

CURRENT PRIORITIES IN FALL PREVENTION RESEARCH AT THE LIBERTY MUTUAL RESEARCH INSTITUTE FOR SAFETY

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At the Liberty Mutual Research Institute for Safety (LMRIS), our approach to fall prevention research recognizes the importance of integrating diverse perspectives across a multiplicity of relevant disciplines, including tribology, biomechanics, epidemiology, and behavioral sciences. This paper is an update of our paper presented at ICFPP2010, providing a brief overview of current LMRIS research efforts aimed at advancing our understanding and prevention of falls.

Introduction

Since its inception nearly 60 years ago, the Research Institute's mission has been the advancement of scientific knowledge in workplace and highway safety, and work disability. The scientific research conducted at the Institute is predicated on Liberty Mutual's creed "to help people live safer, more secure lives." Consistent with this non-proprietary mission, the research findings are published in the peer-reviewed scientific literature. Thus, Liberty Mutual Insurance (LMI) is distinguished as the only property and casualty insurer with a world-class research program dedicated to safety and disability research that adheres to the highest objective standards of scientific integrity.

Until very recently, the research conducted by the Institute has been primarily concerned with occupational safety and related work disability. The focus on occupational safety reflects the historical standing of Liberty Mutual as a workers compensation carrier. Liberty Mutual today is a highly diversified carrier and as part of the Institute's strategic realignment, the scope of research is diversifying to address non-occupational injuries.

Falls represent the leading cause of nonfatal unintentional injury in the U.S. In 2007, there were 8 million reported cases (NEISS, 2007), accounting for 28% of among adults aged 18-64. Falls also represent a leading cause of severe occupational injuries, representing over 25% of compensable losses. According to the 2012 Liberty Mutual Workplace Safety Index (2012), the most disabling workplace injuries and illnesses that occurred in 2010 (the latest year for which data are available) amounted to \$51.1 billion in direct U.S. workers compensation costs. Fall on same level ranked second as a leading cause of disabling injury. With direct costs of \$8.61 billion, this category accounted for 16.9% of the total injury burden. Fall to lower level ranked fourth at \$5.12 billion. Together, the cost of slips and falls on same level and to lower level in 2010 amounted to \$13.7 billion, representing 26.9% of the total burden (see Figure 1). The burden would actually be about 5% higher if bodily injury were to be included, representing slips and trips without falling.

According to the Bureau of Labor Statistics data, over the period 1998 to 2010 the frequency of falls on same level and falls to lower level that resulted in more than 5 days away from work declined by 17% and 31%, respectively. It is remarkable that while the frequency of

work-related falls has declined over the 12 years, the burden associated with falls has grown considerably over this same period. The cost burden associated with falls on same level and falls to lower level actually increased by 42.3% and 3.7%, respectively. In fact, the cost burden associated with falls grew substantially more than any other injury category.

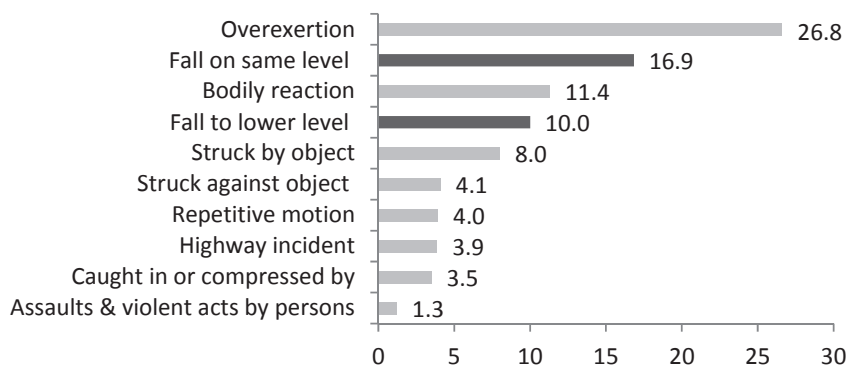


Figure 1. 2012 Liberty Mutual Workplace Safety Index: Top ten causes and % of burden

Slips, trips and falls occur as a result of the confluence of factors, and a comprehensive program of research must bring together engineering, biomechanical, epidemiological and cognitive and sociotechnical systems perspectives. A unique strength of the Institute is its ability to engage a broad range of disciplines in addressing the key domains of research interest - slips, trips and falls being a core domain. The Institute's four research centers, specializing in injury epidemiology, physical ergonomics, behavioral sciences and return-to-work, provide complementary perspectives to falls-related research. The studies described below provide a brief overview of current research on falls.

Falls on same level

Slips and falls among limited-service restaurant workers

A multi-disciplinary field study of slips and falls among limited-service restaurant workers was conducted in conjunction with research partners at the Harvard University School of Public Health. In this study, we examined the slip and fall experiences of workers from 36 limited-service restaurants in six U.S. states. The study investigated how factors such as floor surface characteristics, slip-resistant shoes, floor cleaning practices, safety climate, and transient risk factors (e.g., contamination, distraction and rushing) affect the risk of slipping. A total of 475 workers participated in the study. For each restaurant surveyed, participants completed a baseline survey that gathered information on demographics, perceptions of floor slipperiness, slip-resistant shoe use, floor cleaning practices, and number of slips experienced in the four weeks prior to the start of the study. In addition, restaurant managers provided information on floor cleaning protocols and shoe policies. During the subsequent 12 weeks, participants reported their slip experiences.

The data indicated a high rate of slipping in these restaurants, with an overall rate of 22 slips annually per full-time worker. (Verma, Chang *et al.*, 2010) The mean individual slipping rate varied among the restaurants from 0.02 to 2.49 slips per 40 work hours. Liquid and grease were implicated in more than 70% of slips, and the highest numbers of slips occurred in the sink and fryer areas. The rate of slipping decreased by 21% for each 0.1 increase in the mean coefficient of friction (COF).

About 70% of the restaurants used enzyme-based floor cleaners. In these restaurants, however, 63% of study participants reported that they used hot/warm water to dilute the cleaner, which is contrary to the manufacturers' instructions to use cold water and may decrease cleaning effectiveness. Other findings are described below under separate headings. These

findings will be used to inform safety recommendations and guidelines with respect to floor selection, floor cleaning protocols, slip-resistant shoe use, and safety policies related to fall prevention.

Slip-resistant shoes and risk of slipping (Verma, Chang et al., 2011)

A strong association was observed between the use of slip-resistant shoes and the rate of slipping. A shoe was considered slip-resistant if it bore the manufacturer's "slip-resistant" marking on the sole. After adjusting for age, gender, body mass index, education, primary language, job tenure, and type of restaurant chain, the use of slip-resistant shoes was associated with a 54% reduction in the reported slipping rate. These results support the use of slip-resistant shoes along with measures to increase COF as preventive interventions to reduce slips, falls, and related injuries.

Factors influencing the use of slip-resistant shoes among limited-service restaurant workers (Verma, Courtney et al., 2012)

To understand the factors that influence an individual's use of slip-resistant shoes at work, researchers examined demographic and job characteristic data from the study's 475 participants. Restaurant managers were asked whether the employer provided and paid for slip-resistant shoes; and, if not, whether the employer had given any guidance regarding slip-resistant shoe use. A multivariate analysis indicated that slip-resistant shoe use was lowest in the 15- to 19-year-old age group. Education level, job tenure, and the mean COF had no significant effects on the use of slip-resistant shoes. Women were 18% more likely than men to wear slip-resistant shoes. Workers whose employers provided slip-resistant shoes were 52 percent more likely to wear them and these workers had the highest proportion of use (91%), as compared to workers who received no shoes and no guidance regarding slip-resistant shoe use. These results suggest that employer provision of slip-resistant shoes was the strongest predictor of their use. Given their effectiveness and an average cost of about US \$30, slip-resistant shoes can be a cost-effective intervention to reduce slips and falls.

Impact of transient risk factors on slipping (Verma, Lombardi et al., 2011)

A nested case-crossover design was used to examine the association between certain transient risk factors—rushing, distraction, and walking on a contaminated floor—and the rate of slipping. The data included average work hours, average weekly duration of exposure to each transient risk factor, job tenure at the current location, weekly slip experience, and whether any of the three transient risk factors were present at the time of slipping. The results indicate that the rate of slipping when workers were rushing was 2.9 times higher than when they were working at a normal pace. Distraction and walking on a contaminated floor also significantly increased the rate of slipping by 1.7 and 14.6 times, respectively. Slip-resistant shoe use decreased the effects of rushing and walking on a contaminated floor, and the effects of all three transient factors (rushing, distraction, and contamination) decreased monotonically as job tenure increased. Participants on average reported walking on a contaminated floor for about one third of their work time. These findings suggest that rushing, distraction, and floor contamination have significant effects on slipping rates among restaurant workers. Reducing the transient exposures of rushing, distraction, and floor contamination; encouraging the use of slip-resistant shoes; and establishing a greater safety focus may help reduce the incidence of slipping.

Perceived versus actual risk of slips and falls (Courtney et al., 2013)

To examine the association between subjective measures of risk and the actual risk of slipping in the workplace, participants were asked to rate floor slipperiness using a four-point scale in eight functional areas of the restaurant kitchen: front counter, drive-through, sandwich assembly, fryer, grill, sink, cooler/freezer, and ice machine at the baseline. Participants reported their slip experience every week for the following 12 weeks. The results indicated that each 1-point increase in mean restaurant-level perception of slipperiness (on the 4-point scale) was associated with a 2.71 times higher rate of subsequent slipping. These data indicate that

perceptions of slipperiness and the subsequent rate of slipping were strongly associated, suggesting that worker perceptions of slipperiness could be used as a leading indicator to identify slipping hazards and assess intervention effectiveness.

Risk of slips, trips, and falls in full-service restaurants

This study extends the work described above to study the effects of floor surface, shoe type, and floor cleaning practices on the risk of slips and falls in full-service restaurants. It also aims to investigate the impact of restaurant design and other factors related to slip, trip, and fall risk. In each of the 48 restaurants that participated in the study, researchers measured the COF on selected floor tiles in the kitchen and dining areas. They also gathered data on floor types, transitions from one floor type to another, and lighting. During working hours, researchers recorded practices or designs that could affect the risk of slipping and tripping. They also examined workers' shoes to determine slip resistance and collected data from managers on floor-cleaning frequency, products, and protocols. Interviews held with over 750 participants gathered basic demographic data, as well as information on job tasks, responsibilities, and prior experiences related to slips, trips, and falls. Specific questions related to fatigue were included, such as information on working hours, break times, double shifts, personal sleeping patterns, and levels of alertness during the workday. Following the interviews, study participants submitted weekly reports of their slip, trip, fall, and injury experiences and hours worked over a 12-week period. Analyses are underway and should enhance our understanding of worker slip, trip, and fall risks in the kitchen and dining areas of full-service restaurants. The information gained is expected to have significant safety implications for restaurant workers and patrons.

Multidisciplinary approaches toward the measurement of slipperiness in a laboratory environment

This study is part of a larger project aimed at understanding the relationships among perception, gait and related mechanisms involved in falls due to slips. Figure 2 represents a simplified conceptual model of the perception-action cycle of a pedestrian walking on a floor surface. The "Perception" box represents a version of the original Brunswik Lens Model (Brunswik, 1952) in which multiple inputs are differentially weighted. In this case, visual and proprioceptive cues are evaluated with weightings dependent on exposure. That is, early gait adjustments are based primarily on visual information and subsequent adjustments incorporate both visual and proprioceptive feedback.

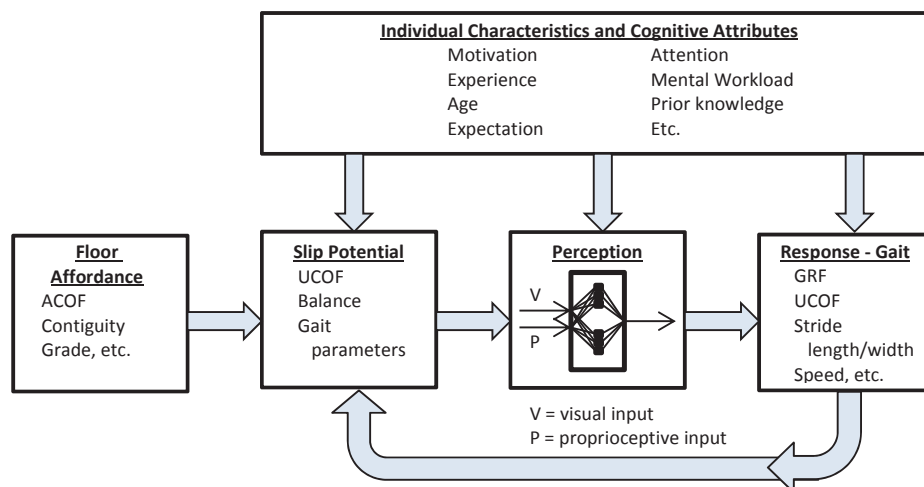


Figure 2. Conceptual model of perception-action cycle in walking

In this first study, we were interested in the principal components of the measurement of slipperiness. Participants were exposed to 15 conditions of different degrees of slipperiness (five floor surfaces and three conditions: dry, water, glycerol) and were asked to walk as fast as possible without a slip. The five floor surfaces were selected from 37 common floor types due to their distinctive features that represented different combinations of friction levels and perceptual cues to slipperiness. Preliminary multiple and bivariate regression analyses examined the relationships among perception ratings of slipperiness, gait parameters and COF. The results indicated that the frictional demand, heel angle and perception ratings of slipperiness had the highest adjusted R^2 in the multiple linear regression analyses. Although each variable in the final data pool could reflect some measurement of slipperiness, these three variables are more inclusive than others in representing the other variables. Additional analyses will examine the interrelationships among behavioral, biomechanical and tribological mechanisms.

A statistical model to predict slip probability (Chang *et al.*, 2012)

The probability of a slip can be estimated using a statistical model by comparing the available coefficient of friction (ACOF) with the required coefficient of friction (RCOF). The models available in the literature use mean values to estimate the risk of slips. However, it may be possible to derive more accurate estimates by determining the stochastic properties of these variables. This study investigated the stochastic distributions of the ACOF of five different floor surfaces under three conditions; dry, water and glycerol. The results of 50 participants showed that in 86% of the time the RCOF can be represented by the normal distribution, though in 76% of the cases the distributions for the left and right foot were different. The distributions of the ACOF could only be represented by the normal curve in 20% of the cases. In practice, the ACOF can be considered a constant when it is near zero or much higher than the RCOF.

Falls to lower level

*Risk factors for work-related portable ladder falls (Lombardi *et al.*, 2011)*

A field study designed to identify ways to prevent or reduce the risk for work-related falls from portable ladders, which account for the majority of disabling ladder-related injuries, was conducted in collaboration with the Harvard University School of Public Health, the U.S. Consumer Product Safety Commission (CPSC), the National Institute for Occupational Safety and Health, and the Center for Construction Research and Training (CPWR). Using cases identified from the National Electronic Injury Surveillance System (NEISS) – a stratified national probability sample of all injuries reported in US emergency rooms, we interviewed 306 workers who had experienced and were treated for a ladder-fall injury. Initial analyses focused on specific, modifiable factors that may trigger portable ladder falls. Secondly, we evaluated the risk of fractures—the most frequent and severe outcome from ladder falls—as a function of several variables related to work environment, equipment, and the workers themselves. The injured workers were most often employed in construction, installation, maintenance and repair, and sales-related fields. The falls originated from a step, trestle, extension, straight, or rolling ladder, at an average height of 7.5 feet (35% of falls originated from <5 feet, and 5% from >20 feet). The most frequent bodily injury sites were the arm, elbow or shoulder; the head, neck or face; and the lower trunk. Diagnoses were primarily fractures, strains or sprains, and contusions or abrasions. Typically, workers were most often standing or sitting while working on the ladder while installing or hanging an item or performing repairs and maintenance tasks preceding their falls. Ladder movement was an important mechanism; in 40% of the cases studied (varying by ladder type), the bottom of the ladder moved before the fall. The study found a significant monotonic relationship between increasing fall height and fracture risk, and this relationship was also influenced by an increase in worker age, and increased when working on the ladder, as

compared to climbing up or down. The findings have particularly important implications for older workers, who comprise the fastest-growing segment of the U.S. workforce.

Effect of rest breaks on injury risk for ladder falls (Arlinghaus et al., 2012)

Additional analyses of the 302 cases from the NEISS examined whether workers who take rest breaks are able to work longer into the workday without injury than workers without rest breaks, and, if so, whether a longer accumulated rest-break time has a greater protective effect (i.e., a longer time-to-injury) than a shorter total break time?

The findings indicated that longer accumulated rest break time exhibited a significant protective effect allowing for a prolonged time spent on task without injury (see Figure 3). This finding suggests that rest-break design could be used to inform fatigue management strategies aimed at improving workplace safety.

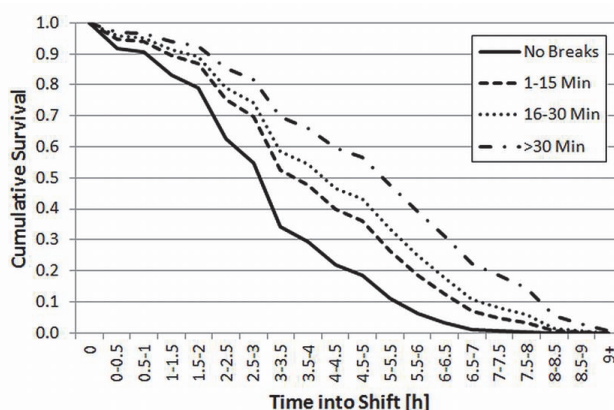


Figure 3. Effect of rest breaks on time to injury stratified by rest break duration lateral reaching while on stepladders: Balance control and risk perception

In 2010, falls from ladders accounted for 5.5% of injuries involving days away from work in the U.S. construction industry sector (Bureau of Labor Statistics, 2011) and are also a major cause of injury in other industries. Several laboratory experiments examined factors affecting lateral reaching while on stepladders. For example, one study examined the effect of ladder experience and risk perception on lateral reaching distance and stability. Twenty-four experienced and 24 novice male ladder users performed lateral reaches while standing on 6- and 12-foot stepladders. Participants stood on the third rung from the top of the ladder and reached for a target as researchers measured lateral reach distances, ground reaction forces, postures, and kinematics. The study also examined the effect of motivation on maximum reach, induced by placing a reach-to target at the extreme lateral position for the participant (as opposed to the unmotivated condition where no target was presented). The data indicated that the average maximum lateral reach distance was 66 mm shorter on the 12-foot stepladder than on the 6-foot ladder. Acclimation led to a 35 mm increase in unmotivated reach distances. Motivation brought about a further increase of 66 mm. Across all conditions, the sum of the forces under the two ladder legs furthest from the target decreased from approximately 50% to 12–18% of the total vertical forces created by the individual and ladder. After a short period of acclimation, users were able to reach further without significantly affecting the forces underneath the ladder.

Straight ladder set-up and use in a field environment

Prior research has explored ladder setup methods and friction requirements in laboratory settings (Chang et al., 2004). However, few studies have observed individuals set up and use ladders in real-world settings. In this research, we studied a group of utility workers who routinely use ladders, following each worker as they proceeded to various worksites during the

course of a normal workday. We collected information on climbing behavior, the use of personal protective equipment, ladder-carrying, and ladder setup angle, as well as relevant ground and weather conditions. At the end of each workday, participants completed a questionnaire assessing their knowledge of ladder setup. The results are currently being analyzed to determine the relationships between setup behavior, training, and setup outcomes. In addition, the data are being analyzed to ascertain the impact of safety climate on ladder use and injury outcomes. Study findings will provide insight into the effectiveness of training on ladder use and setup, and will be used to inform and update ladder safety recommendations.

Summary

The LMRIS program comprises both field and laboratory studies to identify risk factors and underlying mechanisms associated with falls. The program is focused on falls on same level due to slips and falls from ladders. Our program is leveraged through joint research with several partners including the Harvard University School of Public Health. Findings from these studies provide a scientific basis for the development of cost-effective interventions and strategies for reducing the incidence of work and non-work related slip and fall-related injuries.

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