting relationships, workers' compensation, and liability insurance arrangements influence safety could shift risk management efforts from worker behaviors to a broader focus on how these programs and relationships affect incentives and disincentives for workplace safety and health.

McGlothlin, J., et al. (2009). "Ergonomics. Case study: safety training issues for Hispanic construction workers." J Occup Environ Hyg 6(9): D45-50.

Case study found that few of the Hispanic construction workers in the sample had formal safety training and many did not understand safety and health terms used in training.

Mendeloff, J. and R. Burns (2013). "States with low non-fatal injury rates have high fatality rates and vice-versa." Am J Ind Med 56(5): 509-519.

BACKGROUND: State-level injury rates or fatality rates are sometimes used in studies of the impact of various safety programs or other state policies. How much does the metric used affect the view of relative occupational risks among U.S. states? This paper uses a measure of severe injuries (fatalities) and of less severe injuries (non-fatal injuries with days away from work, restricted work, or job transfer-DART) to examine that issue. METHODS: We looked at the correlation between the average DART injury rate (from the BLS Survey of Occupational Injuries and Illnesses) and an adjusted average fatality rate (from the BLS Census of Fatal Occupational Injuries) in the construction sector for states for 2003-2005 and for 2006-2008. The RAND Human Subjects Protection Committee determined that this study was exempt from review. RESULTS: The correlations between the fatal and non-fatal injury rates were between -0.30 and -0.70 for all construction and for the subsector of special trade contractors. The negative correlation was much smaller between the rate of fatal falls from heights and the rate of non-fatal falls from heights. Adjusting for differences in the industry composition of the construction sector across states had minor effects on these results. CONCLUSION: Although some have suggested that fatal and non-fatal injury rates should not necessarily be positively correlated, no one has suggested that the correlation is negative, which is what we find. We know that reported non-fatal rates are influenced by workers' compensation benefits and other factors. Fatality rates appear to be a more valid measure of risk. Efforts to explain the variations that we find should be undertaken.

Menzel, N. N. and P. P. Shrestha (2012). "Social marketing to plan a fall prevention program for Latino construction workers." Am J Ind Med 55(8): 729-735.

BACKGROUND: Latino construction workers experience disparities in occupational death and injury rates. The Occupational Safety and Health Administration funded a fall prevention training program at the University of Nevada, Las Vegas in response to sharp increases in fall-related accidents from 2005 to 2007. The grant's purpose was to improve fall protection for construction workers, with a focus on Latinos. This study assessed the effectiveness of social marketing for increasing fall prevention behaviors. METHODS: A multi-disciplinary team used a social marketing approach to plan the program. We conducted same day class evaluations and follow-up interviews 8 weeks later. RESULTS: The classes met trainee needs as evidenced by class evaluations and increased safety behaviors. However, Spanish-speaking Latinos did not attend in the same proportion as their representation in the Las Vegas population. CONCLUSIONS: A social marketing approach to planning was helpful to customize the training to Latino worker needs. However, due to the limitations of behavior change strategies, future programs should target employers and their obligation to provide safer workplaces.

Mohan, S. and W. C. Zech (2005). "Characteristics of worker accidents on NYSDOT construction projects." J Safety Res 36(4): 353-360.

INTRODUCTION: This paper aims at providing cost-effective safety measures to protect construction workers in highway work zones, based on real data. Two types of accidents that occur in work zones were: (a) construction work area accidents, and (b) traffic accidents involving construction worker(s). METHODOLOGY/RESULTS: A detailed analysis of work zone accidents involving 36 fatalities and 3,055 severe injuries to construction workers on New York State Department of Transportation (NYSDOT) construction projects from 1990 to 2001 established that five accident types: (a) Struck/Pinned by Large Equipment, (b) Trip or Fall (elevated), (c) Contact w/Electrical or Gas Utility, (d) Struck-by Moving/Falling Load, and (e) Crane/Lift Device Failure accounted for nearly 96% of the fatal accidents, nearly 63% of the hospital-level injury accidents, and nearly 91% of the total costs. These construction work area accidents had a total cost of $133.8 million. Traffic accidents that involve contractors' employees were also examined. Statistical analyses of the traffic accidents established that five traffic accident types: (a) Work Space Intrusion, (b) Worker Struck-by Vehicle Inside Work Space, (c) Flagger Struck-by Vehicle, (d) Worker Struck-by Vehicle Entering/Exiting Work Space, and (e) Construction Equipment Struck-by Vehicle Inside Work Space accounted for nearly 86% of the fatal, nearly 70% of the hospital-level injury and minor injury traffic accidents, and $45.4 million (79.4%) of the total traffic accident costs. CONCLUSIONS: The results of this paper provide real statistics on construction worker related accidents reported on construction work zones. Potential preventions based on real statistics have also been suggested. IMPACT ON INDUSTRY: The ranking of accident types, both within the work area as well as in traffic, will guide the heavy highway contractor and owner agencies in identifying the most cost effective safety preventions.

Murphy, P. L. and T. K. Courtney (2000). "Low back pain disability: Relative costs by antecedent and industry group." Am J Ind Med 37(5): 558-571.

Background: Previous studies of workers' compensation claims for low back pain (LBP) have revealed that the preponderance of disability is borne by a fraction of cases. However, less is known regarding the influence of occupational factors on these extreme conditions. Methods: Workers' compensation claims (n = 107,867) for LBP reported to a large, national insurer in

1992 were examined by antecedent event and industry class. In addition to summaries of the frequency and cost distribution, each factor was examined at two points on its cost distribution: one more representative of the typical case and one more representative of the case with long disability. These alternative disability indicators were introduced to explore a different perspective of LBP disability. Results: The information provided by the alternative indicators was distinct from the information provided by the traditional aggregate indicators (claim frequency and claim cost frequency). In particular, this method identified increased severity for claims in the construction and services sectors, as well as for claims arising from falls and motor vehicle crashes. Conclusions: The results suggest that the construction and service sectors confront unique challenges to prevention and management of LBP disability, LBP related to discrete antecedents such as falls and motor vehicle crashes merits consideration on the basis of exceptionally severe disability. (C) 2000 Wiley-Liss, Inc.

Osburn, L., et al. (2022). "Formal Prevention through Design Process and Implementation for Mechanical, Electrical, and Plumbing Worker Safety." Journal of Management in Engineering 38(5): 05022011.

There are many studies that focus on Prevention through Design (PtD) for construction workers and developing formalized PtD processes for construction projects. However, few studies have aimed at developing a formalized PtD process for mechanical/electrical/plumbing (MEP) worker safety. A formal process for implementing PtD for MEP worker safety is badly needed because MEP work onsite and during operation and maintenance (O&M) can lead to injury and death. To address this knowledge gap, our research team aimed to create a formalized PtD process for MEP safety and developed case studies that detail how the process can be implemented in the field. The formalized process and case studies would then be used in an implementation guide created specifically for the industry. This project was completed through expert interviews, six case studies, and ongoing discussion and review by an Industry Advisory Council. Using these methods, the team identified factors for implementation success and developed a formalized PtD process specific to the MEP worker context. The process consists of five phases: (1) hazard identification, (2) risk assessment, (3) design review, (4) implementation, and (5) learning. We anticipate that this study will contribute to the field of PtD research through creating one of the first formalized PtD processes for MEP construction and O&M worker safety, and through a cross-case analysis of the six PtD cases that indicated not only the importance of stakeholder engagement and cross-disciplinary dialogue, but that effective PtD implementation can occur even outside of a collaborative project delivery context at any point during design and construction.

Pan, C. S., et al. (2009). "Effects of foot placement on postural stability of construction workers on stilts." Appl Ergon 40(4): 781-789.

Stilts are elevated tools that are frequently used by construction workers to raise workers 18-40 inches above the ground. The objective of this laboratory study was to evaluate the potential loss of postural stability associated with the use of stilts in various foot placements. Twenty construction workers with at least 1 year of experience in the use of stilts participated in this study. One Kistler force platform was used to collect kinetic data. Participants were tested under six-foot-placement conditions. These 6 experimental conditions were statically tested under all combinations of 3 levels of elevation: 0" (no stilts), 24" stilt

height and 40" stilt height. SAS mixed procedure was used to evaluate the effect of different experimental conditions. The results of the multivariate analysis of variance (MANOVA) and repeated measures of univariate analyses of variance (ANOVAs) demonstrated that stilt height, foot-placement direction, and foot-placement width all had significant effects on the whole-body postural stability. This study found that the higher the stilts were elevated, the greater the postural instability. A stance position with one foot placed forward of the other foot produced greater postural instability than a position with the feet parallel and directly beneath the body. This study found that placement of the feet parallel and directly beneath the body, with the feet positioned a half shoulder width apart, caused a greater amount of postural sway and instability than one and one-and-half shoulder width. This study also found that construction workers using the stilts could perceive the likely postural instability due to the change in foot placements.

Perry, M. J., et al. (2015). "Evaluating Fall Safety Compliance among Skilled Trades in Construction (CPWR Report)."

PHILAPOSH (2014). "Using Social Media to Inform Latino Construction Workers about Fall Protection (CPWR Report)."

Prahlow, J. A., et al. (2020). "Elevator-Related Deaths." J Forensic Sci 65(3): 823-832.

Elevators are mechanical transportation devices used to move vertically between different levels of a building. When first developed, elevators lacked the safety features. When safety mechanisms were developed, elevators became a common feature of multistory buildings. Despite their well-regarded safety record, elevators are not without the potential for danger of injury or death. Persons at-risk for elevator-related death include maintenance and construction workers, other employees, and those who are prone to risky behavior. Deaths may be related to asphyxia, blunt force, avulsion injuries, and various forms of environmental trauma. In this review, we report on 48 elevator-related deaths that occurred in nine different medicolegal death investigation jurisdictions within the United States over an approximately 30-year period. The data represents a cross-section of the different types of elevator-related deaths that may be encountered. The review also presents an overview of preventive strategies for the purpose of avoiding future elevator-related fatalities.

Rajendran, S. and J. Gambatese (2013). "Risk and financial impacts of prevention through design solutions." Practice Periodical on Structural Design and Construction 18(1): 67-72.

Falls from roofs are a significant risk for both construction and maintenance workers. A roof anchor system is the common design solution to eliminate the falling hazard. This paper presents the findings of a case study to serve as a preliminary investigation of the financial impact and risk of roof fall protection solutions. The research began with the selection of a project that featured a roof anchor system and a parapet that does not meet Occupational Safety and Health Administration (OSHA) guardrail height requirements. The intent of the research was to compare the cost of design and installation of the roof anchors and parapet with that of two other design options on the same project: only a parapet that meets the OSHA guardrail requirements; and no anchors or parapet. Data used for the study were collected through interviews of project personnel and reviews of project documentation. The parapet system was found be an expensive, but safer, alternative compared with the roof anchor system. The roof

anchor system creates more risk to worker safety because of the extensive amount of temporary fall protection measures required during construction. This requirement puts more workers at risk of injury during installation of temporary guardrails and while working near the leading edge. The roof anchor system indirectly affects worker productivity by at least 15% compared with the parapet system. Using this study as a starting point, more research is recommended that examines the costs and risks associated with various prevention through design (PtD) solutions. Such research will assist owners and designers in making informed decisions while choosing PtD solutions. © 2013 American Society of Civil Engineers.

Rietdyk, S., et al. (2005). "Work experience mitigated age-related differences in balance and mobility during surface accommodation." Clin Biomech (Bristol, Avon) 20(10): 1085-1093.

BACKGROUND: Locomotor behavior at the roofing worksite is challenged by factors such as sloped surfaces, wind gusts and handling loads. Chronic exposure to this environment may result in enhanced locomotor strategies that are resistant to aging effects. The purpose of this study was to determine if roofers demonstrated enhanced locomotor strategies and if the strategies were maintained with age. METHODS: The gait of ten younger roofers (mean age 27.2 years), eight older roofers (55.4 years), ten younger controls (25.4 years) and nine older controls (57.6 years) was examined during level gait and stepping up onto a wooden surface (0.15m high). Subjects either carried no load, an empty box or the same box loaded to the equivalent of 5% body mass. FINDINGS: Work by age interactions were observed for toe clearance, step width, net angular momentum of the head, arms and trunk segment and gait speed ($P<0.0001$). Younger roofers demonstrated the greatest toe clearance; older roofers had a smaller lead clearance but decreased variability. Older control groups had the greatest risk of tripping due to low lead toe clearance and high variability, and were least likely to recover if they did trip due to faster gait speed and increased net angular momentum. Work experience resulted in enhanced changes in lead toe clearance and mitigated age-related changes in step width and net angular momentum. INTERPRETATION: Challenging environments show promise for maintaining balance skills in older adults; however care should be taken when introducing inexperienced older adults to a challenging environment.

Rietdyk, S. and C. K. Rhea (2011). "The effect of the visual characteristics of obstacles on risk of tripping and gait parameters during locomotion." Ophthalmic Physiol Opt 31(3): 302-310.

PURPOSE: Injuries from falls are a serious health issue. Approaches to preventing falls should consider increasing relevant visual information of an obstacle. Obstacle parameters, such as position and height, may be specified by the visible structure of an obstacle. The present study examined the relationship between visible structure of an obstacle and locomotor behaviour. This relationship may be modified as a function of experience with navigating obstacles. Since workers at construction sites must navigate through cluttered environments with varied obstacles, these workers may have superior skills at avoiding obstacles. Therefore, the effect of work experience was also examined. METHODS: Nine construction workers and 10 age- and gender-matched control subjects participated. Subjects stepped over obstacles in an 8 m walkway. Three different obstacles were examined, arranged according to a hierarchy ranging from most to least visible structure: a solid obstacle, a three-edge outline obstacle and a top-edge obstacle. The obstacles were 10, 20 or 30 cm high. In addition, visual information was decreased with goggles which obstructed the lower visual field, removing information of the obstacle and foot-relative-to-obstacle in the two steps before the obstacle. All conditions were

presented randomly. RESULTS: Higher risk of contact and higher lead and trail toe clearance variability were observed for the top-edge obstacle. Higher risk of contact was observed when the lower visual field was obstructed and for the 30 cm obstacle. Work experience did not influence risk of contact. Construction workers had lower trail toe clearances and lower trail toe clearance variability for the 10 cm obstacle, but were not different from controls for the 30 cm obstacle. CONCLUSIONS: Decreased visible structure of an obstacle resulted in increased gait variability and increased risk of contact. The changes are consistent with decreased accuracy of the sensory-to-motor transformation used to control the lead and trail limb during obstacle crossing when only the top-edge was visible. There is some evidence that construction workers were better able to transform the visual information to motor actions, as reflected by decreased gait variability, but these findings were not supported by decreased risk of obstacle contact.

Riley, K. and R. Majano (2021). "Using workers' compensation claims to investigate occupational injuries among residential day laborers and domestic workers." Am J Ind Med 64(5): 358-368.

BACKGROUND: While many states have legal provisions to extend workers' compensation eligibility to day laborers or domestic workers hired directly by homeowners or families, little is known about the nature or frequency of injury claims submitted on behalf of these "residential employees." METHODS: We examined California workers' compensation claims records for injuries that appear to have occurred in residential settings between 2008 and 2018 and where the employer of record was an individual or family. We examined the demographic, occupational, and injury characteristics of our sample and analyzed factors that contribute to the likelihood of a claim resulting in some sort of payment. RESULTS: We identified 5,463 workers' compensation claims that were likely submitted on behalf of residential employees. Claims most commonly reflected injuries to workers performing housekeeping tasks, followed by construction/maintenance and caregiving. Workers performing construction/maintenance or gardening/landscaping tasks were more likely to be injured on the same day of hire and were more likely to require hospitalization or emergency treatment for their injuries; however, these workers also had a smaller proportion of claims that resulted in payment. We found that employment tenure had the biggest impact on the likelihood of payment, with the odds increasing sharply after the first day of work. CONCLUSIONS: Although the claims in our data set likely represent only a small fraction of all injuries to residential day laborers and domestic workers during this period, we suggest that workers' compensation claims can provide valuable clues for better understanding occupational injuries among workers in this largely informal sector.

Roelofs, C., et al. (2011). "A qualitative investigation of Hispanic construction worker perspectives on factors impacting worksite safety and risk." Environ Health 10: 84.

BACKGROUND: Hispanic workers have higher rates of injury and death on construction worksites than workers of other ethnicities. Language barriers and cultural differences have been hypothesized as reasons behind the disparate rates. METHODS: We conducted two series of focus groups with union and non-union Hispanic construction workers to ask them about their perceptions of the causes for the unequal rates. Spanish transcripts were translated and coded in QSR NVivo software for common themes. RESULTS: Workers reported a difficult work environment characterized by supervisor pressure, competition for jobs and intimidation with regard to raising safety concerns. Language barriers or cultural

factors were not strongly represented as causative factors behind the rates. CONCLUSION: The results of this study have informed the development of an intervention trial that seeks to prevent falls and silica dust exposure by training contractors employing Hispanic construction workers in the elements of safety leadership, including building respect for their Hispanic workers and facilitating their participation in a safety program.

Ronk, C. J., et al. (2011). "Is renovation riskier than new construction?: an observational comparison of risk factors for stepladder-related falls." Am J Ind Med 54(8): 579-585.

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.

Sa, J., et al. (2009). "Comparison of risk factors for falls from height between commercial and residential roofers." J Safety Res 40(1): 1-6.

INTRODUCTION: The purpose of this investigation was to compare commercial roofers and residential roofers in terms of their behaviors, beliefs, working conditions, and attitudes toward the use of fall protection devices, which could lead to fall accidents. METHODS: A cross-sectional sample of 252 roofers participated in the survey in the Midwest (Wisconsin, Illinois, Michigan, Indiana, and Iowa). RESULTS: Residential roofers were more likely to fall (prevalence ratio = 2.28, 95% CI = 1.58, 3.29) [corrected] than commercial roofers. Race/ethnicity, company size, work type, existence [corrected] of fall protection programs, enforcement of fall protection device use, actual use of fall protection devices, years of experience as a roofer, and perceived level of safety at roofing sites were [corrected] significantly associated with fall accidents. IMPACT ON INDUSTRY: This study adds insight into fall accidents from roofs in the construction industry and provides industry-specific cautions against fall accidents that can be reflected in regulatory agency implementation.

Schoenfisch, A., et al. (2014). "Rates of and circumstances surrounding work-related falls from height among union drywall carpenters in Washington State, 1989-2008." J Safety Res 51: 117-124.

BACKGROUND: Drywall installers are at high risk for work-related falls from height (FFH). METHODS: We defined a 20-year (1989-2008) cohort of 5,073 union drywall carpenters in Washington State, their worker-hours, and FFH. FFH rate patterns were examined using Poisson regression. RESULTS: Drywall installers' FFH rates declined over time and varied little by worker age and time in the union. However, among FFH involving drywall sheets, workers with <10 union years were at high risk. Narratives consistently described the surface from which workers fell, commonly scaffolds (33%), ladders (21%), and stilts (13%).

Work task, height fallen, protective equipment use, work speed, weather, influence of other workers/workgroups, and tool/equipment specifics were not often reported. PRACTICAL APPLICATIONS: In addition to continued efforts to prevent falls from scaffolds and ladders, efforts should address stilt use and less experienced workers who may have greater exposure. Consistency in reported narrative elements may improve FFH risk factor identification and prevention effort evaluation.

Schoenfisch, A. L., et al. (2013). "Work-related injuries among union drywall carpenters in Washington State, 1989-2008." Am J Ind Med 56(10): 1137-1148.

BACKGROUND: Drywall installers are at high-risk of work-related injury. Comprehensive descriptive epidemiology of injuries among drywall installers, particularly over time, is lacking. METHODS: We identified worker-hours and reported and accepted workers' compensation (WC) claims for a 20-year (1989-2008) cohort of 24,830 Washington State union carpenters. Stratified by predominant type of work (drywall installation, other carpentry), work-related injury rates were examined over calendar time and by worker characteristics. Expert interviews provided contextual details. RESULTS: Drywall installers' injury rates, higher than those of other carpenters, declined substantially over this period by 73.6%. Common injury mechanisms were struck by/against, overexertion and falls. Drywall material was considered a contributing factor in 19.7% of injuries. One-third of these drywall material-related injuries resulted in paid lost time, compared to 19.4% of injuries from other sources. Rates of injury were particularly high among workers with 2 to <4 years in the union. Notable declines over time in rates of overexertion injury in which drywall material was a contributing factor were still observed after controlling for secular temporal trends. Experts highlighted changes over the past 20 years that improved both work safety and, in some cases, production. CONCLUSIONS: Declines in drywall installers' injury rates over time likely reflect, in part, enhanced workplace safety, including efforts to reduce overexertion hazards associated with handling drywall. Continued injury prevention efforts are needed, particularly for less tenured workers. Given the potential for under-reporting to WC, additional sources of health outcomes data may provide a more complete picture of workers' health.

Schoenfisch, A. L., et al. (2017). "Effectiveness of OSHA Outreach Training on carpenters' work-related injury rates, Washington State 2000–2008." Am J Ind Med 60(1): 45-57.

Introduction: Despite the size and breadth of OSHA's Outreach Training program for construction, information on its impact on work-related injury rates is limited. Methods: In a 9-year dynamic cohort of 17,106 union carpenters in Washington State, the effectiveness of OSHA Outreach Training on workers' compensation claims rate was explored. Injury rates were calculated by training status overall and by carpenters' demographic and work characteristics using Poisson regression. Results: OSHA Outreach Training resulted in a 13% non-significant reduction in injury claims rates overall. The protective effect was more pronounced for carpenters in their apprenticeship years, drywall installers, and with increasing time since training. Conclusions: In line with these observed effects and prior research, it is unrealistic to expect OSHA Outreach Training alone to have large effects on union construction workers' injury rates. Standard construction industry practice should include hazard awareness and protection training, coupled with more efficient approaches to injury control. Am. J. Ind. Med. 60:45–57, 2017. © 2016 Wiley Periodicals, Inc. © 2016 Wiley Periodicals, Inc.

Shishlov, K. S., et al. (2011). "Non-fatal construction industry fall-related injuries treated in US emergency departments, 1998-2005." Am J Ind Med 54(2): 128-135.

BACKGROUND: There is a growing recognition that common occupational injury surveillance systems in the US fail to reflect true injury risk; this failure limits efforts to accurately monitor efforts to prevent work-related injuries on a national level. METHODS: Data from the National Electronic Injury Surveillance System occupational supplement (NEISS-Work) were used to describe fall-related injuries treated in US emergency departments among workers in the construction industry (1998-2005). These data do not require workers' compensation as the payer in order to be classified as work-related. RESULTS: Based on NEISS-Work estimates, a total of 555,700 (95% confidence interval (CI): 390,700-720,800) non-fatal work-related injuries among workers in the construction industry were the result of a fall, resulting in an annual rate of 70 (95% CI: 49-91) per 10,000 full-time equivalents. Younger workers had higher rates of falls, whereas older workers were more likely to suffer serious injuries. The majority of the injuries (70%) were precipitated by falls to a lower level from roofs, ladders, and scaffolding. CONCLUSIONS: The patterns of fall-related injuries identified in these data are consistent with other reports. In contrast to the declining rates of falls requiring days away from work reported through the Bureau of Labor Statistics Survey of Occupational Injuries and Illnesses, construction industry fall-related injury rates estimated through NEISS-Work remained unchanged from 1998 to 2005 providing another perspective on this serious cause of morbidity in the construction industry.

Shrestha, P. P., et al. (2018). "Types and factors affecting injury rates of mechanical contractors." Work 61(1): 135-148.

BACKGROUND: In the United States, about 38,000 cases of nonfatal workplace injuries were reported in 2015, in the category of 'mechanical work' (plumbing, heating, and air conditioning); this is nearly identical to the number of cases reported under 'building construction'. OBJECTIVE: This paper analyzes the types and rates of injuries and illnesses of mechanical contractors of southern Nevada, including the nature of the injuries and illnesses, body parts affected by injuries, causes of injuries, and factors affecting the injury rates. METHODS: To obtain data, a survey consisting of questions regarding the number of injuries and types of injuries was conducted with 31 mechanical contractors of southern Nevada involved in plumbing, piping, heating, refrigeration, and air conditioning. RESULTS: The injury rate for larger mechanical contractors (n = 16), in terms of number of employees and annual revenue, was significantly lower than for smaller mechanical contractors (n = 15). Mechanical contractors who worked on residential buildings (n = 13) had significantly higher rates of injuries than those involved with industrial (n = 7) or commercial buildings (n = 10). Results showed that sprains and strains (31%) were dominant injuries, and the major causes were from parts and materials (39%), hand tools (16%), contact with objects (14%), and falls (7%). CONCLUSIONS: The study concluded that the injury rate for these mechanical contractors was found to be higher than that reported by the Occupational Safety and Health Administration for specialty trade contractors.

Siddula, M., et al. (2016). "Classifying construction site photos for roof detection." Construction Innovation 16(3): 368-389.

Purpose - Roofing is one of the most dangerous jobs in the construction industry. Due to factors suchas lack of planning, training and use of precaution, roofing contractors and workers

continuouslyviolate the fall protection standards enforced by the US Occupational Safety and HealthAdministration. A preferable way to alleviate this situation is automating the process ofnon-compliance checking of safety standards through measurements conducted in site dailyaccumulated videos and photos. As a key component, the purpose of this paper is to devise a method todetect roofs in site images that is indispensable for such automation process. Design/methodology/approach - This method represents roof objects through imagesegmentation and visual feature extraction. The visual features include colour, texture, compactness,contrast and the presence of roof corner. A classification algorithm is selected to use the derivedrepresentation for statistical learning and detection. Findings - The experiments led to detection accuracy of 97.50 per cent, with over 15 per centimprovement in comparison to conventional classifiers, signifying the effectiveness of the proposedmethod. Research limitations/implications - This study did not test on images of roofs in the followingconditions: roofs initially built without apparent appearance (e.g. structural roof framing completed andundergoing the sheathing process) and flat, barrel and dome roofs. From a standpoint of constructionsafety, while the present work is vital, coupling with semantic representation and analysis is still neededto allow for risk analysis of fall violations on roof sites. Originality/value - This study is the first to address roof detection in site images. Its findings providea basis to enable semantic representation of roof site objects of interests (e.g. co-existence andcorrelation among roof site, roofer, guardrail and personal fall arrest system) that is needed to automatethe non-compliance checking of safety standards on roof sites. © Emerald Group Publishing Limited.

Simeonov, P. and H. Hsiao (2001). "Height, surface firmness, and visual reference effects on balance control." Inj Prev 7(SUPPL. 1): i50-i53.

Objectives - To investigate the effects of height, surface firmness, and visual reference on standing balance in construction workers. Design - Controlled laboratory study with balanced repeated measures. Participants - Twenty four construction workers. Setting - Test subjects performed standing tasks at ground level as well as at 3 m and 9 m high balconies on firm or deformable surfaces with close visual references included or excluded from their visual field. Methods - Standing balance was determined from center of pressure as measured by a force platform. Dependent variables were root mean square of sway in medial-lateral and anterior-posterior directions, area of sway, and velocity of sway. Results - Heights without close visual references significantly increased all sway parameters. The effect of height in conditions without close visual references increased dramatically on deformable surfaces. Conclusions - Elevated work environments and deformable work surfaces negatively affect balance and may be associated with increased risk of fall incidents. Appropriate close visual references increase the ability to maintain balance.

Simeonov, P., et al. (2009). "Effectiveness of vertical visual reference for reducing postural instability on inclined and compliant surfaces at elevation." Appl Ergon 40(3): 353-361.

Falls from elevation continue to be the most serious hazard for the workers in construction. Simple and cost effective technical approaches to improve workers' balance on sloped roofs and deformable/unstable platforms have potential to reduce the risk of falls. This study evaluated the effectiveness of simple vertical structures as visual references (cue) for balance improvement. Twenty-four construction workers were tested while standing on sloped and deformable surfaces at elevation and performing undemanding visual tasks with vertical

structures positioned at different proximal locations. Workers' balance performance was assessed by sway parameters calculated from the center-of-pressure movement collected with a force platform. The study results indicate increased instability on the sloped and deformable surfaces at elevation, and show that a simple vertical structure, e.g., a narrow bar, can serve as a visual cue and assist workers' balance. Workers' balance improved linearly with cue proximity in the tested distance range both on the sloped and the deformable surfaces. At a moment of instability, workers can redirect their attention to a proximal structure, available in the line of sight, to assist balance control. These findings may be useful in modifying elevated work environments and construction procedures to improve workers' postural balance during various construction phases.

Simeonov, P., et al. (2012). "Factors affecting extension ladder angular positioning." Hum Factors 54(3): 334-345.

OBJECTIVE: The study objectives were to identify factors affecting extension ladders' angular positioning and evaluate the effectiveness of two anthropometric positioning methods. BACKGROUND: A leading cause for extension ladder fall incidents is a slide-out event, usually related to suboptimal ladder inclination. An improved ladder positioning method or procedure could reduce the risk of ladder stability failure and the related fall injury. METHOD: Participants in the study were 20 experienced and 20 inexperienced ladder users. A series of ladder positioning tests was performed in a laboratory environment with 4.88-m (16-ft) and 7.32-m (24-ft) ladders in extended and retracted positions. The setup methods included a no-instruction condition and two anthropometric approaches: the American National Standards Institute A14 and "fireman" methods. Performance measures included positioning angle and time. RESULTS: The results indicated that ladder setup method and ladder effective length, defined by size and extended state, affected ladder positioning angle. On average, both anthropometric methods were effective in improving extension ladder positioning; however, they required 50% more time than did the no-instruction condition and had a 9.5% probability of setting the ladder at a less-than-70 degrees angle. Shorter ladders were consistently positioned at shallower angles. CONCLUSION: Anthropometric methods may lead to safer ladder positioning than does no instruction when accurately and correctly performed. Workers tended to underperform as compared with their theoretical anthropometric estimates. Specific training or use of an assistive device may be needed to improve ladder users' performance. APPLICATION: The results provide practical insights for employers and workers to correctly set up extension ladders.

Simeonov, P., et al. (2008). "Footwear effects on walking balance at elevation." Ergonomics 51(12): 1885-1905.

The study evaluated the effects of shoe style on workers' instability during walking at elevation. Twenty-four construction workers performed walking tasks on roof planks in a surround-screen virtual reality system, which simulated a residential roof environment. Three common athletic and three work shoe styles were tested on wide, narrow and tilted planks on a simulated roof and on an unrestricted surface at simulated ground. Dependent variables included lateral angular velocities of the trunk and the rear foot, as well as the workers' rated perceptions of instability. The results demonstrated that shoe style significantly affected workers walking instability at elevated work environments. The results highlighted two major shoe-design pathways for improving walking balance at elevation: enhancing rear foot motion

control; and improving ankle proprioception. This study also outlined some of the challenges in optimal shoe selection and specific shoe-design needs for improved walking stability during roof work. The study adds to the knowledge in the area of balance control, by emphasising the role of footwear as a critical human-support surface interface during work on narrow surfaces at height. The results can be used for footwear selection and improvements to reduce risk of falls from elevation.

Simeonov, P., et al. (2011). "Postural stability effects of random vibration at the feet of construction workers in simulated elevation." Appl Ergon 42(5): 672-681.

The risk of falls from height on a construction site increases under conditions which degrade workers' postural control. At elevation, workers depend heavily on sensory information from their feet to maintain balance. The study tested two hypotheses: "sensory enhancement"--sub-sensory (undetectable) random mechanical vibrations at the plantar surface of the feet can improve worker's balance at elevation; and "sensory suppression"--supra-sensory (detectable) random mechanical vibrations can have a degrading effect on balance in the same experimental settings. Six young (age 20-35) and six aging (age 45-60) construction workers were tested while standing in standard and semi-tandem postures on instrumented gel insoles. The insoles applied sub- or supra-sensory levels of random mechanical vibrations to the feet. The tests were conducted in a surround-screen virtual reality system, which simulated a narrow plank at elevation on a construction site. Upper body kinematics was assessed with a motion-measurement system. Postural stability effects were evaluated by conventional and statistical mechanics sway measures, as well as trunk angular displacement parameters. Analysis of variance did not confirm the "sensory enhancement" hypothesis, but provided evidence for the "sensory suppression" hypothesis. The supra-sensory vibration had a destabilizing effect, which was considerably stronger in the semi-tandem posture and affected most of the sway variables. Sensory suppression associated with elevated vibration levels on a construction site may increase the danger of losing balance. Construction workers at elevation, e.g., on a beam or narrow plank might be at increased risk of fall if they can detect vibrations under their feet. To reduce the possibility of losing balance, mechanical vibration to supporting structures used as walking/working surfaces should be minimized when performing construction tasks at elevation.

Simeonov, P. I., et al. (2003). "Control and perception of balance at elevated and sloped surfaces." Hum Factors 45(1): 136-147.

Understanding roof-work-related risk of falls and developing low-cost, practical engineering controls for reducing this risk remain in high demand in the construction industry. This study investigated the effects of the roof work environment characteristics of surface slope, height, and visual reference on standing balance in construction workers. The 24 participants were tested in a laboratory setting at 4 slopes (0°, 18°, 26°, and 34°), 2 heights (0, 3 m), and 2 visual conditions (with and without visual references). Postural sway characteristics were calculated using center of pressure recordings from a force platform. Workers' perceptions of postural sway and instability were also evaluated. The results indicated that slope and height synergistically increased workers' standing postural instability. Workers recognized the individual destabilizing effects of slope and height but did not recognize the synergistic effect of the two. Visual references significantly reduced the destabilizing effects of height and slope. Actual and potential applications of this research include the use of temporary level work

surfaces and proximal vertical reference structures as postural instability control measures during roofing work.

Sinyai, C. and S. Choi (2020). "Fifteen years of American construction occupational safety and health research." Safety science 131: 104915.

The researchers reviewed construction occupational safety and health research published in high-impact, peer-reviewed academic journals between 2002 and 2016 to assess whether research in the field is efficiently targeted to produce evidence-based interventions addressing the industry's most serious occupational hazards. Unlike most previous surveys of the field, this interdisciplinary literature search captured research published in the construction management and engineering literature as well as that in public health and medicine journals. The researchers found 741 articles by US-based lead authors, with falls the most-studied safety hazard (89 articles) and airborne silica exposure the most-studied health hazard (51), both among the deadliest current hazards in construction occupational safety and health, but much asbestos research was sponsored by companies involved in litigation, generating few findings useful for protecting today's workers. The review described important trends in the literature, including increased attention to noise and hearing loss, a growing number of intervention studies, and greater concern for populations at disproportionate risk (e.g., small/residential, Latino/immigrant, younger/older workers, & women working in construction). The National Institute for Occupational Safety and Health (NIOSH) directly or indirectly funded a majority of the published research. Policymakers should understand that most occupational safety and health research depends on NIOSH funding.

Smith, G. S., et al. (2006). "Work-related ladder fall fractures: identification and diagnosis validation using narrative text." Accid Anal Prev 38(5): 973-980.

OBJECTIVE: To identify ladder-related fracture injuries and determine how ladder fall fractures differ from other ladder-related injuries. METHODS: Ladder-related fracture cases were identified using narrative text and coded data from workers' compensation claims. Potential cases were identified by text searches and verified with claim records. Injury characteristics were compared using proportionate injury ratios. RESULTS: Of 9826 ladder-related injuries, 7% resulted in fracture cases. Falls caused 89% of fractures and resulted in more medical costs and disability days than other injuries. Frequent mechanisms were ladder instability (22%) and lost footing (22%). Narrative text searches identified 17% more fractures than injury codes alone. Males were more likely to sustain a fall fracture than other injuries; construction workers were most likely, and retail workers were the least likely to sustain fractures. CONCLUSIONS: Fractures are an important injury from ladder falls, resulting more serious consequences than other ladder-related injuries. Text analysis can improve the quality and utility of workers compensation data by identifying and understanding injury causes. Proportionate injury ratios are also useful for making cross-group comparisons of injury experience when denominator data are not available. Greater attention to risk factors for ladder falls is needed for targeting interventions.

Socias, C. M., et al. (2014). "Occupational ladder fall injuries - United States, 2011." MMWR Morb Mortal Wkly Rep 63(16): 341-346.

Falls remain a leading cause of unintentional injury mortality nationwide [corrected].Among workers, approximately 20% of fall injuries involve ladders. Among

construction workers, an estimated 81% of fall injuries treated in U.S. emergency departments (EDs) involve a ladder. To fully characterize fatal and nonfatal injuries associated with ladder falls among workers in the United States, CDC's National Institute for Occupational Safety and Health (NIOSH) analyzed data across multiple surveillance systems: 1) the Census of Fatal Occupational Injuries (CFOI), 2) the Survey of Occupational Injuries and Illnesses (SOII), and 3) the National Electronic Injury Surveillance System-occupational supplement (NEISS-Work). In 2011, work-related ladder fall injuries (LFIs) resulted in 113 fatalities (0.09 per 100,000 full-time equivalent [FTE] workers), an estimated 15,460 nonfatal injuries reported by employers that involved >/=1 days away from work (DAFW), and an estimated 34,000 nonfatal injuries treated in EDs. Rates for nonfatal, work-related, ED-treated LFIs were higher (2.6 per 10,000 FTE) than those for such injuries reported by employers (1.2 per 10,000 FTE). LFIs represent a substantial public health burden of preventable injuries for workers. Because falls are the leading cause of work-related injuries and deaths in construction, NIOSH, the Occupational Safety and Health Administration, and the Center for Construction Research and Training are promoting a national campaign to prevent workplace falls. NIOSH is also developing innovative technologies to complement safe ladder use.

Socias-Morales, C. M., et al. (2018). "Fatal work-related falls in the United States, 2003-2014." Am J Ind Med 61(3): 204-215.

BACKGROUND: Falls are the second leading cause of work-related fatalities among US workers. We describe fatal work-related falls from 2003 to 2014, including demographic, work, and injury event characteristics, and changes in rates over time. METHODS: We identified fatal falls from the Bureau of Labor Statistics (BLS), Census of Fatal Occupational Injuries and estimated rates using the BLS Current Population Survey. RESULTS: From 2003 to 2014, there were 8880 fatal work-related falls, at an annual rate of 5.5 per million FTE. Rates increased with age. Occupations with the highest rates included construction/extraction (42.2 per million FTE) and installation/maintenance/repair (12.5 per million FTE). Falls to a lower level represented the majority (n = 7521, 85%) compared to falls on the same level (n = 1128, 13%). CONCLUSIONS: Falls are a persistent source of work-related fatalities. Fall prevention should continue to focus on regulation adherence, Prevention through Design, improving fall protection, training, fostering partnerships, and increasing communication.

Sokas, R. K., et al. (2009). "An intervention effectiveness study of hazard awareness training in the construction building trades." Public Health Rep 124 Suppl 1: 160-168.

OBJECTIVE: We evaluated knowledge, attitudes, and self-reported work practices among apprentice and journeyman trainees in two construction trades at baseline and three months after participation in two training sessions as part of a 10-hour Occupational Safety and Health Administration hazard awareness training program. We developed preliminary assessment of prior and current training impact, accounting for demographics, trade, and construction site safety climate. METHODS: Participants were recruited prior to union-delivered safety training, self-completed a baseline survey prior to class, and completed a follow-up interviewer-administered telephone survey three months later. Discrimination (D) testing evaluated knowledge questions, paired t-tests examined differences in pre- and post-intervention knowledge, and attitude responses were tested with the Wilcoxon signed rank test. Linear regression analysis and logistic regression were used to assess the contribution of different categorical responses to specific sub-questions. RESULTS: Of 175 workers

completing the baseline survey, 127 were born in the U.S. and 41 were born in Mexico; 40% of those who reported ethnicity were Hispanic. Follow-up surveys were completed by 92 (53%) respondents and documented significant increases in both fall safety and electrical safety knowledge. The most recent safety climate was associated with improvement in fall safety attitudes (slope = 0.49, $p < 0.005$) when adjusted by country of birth (slope = 0.51, $p < 0.001$). Workers born in Mexico had less formal education than U.S.-born workers and lower baseline knowledge scores, but more positive attitude scores at baseline and greater improvements in attitude at follow-up. CONCLUSION: Knowledge and attitude improvement following a one-hour safety class was measurable at three months in both U.S.-born and Mexican-born construction workers.

Sokas, R. K., et al. (2007). "Trainer evaluation of a union-based ten-hour safety and health hazard-awareness program for U.S. construction workers." Int J Occup Environ Health 13(1): 56-63.

A web-based survey of union-based outreach instructors evaluated training materials developed to teach OSHA ten-hour hazard-awareness courses to members of the construction trades. Respondents taught an average of five ten-hour hazard-awareness courses per year. When asked about hazards commonly encountered by their trainees, 83% identified falls from ladders, with a range of 1-22 hazards identified. Over one third of the trainers taught individuals whose primary languages were not English. Increased interaction with trainees through subsequent phone calls may be a marker of differential training impact.

Teran, S., et al. (2015). "Promoting adoption of fall prevention measures among Latino workers and residential contractors: Formative research findings." Am J Ind Med 58(8): 870-879.

Background: Falls from heights remain a concern in construction, particularly for foreign-born Latino construction workers employed by small residential contractors. The social ecological model provides a framework to assess the individual and contextual factors influencing the risk for falls. Methods: Five focus groups and thirteen in-depth interviews with workers, small residential contractors, and key informants were conducted in 2012 in San Francisco and Philadelphia. Data were analyzed with qualitative methods. Results: Economic conditions in residential construction, coupled with a lack of enforcement and vulnerabilities of the foreign-born workforce, are principal contributors to risk for falls. Small contractors perceive strong economic disincentives for implementation of fall protection and foreign-born Latino workers experience a variety of social, cultural and occupational pressures impeding its use. Conclusions: Increased adoption of fall protection cannot be accomplished solely by targeting Latino construction workers. Research is needed on incentives to influence contractor behavior and facilitate adoption of fall protection measures. Am. J. Ind. Med. 58:870-879, 2015. © 2015 Wiley Periodicals, Inc.

Tiesman, H. M., et al. (2011). "The epidemiology of fatal occupational traumatic brain injury in the U.S." Am J Prev Med 41(1): 61-67.

BACKGROUND: Although traumatic brain injury (TBI) is one of the leading causes of death and disability in the U.S., work-related TBI has not been well documented. PURPOSE: The aim of this study was to describe the epidemiologic characteristics and temporal trends of fatal occupational TBI in the U.S between 2003 and 2008. METHODS: A cross-sectional analysis of the Census of Fatal Occupational Injury database was performed. Both the

Occupational Injury and Illness Classification System nature of injury codes and body part codes were used to define TBIs. Fatality rates were calculated using denominators derived from the Current Population Survey. Fatality rates were compared among industries, cause of death, and demographics with rate ratios (RRs) and 95% CIs. Poisson regression was used to assess trends in fatality rates. Data were analyzed in 2009-2010. RESULTS: Nearly 7300 occupational TBI deaths occurred between 2003 and 2008, for an average fatality rate of 0.8 per 100,000 workers per year. The leading causes of occupational TBI death were as follows: motor vehicle (31%); falls (29%); assaults and violent acts (20%); and contact with objects/equipment (18%). Fatality rates were 15 times higher in men compared with women (RR=15, 95% CI=13.7, 16.3). Workers aged >/=65 years experienced the highest TBI fatality rate of all age groups (2.5 per 100,000 per year). Construction, transportation, and agriculture/forestry/fishing industries recorded nearly half of all TBI fatalities (n=1828, n=825, n=761, respectively). Occupational TBI death rates declined 23% over the 6-year period (p<0.0001). CONCLUSIONS: This study provides the first national profile of fatal TBIs occurring in the U.S. workplace. Prevention efforts should be directed at those industries with the highest frequency and/or highest risk. The construction industry had the highest number of TBIs, and the agriculture, forestry, and fishing industry had the highest rates. Additionally, workers aged >65 years in all industries would be a good target for future prevention efforts.

Turner, N. L., et al. (2008). "Suspension tolerance in a full-body safety harness, and a prototype harness accessory." J Occup Environ Hyg 5(4): 227-231.

Workers wearing full-body safety harnesses are at risk for suspension trauma if they are not rescued in 5 to 30 min after a successfully arrested fall. Suspension trauma, which may be fatal, occurs when a person's legs are immobile in a vertical posture, leading to the pooling of blood in the legs, pelvis, and abdomen, and the reduction of return blood flow to the heart and brain. To measure suspension tolerance time, 22 men and 18 women with construction experience were suspended from the chest D-ring (CHEST) and back D-ring (BACK) of full-body, fall-arrest harnesses. Fifteen men and 13 women from the original group of subjects were then suspended using a newly developed National Institute for Occupational Safety and Health harness accessory (ACCESS), which supports the upper legs. Midthigh circumference changes were 1.4 and 1.9 cm, changes in minute ventilation were 1.2 and 1.5 L/min, changes in heart rate (HR) were 15.1 and 21.6 bpm, and changes in mean arterial pressure were 5.1 and -2.6 mmHg ($p < \text{or} = 0.05$) for all subjects during CHEST and BACK, respectively. Kaplan-Meier median suspension time for all subjects for the CHEST condition was 29 min (range 4-60 min) and 31 min (range 5-56 min) for the BACK condition. The 95th percentile for suspension time was 7 min for CHEST and 11 min for BACK. Cox regression revealed that body weight had a statistically significant effect on the time until experiencing a medical end point ($p < \text{or} = 0.05$) during the BACK condition. Mean (+/- SD) suspension time was 58 +/- 6 min (range 39-60 min) for all subjects for the ACCESS condition. There were no terminations due to medical symptoms during the ACCESS suspension, changes in physiological variables were small, and 85% of ACCESS subjects completed 60-min suspensions. These data provide information on motionless suspension tolerance time to standards-setting organizations and demonstrate the potential of a prototype harness accessory to delay or prevent suspension trauma.

Wade, C., et al. (2014). "Balance and exposure to an elevated sloped surface." Gait and Posture 39(1): 599-605.

Fall injuries and fatalities exceed 50 billion dollars annually. One half of fatal falls are from pitched roof settings. Falls from elevation in an occupational setting have been documented to be a significant issue in today's workforce. The purpose of this study was to investigate the influence of exposure to inclined surfaces on flat surface balance at varying heights above the ground. Thirty participants, 10 male college students (inexperienced), 10 female college students (inexperienced) and 10 male roofers (experienced) between age 19 and 50 years participated in this study. Participants walked for 20. min on an elevated roof segment (9-14 feet above ground level) and a ground level roof segment (0-5 feet above ground level) on separate days. Results indicated a significant difference for all groups in sway velocity over time at both levels (elevated and ground) and from eyes open to eyes closed conditions at both levels ($p < 0.05$). Statistical analysis revealed that roofers had significantly less increase in sway velocity, post exposure than that of the inexperienced group ($p < 0.05$). These findings provide practical information to employers and employees during the construction of structures that employ a pitched roof design. The implication of these findings include the knowledge that an individual is less stable directly after performing roofing tasks on a pitched roof setting, and should be afforded ample time to recover before moving into activities that would place them at a higher risk of injury from falls. © 2013 Elsevier B.V.

Wade, L. R., et al. (2004). "Effect of personal protective eyewear on postural stability." Ergonomics 47(15): 1614-1623.

Vision is a significant factor in postural stability; this study is the first to report on the effect of OSHA regulated personal protective eyewear on physiological factors associated with postural stability. Twenty college students between the ages of 19 and 25 were randomly tested in each of three eyewear conditions (control, new, and artificially aged) using a NeuroCom Balance Master System and the mCTSIB protocol. Subjects were pre-tested with no eyewear (control) on each day followed by a 5-min assembly task with random eyewear assignment. Subjects were then post-tested following the same protocol while wearing the eyewear. Data were evaluated using a two (pre/post) x three (eyewear) repeated measures analysis of variance (ANOVA). There was a significant main effect for both the eyes open/firm flat surface, and eyes open/foam flat surface conditions ($p <or= .05$). These findings suggest that while personal protective eyewear may serve to protect an individual from eye injury, an individual's use of such personal protective eyewear may have deleterious effects on sensory input from the visual system and compensatory strategies to maintaining or regaining postural stability. Individuals who employ protective eyewear on a daily basis need to be aware of the effect of altered visual input resulting from eyewear on their postural stability, especially during sensory-challenging tasks, such as navigating ladders, scaffolding and elevated surfaces, typically found in construction environments.

Waehrer, G. M., et al. (2007). "Costs of occupational injuries in construction in the United States." Accid Anal Prev 39(6): 1258-1266.

This paper presents costs of fatal and nonfatal injuries for the construction industry using 2002 national incidence data from the Bureau of Labor Statistics and a comprehensive cost model that includes direct medical costs, indirect losses in wage and household productivity, as well as an estimate of the quality of life costs due to injury. Costs are presented at the three-digit industry level, by worker characteristics, and by detailed source and event of injury. The total costs of fatal and nonfatal injuries in the construction industry were estimated

at $11.5 billion in 2002, 15% of the costs for all private industry. The average cost per case of fatal or nonfatal injury is $27,000 in construction, almost double the per-case cost of $15,000 for all industry in 2002. Five industries accounted for over half the industry's total fatal and nonfatal injury costs. They were miscellaneous special trade contractors (SIC 179), followed by plumbing, heating and air-conditioning (SIC 171), electrical work (SIC 173), heavy construction except highway (SIC 162), and residential building construction (SIC 152), each with over $1 billion in costs.

Welch, L. S., et al. (2005). "Occupational injuries among construction workers treated in a major metropolitan emergency department in the United States." Scand J Work Environ Health 31 Suppl 2: 11-21.

OBJECTIVES: The aim of this study was to profile construction workers' injuries for more information about the causes of nonfatal construction worker injuries and identify injury trends for further investigations and prevention programs. METHODS: An injury-tracking program for emergency departments was established in 1990 to gather the data needed for the study. Profiles were obtained for 2916 construction workers' injuries that were identified on hospital registration forms at the George Washington University Emergency Department in Washington, DC, from November 1990 through October 1997. Laborers and construction workers who did not specify a trade were combined, and together they made up the largest group--29% of the injured workers. RESULTS: The leading cause of injury was contact with cutting or piercing objects-most often pieces of metal, razors, knives, power tools, and nails. Workers striking against objects or being struck by objects (including falling objects) accounted for the second-largest group of injuries, and the third leading injury circumstance was falling--either from a height or on the same level. Detailed injury statistics are presented by trade, showing patterns of injury that reflect tasks of these trades and which injuries predominated in each trade. Although many previous reports have described construction workers' injuries, very few have provided detailed data by trade. CONCLUSIONS: The details presented in this analysis allow for a better understanding of the injury circumstances and provide a starting point for injury prevention programs.

Welton, M., et al. (2020). "Construction employment mortality among Mexican immigrants in the South Eastern United States, 2003-2013." International Journal of Migration, Health and Social Care 16(4): 349-358.

Purpose The purpose of this study was to investigate occupational and non-occupational mortality among Mexican immigrants in the South Eastern United States. The construction industry has the highest burden of occupational fatalities in the USA of all industries, and foreign-born Hispanic workers are disproportionately affected. Design/methodology/approach Data were obtained from 3,093 death certificates maintained by the Consulate General of Mexico in Atlanta, Georgia. Standardized mortality ratios (SMR) were used to compare occupational-related deaths among construction industry occupations, and logistic regression models were used to examine the relationship between manners of death not related to occupation and employment in the construction industry. Findings The proportion of Mexican immigrants who died from occupational injuries is higher among all construction workers (SMR = 1.31), roofers (SMR = 2.32) and carpenters (SMR = 2.25) than other workers. Among the population in this analysis suicide [adjusted odds ratio (aOR) = 0.63] and death from natural causes (aOR = 0.70) were inversely related to work in the construction industry. Research

limitations/implications Interventions to reduce occupational fatalities among Mexican migrant construction workers should target roofers and carpenters. Future research should further investigate the industry's association with suicide and natural death. Originality/value This is one of the first analyzes that investigated associations between construction industry employment and non-occupational fatalities among immigrants. The analysis provides evidence that a large portion of the Mexican immigrant population is used in the construction industry (38%) and face elevated risks for occupational fatalities and the results of this investigation should encourage greater surveillance of occupational illness and injury among foreign-born immigrants who work in construction, as well as other high-risk industries.

Winn, G. L., et al. (2004). "Fall protection incentives in the construction industry: literature review and field study." Int J Occup Saf Ergon 10(1): 5-11.

Safety literature confirms that incentives such as money or sunglasses seem to improve safety conditions over the short run. However, no studies could be found which tested the effect of incentives on fall protection for a period longer than a few days. In our research we found that after 6 months, the use of non-material incentives significantly improved on-time delivery and completion rates of a special inspection form (both $p < .005$). In addition, a questionnaire with embedded critical questions showed that even though workers said that they preferred material incentives, we conclude that their behavior was changed by the treatment (incentives). We further conclude that the use of natural reinforcers seems to influence worker behaviors and perception of management's commitment to safety over the long run, even though workers still say that they prefer tangible rewards. Future work should replicate these findings and explore why workers respond to natural incentives but express a preference for material incentives.

Yassin, A. S. and J. Martonik (2004). "The effectiveness of the revised scaffold safety standard in the construction industry." Safety science 42(10): 921-931.

The purpose of this study was to examine the effectiveness of the revised scaffold safety standard in the construction industry and to evaluate time trend analyses on scaffold-related fatalities and injuries, as well as inspections conducted and cited violations of the scaffold safety standard set forth in Title 29 of the Code of Federal Regulations Part 1926, Subpart L. Data on scaffold-related fatalities, injuries, and lost workdays, as well as cited violations of scaffold safety, were assembled from sources such as the US Department of Labor's Occupational Safety and Health Administration (OSHA) Integrated Management Information System, and Bureau of Labor Statistics. Data for the period prior to the revision of the standard were compared with data from the period after the revision. We used autoregressive analyses to evaluate the percentage of change in the mean scaffold-related fatalities, injuries and lost workdays and in the OSHA inspections and cited violations of scaffold safety. Effectiveness analysis was conducted to assess the effectiveness of the revised scaffold safety standard in preventing fatal or nonfatal injuries in the construction industry. Complying with the revised scaffold safety standard would prevent approximately 4.6 fatalities, 404 nonfatal injuries, and 2896 lost workdays per year. A total cost savings associated with compliance was estimated at $5.8 million (2001 US$) per year. Compliance with the revised scaffold safety standard would provide a safer workplace and generate a significant cost saving in the construction industry

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