

# **A TOTAL WORKER SAFETY APPROACH FOR PREVENTING SLIPS, TRIPS, AND FALLS**

**Hongwei Hsiao, Ph.D.**

*National Institute for Occupational Safety and Health (NIOSH)  
1095 Willowdale Road, Morgantown, WV 26505, USA*

Slips, trips, and falls (STF) represent a serious hazard to workers and occupants in many industries, homes, and communities. Often, the cause of a STF incident is multifactorial, encompassing human, environmental, and task risk factors. A STF-related disability can greatly diminish the occupational capability and quality of life of individuals in both the home and the workplace. Countering STF hazards and risks both on and off the job is a “total worker safety” matter, a challenging yet tangible undertaking. As the federal organization responsible for conducting research for the prevention of work-related injuries in the United States, NIOSH has been conducting research on STF controls for some decades. Many NIOSH research outcomes have been utilized for STF prevention in workplaces, with potential for prevention in homes as well. This paper summarizes the concept of total worker safety for STF control, NIOSH priority research goals and activities, and some emerging issues on STF.

## **Introduction**

The most recent report on fatal occupational injuries showed that there were 681 slip-trip-and-fall (STF) related fatalities in 2011 in the United States (U.S. BLS, 2013a), which accounted for 14.5% of the overall occupational fatality cases. In addition, there were 299,090 STF-related nonfatal occupational injuries resulting in days away from work in 2011, which accounted for about 25.3% of all occupational injuries in that year (U.S. BLS, 2012). The construction industry continued to have the highest count of STF-related fatalities (U.S. BLS, 2013), and food servers, healthcare support workers, highway maintenance workers, housekeeping cleaners, and telecommunications line installers experienced the highest rates of nonfatal STF injuries (U.S. BLS, 2011). Many countries are facing the same challenges as the United States with STF injury problems in the workplace (NIOSH, 2011a). Aside from workplace incidents, STFs are the second-leading cause of unintentional death in homes and communities, resulting in more than 25,000 fatalities in 2009 (NSC, 2011). Often, inhabitants fall from ladders, stairs, uneven surfaces, or wet areas at home. Elderly individuals are particularly at risk. In 2011, more than 3.3 million nonfatal fall injuries among older adults (55 ~ 85+ years old) were recorded in emergency departments (NCIPC, 2013). Similar concerns are seen worldwide (WHO, 2007).

Given the prevalence of STF problems, an organized global research/intervention effort is warranted. This paper describes a concept for total worker safety for preventing global STFs, which improves occupational capability and quality of life at both workplaces and homes. The paper also presents NIOSH research goals on STF prevention, selected NIOSH research activities relevant to the concept of total worker safety for STF control, and some emerging issues on STF.

## **A Concept of Total Worker Safety for Slip, Trip, and Fall Prevention**

STFs occur as a result of a complex interaction of risk factors which can be organized into three categories: personal, environmental, and task-related factors (Hsiao and Simeonov, 2001). The personal factors include individual differences (e.g., age, gender, race, and body size), work experience, chronic illness, physical strength, substance use, cognitive capacities, constraints of personal protective equipment (PPE), visual acuity, contrast sensitivity, discrepant vision between the eyes, and expiratory flow rate (Hsiao and Simeonov, 2001; WHO, 2007; Knudtson, Klein, & Klein, 2009). The environmental factors concern the information available from visual and physical interactions with environments, including elevation perception, moving visual scenes, depth perception, visual ambiguity, visual detection of obstacles and their properties, restricted support surfaces, support surfaces inclination, lighting, building design, and material properties of support surfaces (e.g., friction, contaminants, evenness, loose fixtures, and firmness). The task-related factors include load handling, physical exertion and fatigue, footwear, complexity of tasks, social interactions, and community resources (Hsiao and Simeonov, 2001; WHO, 2007).

National and global research efforts on STF are vary among government agencies, healthcare institutes, professional societies, and individual safety and health research organizations. Many of the entities have focused on certain aspects of research topics and applications, such as occupational issues, biomarkers, forensics, and elderly falls. As national and global communities are moving to better workplace safety and quality of life as a whole, countering fall hazards and risks faced by workers and community-dwellers on and off the job becomes even more inseparable. Workers use ladders at work; they also use ladders in their homes for household chores. Community members access building floors through stairways at home as well as at workplaces and public facilities. Moreover, a STF injury typically affects a person's ability in handling tasks at the workplace and the home; it may diminish a person's social capacity in the community as well. The settings may differ, but the scientific basis, risk assessment tools, and control strategies for STF remain the same. The concept of total worker safety for STF prevention considers integration of current knowledge and research efforts among all aspects to: (1) publicize the importance of STF prevention, (2) advance the identification of risk factors and innovations for STF control, and (3) transfer/implement realistic and effective STF interventions.

## **NIOSH Research Goals for Slip, Trip, and Fall Prevention**

While NIOSH research on STF prevention has been occupational in nature, many of the NIOSH research findings, methods, and recommendations for safe practices are equally applicable to non-occupational settings. We are increasing our communication and collaboration with industries, stakeholders, and global partners to advance research efforts on STF control, which would facilitate the implementation of a total worker safety strategy to prevent STFs in the workplace, home, and community. Recently, NIOSH has undertaken a concerted effort to update four of its research goals to address the national STF burden.

Three NIOSH goals for STF prevention research are industry specific, emphasizing program activities and directions that are likely to have the greatest impact on preventing fall injuries and deaths in high risk workplaces. They include goals of reducing fall injuries in the construction industry, wholesale and retail trades (WRT), and public safety, services, manufacturing, and other high-risk industries. These efforts emphasize implementing effective, evidence-based STF prevention and protection designs, technologies, programs, and communications materials for: (1) structure design, worksite implementation, and vulnerable group (e.g., Hispanic workers) protection in the construction industry; (2) the handling, storage, and retrieval of goods in WRT settings; and (3) ambulance, fire truck, and heavy truck apparatus improvements in the public safety sector to reduce falls from these vehicles and implementation of comprehensive STF prevention programs in

the food services industry.

The fourth goal addresses human characteristics, social-organizational characteristics, and biotechnology-based fall control measures which offer fundamental knowledge and practical solutions for STF prevention in the workplace, home, and community. Research organizations can identify human biomarkers, social-organizational characteristics, and human-system interface traits that are common precursors to fall incidents, and use them to design out fall risk or craft engineering solutions and organizational interventions to reduce STF incidences. Accordingly, manufacturers can produce improved fall protection devices and systems that effectively reduce the forces on the human body during fall arrest and fall impact. Furthermore, safety professionals and researchers can develop and use comprehensive digital models of human fall dynamics to evaluate new fall prevention and protection technologies, products, and methods as well as to conduct fall injury investigations and verify solutions.

NIOSH has proposed retiring the goal to reduce STF injuries in the health services industry, given productive research that has been conducted as well as industry adoption of recommended protective measures (NIOSH, 2013). For example, NIOSH has published a user-friendly STF prevention toolkit targeted toward staff in the healthcare sector that is being adopted by many hospitals nationwide (NIOSH, 2011b).

## **Activities and Accomplishments**

Selected research projects associated with the four NIOSH overarching research goals are presented to illustrate our efforts and accomplishments. These projects target high fall-risk industrial sectors and leading sources of fall incidents which coincide with national workplace and community fall injury data.

### *Ladder Safety Research and Innovations*

Ladders are one of the most widely-used means of access to elevated surfaces at home and in the workplace in multiple industries (e.g., construction, wholesale and retail, and public safety sectors). On average more than 164,000 emergency room-treated injuries in the U.S. each year are related to ladders (U.S. CPSC, 2011). What are the current regulations, practice guidelines, and measures to control falls from ladders? What are risk factors, critical knowledge gaps, and emerging issues and technologies to address ladder safety? Partnering with ladder manufacturers, a national ladder safety standards committee, technology research organizations, and other U.S. Government agencies, NIOSH has published literature on solutions and knowledge gaps on extension ladder safety (Hsiao, Simeonov, & Pizatella et al., 2008), identified factors affecting extension ladder angular positioning (Simeonov, Hsiao, Powers, & Kim et al., 2013), and developed and patented a ladder safety software application for mobile devices which features a multimodal indicator and a graphic-oriented guide for ladder selection, inspection, positioning, accessorizing, and safe use (Simeonov, Hsiao, & Powers, 2013). The literature, scientific study outcomes, and the mobile device safety application provide both a scientific basis and practical tools to reduce the risk of fall injury for millions of ladder users across many industries, homes, and communities.

### *Slips, Trips, and Falls Control in Food Services*

Food preparation workers and non-restaurant food servers are among the groups with high fall-on-the-same-level incident rates, with rates of 61.2 and 65 per 10,000 full-time workers, respectively (U.S. BLS, 2012). Partnering with one of the largest food service companies in the US, NIOSH is evaluating the effectiveness of slip-resistant shoes as part of multi-factor prevention programs in reducing STF injuries in the food services industry. This study is a randomized controlled trial with the participation of approximately 4,000 employees for a four year period (Bell, 2009). The research will impact worker safety by providing scientific evidence and business case support for a

comprehensive STF prevention program to reduce STF injuries among food service workers. Food service companies, initially hesitant to expend time and money on prevention programs with unknown effectiveness, could use these findings to help justify implementing prevention strategies. The information will be equally useful for food handling persons at schools and food courts.

### *Safe Fire Truck Aerial System*

A turntable telescopic ladder is perhaps the best-known form of specialized aerial firefighting apparatus, and is used to gain access to fires occurring at heights or areas inaccessible to conventional ground-based ladders. Ascending and descending aerial apparatus present a significant source of fall risk due to apparatus space constraints and challenges in firefighter-apparatus-interface design in accommodating the uses at various ladder heights and angles, from almost vertical to almost horizontal settings. The environmental constraints of firefighting scenes and the increased physical and mental loads of bunker gear on firefighters often worsen the fall risk. NIOSH is conducting a series of research projects on the ergonomic design of aerial ladder systems (Simeonov and Hsiao, 2013). Among the objectives are: (1) determination of optimal rung spacing, (2) identification of range of optimal angles for aerial ladder use, and (3) development of an automated dynamic rung profile that presents a stable horizontal footing surface independent of aerial ladder slope angle.

### *Fall-Arrest Harness System Safety*

The Occupational Safety and Health Administration (OSHA) mandated a construction standard in 1998 that full-body harnesses replace waist belts for fall arrest in personal fall arrest systems (U.S. DOL, 2011). This provided improved protection against falls from height for 6.3 million construction workers. Some knowledge gaps remain on suspension trauma risk and how harness fit affects dynamic loading to the head and neck during fall arrests as well as information about optimal harness sizing and design to accommodate diverse worker populations. Partnering with harness manufacturers, national safety standards committees, and research organizations, NIOSH has published improved sizing systems and suggested specification ranges for harness straps (Hsiao, Friess, & Bradtmiller et al., 2009; Hsiao, Whitestone, & Taylor et al., 2009) and has identified factors that affect harness-body fit and interface (Hsiao, Whitestone, & Kau, 2007). In addition, NIOSH has reported the effects of body characteristics and harness fit on human suspension tolerance time (Hsiao, Turner, & Whisler et al., 2012) and the merits and risks of fall-arrest system use for operators of mechanized access platforms (Pan, Powers, & Hartsell et al., 2012 ).

### *Scaffolding Safety in Fall Injury Prevention*

Dismantling of frame scaffolds was reported as one of the most hazardous tasks for the carpenter trade in the construction industry due to overexertion and fall hazards (National Constructors Association, 1985). A significant portion of these hazards are associated with scaffold-end-frame (23 kg) dismantling tasks which require both muscle strength and postural balance skills. Most workers tend to place their hands at the below-hip locations to generate greater lifting power. They, however, face a fall risk once they lift up the end frame; the center of mass of the end frame is far above their hands and thus difficult to manipulate. NIOSH studies demonstrated that hand location between elbow height and chest height with a hand separation distance of 46 cm would allow workers to generate sufficient isometric strength to disassemble typical 23 kg scaffolds while concurrently allowing them to mitigate the likelihood of postural imbalance (Cutlip, Hsiao, & Garcia et al., 2002). As scaffolding technology has advanced, mast climbing work platforms (a new elevating system that can lift construction workers to extreme elevations) are increasingly being used in major construction projects in the U.S. with some 4,200 operations daily (Pan, 2010). Increasing numbers of high-visibility incidents (i.e., multiple fatalities) have occurred in recent years in public settings, which concern OSHA and many construction safety officials. NIOSH is conducting research to identify fall protection strategies and effective intervention programs for

workers who are at risk of injury from work at elevation on mast climbing work platforms, using both computer modeling and field testing approaches. The end products will include recommendations and informational literature associated with mast climbing work platform fall protection systems for use by standards committees, manufacturers, employers, and workers.

### *Human Characteristics and Biomarkers in Fall Injury Controls*

The majority of human falls can be regarded as loss-of-balance incidents. Factors that may lead to disruption of balance include lack of adequate visual cues, inadequate lighting or visual information in the work environment, narrow and inclined support surfaces, unexpected changes in surface properties, load handling, physical exertion, fatigue, task complexity that diverts workers' attention, individual differences, lack of work experience and training, and the physiological and mental load imposed by personal protective equipment (Hsiao and Simeonov, 2001). NIOSH has conducted a series of studies on human characteristics and biomarkers with practical implications to advance fall injury controls. For instance, a simple vertical structure, e.g., a narrow bar, available in line of sight can serve as a visual cue to assist workers' balance (Simeonov, Hsiao, & Hendricks, 2009). The finding may be useful in modifying elevated work environments and construction procedures to improve workers' postural balance during construction or structure repair jobs. In addition, at elevation, workers depend heavily on sensory information from their feet to maintain balance. Sensory suppression associated with elevated vibration levels at a work site may increase the risk of losing balance. Mechanical vibration transmitted to walking/working surfaces through supporting structures needs to be controlled when workers are performing tasks at elevation (Simeonov, Hsiao, & Powers et al., 2011). Moreover, NIOSH studies showed that shoes with characteristics of tight fit, good motion control of the rear, high flexibility of the front, moderate torsional stiffness, and a very flexible high-cut upper can minimise the risk of loss of balance, making them a better choice than casual shoes for work on elevated and narrow surfaces (Simeonov, Hsiao, & Powers et al., 2008).

### **Emerging Issues - For Total Worker Safety for Slip, Trip, and Fall Control**

First, populations of a given age, gender, ethnicity, and occupation permutation may have unique body size and shape compositions. Workplaces, community environments, and PPE need to be adequately designed to accommodate diverse populations. Through anthropometric research, NIOSH has provided both scientific theories and practical manufacturing information to advance harness design for protecting workers from fall injury in the construction sector. Developing improved protective gear, better home and community environments, and user-friendly assist devices for fall prevention that fit diverse population groups is a significant agenda for the community. Second, in this new era of changing technology, there are unique issues in the booming green energy and digital communication businesses in which safety professionals can make a significant contribution (e.g., safe erection of wind turbines and communication towers). Third, workers of specific age, social, and economic characteristics may have unique vulnerabilities for fall injury. It is important to focus on these populations, particularly as they have been largely underserved in the past. One example is the study of the constraints of aging workforces in coping with injury risks; injury data systems have shown that 42% of fatal STF victims in 2011 were age 55 and above (U.S. BLS, 2013b).

Finally, innovation and implementation should be an important chapter in total worker safety in STF control. Current design paradigms provide a framework to build upon, but may limit design creativity. It took 20 years for airbags to become a standard safety device for reducing vehicle-crash-related injuries. While skeptics will always exist with the introduction of new technologies (e.g., the concept of wearable airbags) to combat falls, with advancements in durability and reduction of cost, wearable airbags to reduce fall-related injuries may become an integral part of worker fall protection systems in the near future. The notion is equally valuable in protecting



inhabitants during household-chore activities (e.g., window cleaning) and reducing resident fall injury risk in healthcare or homecare settings during daily activities. Furthermore, smart phone based safety software/applications (apps) represent an emerging area of total worker safety for STF control; many STF risk exposure assessment tools and safety guidelines can be developed into mobile apps for STF prevention in workplaces and homes. The NIOSH ladder safety mobile app mentioned in the “Ladder Safety Research and Innovations” subsection is a successful example.

## Summary

STF research has long been recognized as one of the most important and needed areas of occupational and non-occupational injury prevention research. The complex and multifactorial nature of STFs in workplaces, homes, and communities demands a proactive and systematic approach to prevention. A total worker safety strategy for STF prevention offers an opportunity to integrate science-based information to publicize the importance of fall prevention and further STF risk factor identification and control. It also facilitates practical and effective STF innovations and implementation in the community. To maximize the benefits of the opportunity, collaborations should be actively implemented among national and international government entities, medical institutes, technology firms, STF control assist-device developers, and research centers to develop global research agendas, promote knowledge exchange, and conduct joint research.

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