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Fall Prevention and Protection: A Public Health Matter

Hongwei Hsiao

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ABSTRACT Slips, trips, and falls (STF) represent a serious hazard to workers and occupants in many industries, homes, and communities. Countering STF hazards and risks through all aspects of control measures is a public health matter, a challenging yet tangible undertaking. This chapter describes a public health approach to STF prevention. It summarizes the industries, occupations, and special population groups that are at increased STF risk due to their high STF-related fatality or nonfatal injury counts (or rates). The chapter also suggests critical research topics for global STF control, which correspond to the overall structure of this book—from fall injury risk factors to fall prevention research, evidence-based fall prevention practices, fall injury case studies, and emerging issues in fall prevention and protection.

KEY WORDS: *falls, construction, healthcare, trade, aging, human characteristics, public health, control measure.*

1.1 Introduction

The most recent report on fatal occupational injuries showed that slips, trips, and falls (STF) took the lives of 699 workers in the United States in 2013 (BLS, 2014a), which accounted for 16% of all occupational fatality cases. In addition, there were 296,140 STF-related nonfatal occupational injuries resulting in days away from work in 2013, which accounted for about 25.5% of all occupational injuries in that year (BLS, 2015a). The construction industry continued to have the highest count of STF-related fatalities (BLS, 2014a). The health-care and social assistance sector, retail trade, and accommodation and food services have the highest number of nonfatal STF-related injuries (BLS, 2015b). In addition, transportation and warehousing, agriculture and the forestry industry, and the construction sector have the highest rate (per 10,000 full-time workers) of nonfatal STF-related injuries (BLS, 2015c). Many countries are facing the same challenges as the United States with STF injury problems in the workplace (NIOSH, 2011a).

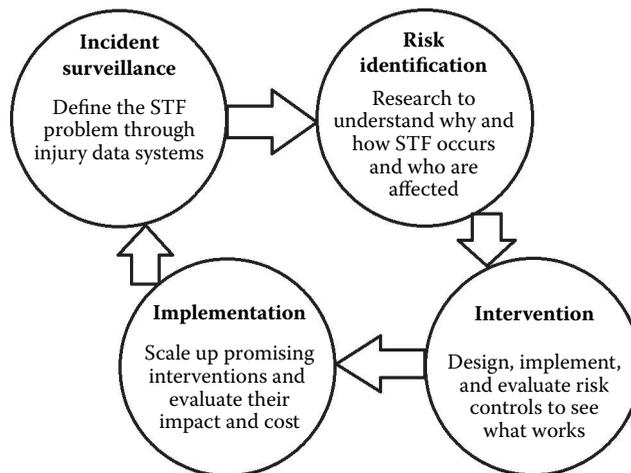
Aside from workplace incidents, STFs are the second leading cause of unintentional death in homes and communities, resulting in more than 27,100 fatalities in 2012 (NSC, 2014). In addition, falls were the leading cause of nonfatal injuries among the general population in the United States in 2013 for all age groups from <1 to 85+, except for the 10–24 age group, who had more struck-by-related injuries than falls (NCIPC, 2015). Often, inhabitants fall from ladders, from stairs, on uneven surfaces, or in wet areas at home. Elderly individuals are particularly at risk. In 2013, more than 3.4 million nonfatal fall injuries among older adults (55–85+ years old) were recorded in emergency departments (NCIPC, 2015). Similar concerns are seen worldwide (WHO, 2007).

Given the prevalence of STF problems, an organized national and global prevention research and practice effort is warranted. Considering STF control as a public health matter, we can prioritize our resources for STF prevention actions on industries and populations with the highest counts or rates of STF-related fatalities and injuries. We can also focus on the most compelling STF-related risks facing workers across all industry sectors and citizens in homes and communities to effectively reduce STF-related injuries and deaths. This book is organized around the public health concept and includes information on fall injury data, fall injury risk factors, fall prevention and protection research, evidence-based fall -prevention practices, fall injury investigation and case studies, and emerging issues in fall prevention and protection. This chapter describes the public health view on STF prevention.

1.2 Public Health View on Slip, Trip, and Fall Prevention

1.2.1 Public Health Approach

To effectively reduce national or global STF-related injuries and deaths, a focused effort that considers high-quality research, active partnerships, and research-to-practice actions is necessary. High-quality research refers to organized explorations with meaningful impacts. The public health approach provides a means to prioritize national and global efforts and assess impacts. The public health approach includes incident surveillance, risk identification, intervention, and implementation (Figure 1.1; Hsiao, 2014). Incident surveillance identifies the magnitude and severity of problems. Often, injury data systems and

**FIGURE 1.1**

Public health approach for slip, trip, and fall prevention. (From Hsiao, H., *Industrial Health*, 52, 381–392, 2014.)

fatality reports reveal trends or changes in STF problems. Risk identification characterizes risks and causes. It is a step toward understanding why and how STF occurs and who is affected. Intervention refers to the design and evaluation of risk controls. Both field and laboratory studies can be performed to understand what mechanisms work and their levels of effectiveness. Implementation promotes promising interventions and evaluates their impact and cost-effectiveness; the idea of implementation is to bring STF prevention measures to a broad segment of the population and reduce STF at a population level. The public health approach is a continuing process to understand the causes and sources for STF prevention and policy/strategy interventions.

1.2.2 Incident Surveillance

While most current injury data systems do not include detailed information on how a fatality or injury incident happened, some systems provide sufficient consolidated information on STF incidents by industry, occupation, population, age, and other parameters for national strategic goal-planning purposes. Among the available databases are the Census of Fatal Occupational Injuries and Nonfatal Occupational Injuries and Illnesses from the Survey of Occupational Injuries and Illnesses by the Bureau of Labor Statistics (BLS, 2014a, 2015a) and the Web-based Injury Statistics Query and Reporting System (WISQARS) by the National Center for Injury Prevention and Control (NCIPC, 2015).

The Census of Fatal Occupational Injuries (Table 1.1; BLS, 2014a) reported that the construction sector had the highest count of STF-related fatalities in 2013, followed by the waste-management sector. The same database (Table 1.2; BLS, 2015d) indicated that construction and extraction occupations encountered the highest number of STF-related fatalities, followed by the building- and grounds-cleaning/maintenance occupations; installation, maintenance, and repair occupations; and transportation and material-moving occupations. Most of these incidents (574 out of 699) were falls to a lower level, and of the cases where the height of the fall was known (466 cases), three out of every five were falls of 20 ft or less (BLS, 2014b).

The Survey of Occupational Injuries and Illnesses (Table 1.3; BLS, 2015b) showed that the health-care and social assistance sector had the highest *count* of STF-related nonfatal

TABLE 1.1

Fatal Occupational Falls by Industry in the United States in 2013

Industry	NAICS Code	Total STF Count (699)
Agriculture, forestry, fishing and hunting	11	30
Mining	21	19
Construction	23	294
Manufacturing	31, 32, 33	41
Wholesale trade	42	23
Retail trade	44, 45	31
Transportation and warehousing	48, 49	35
Information	51	10
Finance and insurance	52	0
Real estate and rental and leasing	53	13
Professional, scientific, and technical services	54	7
Management of companies and enterprises	55	0
Administrative, support, waste management, remediation	56	78
Education services	61	3
Health-care and social assistance	62	10
Art, entertainment, and recreation	71	8
Accommodation and food services	72	15
Other services, except public administration	81	27
Federal government		13
State government		6
Local government		31

Source: BLS, Fatal occupational injuries by industry and event or exposure, All U.S., 2013, (Table A.1), 9/11/2014. US Bureau of Labor Statistics, Washington, DC, 2014a. <http://www.bls.gov/iif/oshwc/foi/cftb0277.pdf>.

injuries, followed by the retail trade and the accommodation and food services sector. The transportation and warehousing sector had the highest *rate* (per 10,000 full-time workers) of STF-related nonfatal injuries (Table 1.3; BLS, 2015c), followed by the agriculture, forestry, fishing, and hunting sector and the construction sector. The same database revealed that transportation and material-moving occupations had the highest *number* of STF-related nonfatal injuries (Table 1.4; BLS, 2015e), followed by the food preparation and serving occupations and the construction and extraction occupations. The building- and grounds-cleaning and maintenance occupations had the highest *rate* of STF-related nonfatal injuries, followed by the transportation and material-moving occupations and the construction and extraction occupations (Table 1.4; BLS, 2015f).

Data from WISQARS showed 31,240 fall deaths among the general population in the United States in 2013 (Table 1.5; NCIPC, 2015), which is equivalent to 9.88 cases per 100,000 citizens. Of the cases, 51% (N = 15,957) were males and 49% (N = 15,283) were females. For males, about 85% (N = 13,527) of the deaths were at age 55–85+. For females, about 95% (N = 14,501) of the deaths were in the same age category. The same system reported that there were 8,790,337 STF-related nonfatal injuries among the general population in 2013 (Table 1.6; NCIPC, 2015). Among them, 45% (N = 3,960,046) were male and 55% (N = 4,830,224) were female; there were 66 cases in which gender was not recorded. Older groups, aged 55–85+, had higher fall injury rates than the younger groups.

TABLE 1.2

Fatal Occupational Falls by Occupation in the United States in 2013

Occupation	Occupation Code	Total STF Count (699)
Management occupations	11	39
Business and financial operations	13	3
Computer and mathematical occupations	15	0
Architecture and engineering	17	6
Life, physical, and social science	19	0
Community and social service	21	3
Legal occupations	23	4
Education, training, and library	25	5
Arts, design, entertainment, sports, and media	27	8
Health-care practitioners and technical occupations	29	3
Health-care support occupations	31	1
Protective service occupations	33	12
Food preparation and serving-related occupations	35	12
Building and grounds cleaning and maintenance	37	76
Personal care and service occupations	39	6
Sales and related occupations	41	20
Office and administrative support occupations	43	17
Farming, fishing, and forestry occupations	45	10
Construction and extraction occupations	47	293
Installation, maintenance, and repair occupations	49	70
Production occupations	51	38
Transportation and material-moving occupations	53	66
Military-specific occupations	—	4

Source: BLS, Table A.5. Fatal occupational injuries by occupation and event or exposure, All U.S., 2013. US Bureau of Labor Statistics, Washington, DC, 2015d. <http://www.bls.gov/iif/oshwc/cfoi/cftb0281.pdf>.

1.2.3 Risk Identification

The incident surveillance data mentioned in the previous section provide a direction for organizations that are in charge of or interested in fall prevention strategic planning to effectively organize resources for the greatest impact. In addition to the data, the next key step for successful STF control is to identify risk factors. 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 (Table 1.7; Hsiao and Simeonov, 2001).

The personal factors include individual differences: age, gender, race, 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 (WHO, 2007; Hsiao and Simeonov, 2001; Knudtson et al., 2009; Gauchard et al., 2001; Tinetti and Speechley, 1989; Mesure et al., 1997; Robertson et al., 1994; Black et al., 1993). The environmental factors concern the properties of environments as well as 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, inclination of support surfaces, lighting, building design, and material properties of support surfaces (e.g., friction, contaminants, evenness, loose fixtures, and firmness) (Hsiao and Simeonov, 2001; Gauchard et al., 2001; Bles et al., 1980; Brandt et al.,

TABLE 1.3

Nonfatal Occupational Falls by Industrial Sector in Private Industry in the United States in 2013

Nonfatal Occupational Falls by Industry (Private Industry)	NAICS Code	Number ^a				Rate per 10,000 Workers ^b			
		Total STF	Fall to Lower Level	Fall on Same Level	Slips or Trips without Fall	Total STF	Fall to Lower Level	Fall on Same Level	Slips or Trips without Fall
Agriculture, forestry, fishing and hunting	11	5,030	1,960	2,310	600	52.1	20.3	23.9	6.2
Mining	21	1,550	470	780	210	18.1	5.5	9.2	2.4
Construction	23	21,890	9,560	8,560	3,010	41.3	18	16.1	5.7
Manufacturing	31–33	21,430	4,370	12,730	3,790	18	3.7	10.7	3.2
Wholesale trade	42	12,640	3,390	6,430	2,100	22.4	6	11.4	3.7
Retail trade	44, 45	29,690	5,810	19,680	3,660	26	5.1	17.2	3.2
Transportation and warehousing	48, 49	21,970	4,890	11,460	4,140	54.3	12.1	28.3	10.2
Information	51	4,850	920	2,640	1,150	19.5	3.7	10.6	4.6
Finance and insurance	52	4,620	490	3,610	500	8.6	0.9	6.7	0.9
Real estate and rental and leasing	53	4,430	1,440	1,920	720	24.8	8.1	10.7	4.1
Professional, scientific, and technical services	54	4,280	980	2,360	870	5.7	1.3	3.1	1.1
Management of companies and enterprises	55	2,170	370	1,600	200	11.3	1.9	8.3	1
Administrative, support, waste management	56	12,850	2,840	7,540	2,290	27	6	15.9	4.8
Education services	61	3,930	510	2,910	450	21.2	2.8	15.7	2.4
Health care and social assistance	62	43,820	3,890	33,290	6,340	32.9	2.9	25	4.8
Art, entertainment, and recreation	71	4,310	620	2,920	620	33.4	4.8	22.7	4.8
Accommodation and food services	72	22,810	2,610	17,100	2,800	29.3	3.4	22	3.6
Other services, except public administration	81	5,860	1,690	2,710	1,280	19.3	5.6	8.9	4.2

^a BLS, Table R4. Number of nonfatal occupational injuries and illnesses involving days away from work by industry and selected events or exposures leading to injury or illness, private industry, 2013. US Bureau of Labor Statistics, Washington, DC. 2015b. <http://www.bls.gov/iif/oshwc/osh/case/ostb3985.pdf>.

^b BLS, Table R8. Incidence rates for nonfatal occupational injuries and illnesses involving days away from work per 10,000 full-time workers by industry and selected events or exposures leading to injury or illness, private industry, 2013. US Bureau of Labor Statistics, Washington, DC. 2015c. <http://www.bls.gov/iif/oshwc/osh/case/ostb3989.pdf>.

TABLE 1.4

Nonfatal Occupational Falls by Occupation in Private Industry in the United States in 2013

Nonfatal Occupational Falls by Occupation (Private Industry)	Occup. Code	Number ^a				Rate Per 10,000 Workers ^b			
		Total STF	Fall to Lower Level	Fall on Same Level	Slips or Trips without Fall	Total STF	Fall to Lower Level	Fall on Same Level	Slips or Trips without Fall
Management occupations	11	7,960	1,530	5,180	1,170	14	2.7	9.1	2.1
Business and financial operations	13	3,390	490	2,650	230	6.8	1	5.4	0.5
Computer and mathematical occupations	15	720	180	460	70	2.4	0.6	1.5	0.2
Architecture and engineering	17	720	140	450	110	3.7	0.7	2.3	0.6
Life, physical, and social science	19	510	150	280	20	8.4	2.5	4.5	0.4
Community and social service	21	2,470	350	1,770	330	26.5	3.8	19	3.6
Legal occupations	23	310	30	270	0	4.3	0.4	3.7	0
Education, training, and library	25	2,830	220	2,100	470	20	1.5	14.9	3.3
Arts, design, entertainment, sports, and media	27	1,540	250	860	340	12.5	2	7	2.8
Health-care practitioners and technical occupations	29	13,830	950	10,480	2,290	25.7	1.8	19.4	4.3
Health-care support occupations	31	11,770	850	9,190	1,660	43.1	3.1	33.6	6.1
Protective service occupations	33	3,810	630	2,530	550	41.1	6.8	27.3	5.9
Food preparation and serving	35	20,530	1,570	16,300	2,470	27.6	2.1	21.9	3.3
Building and grounds cleaning and maintenance	37	16,290	3,460	9,840	2,390	60.6	12.9	36.6	8.9
Personal care and service	39	5,710	840	3,830	980	23.5	3.5	15.8	4.1
Sales and related occupations	41	17,440	3,800	11,010	2,270	16.1	3.5	10.2	2.1
Office and administrative support	43	19,640	2,360	14,210	2,850	13.7	1.6	9.9	2
Farming, fishing, and forestry	45	4,140	1,590	1,890	560	46.4	17.8	21.2	6.3
Construction and extraction	47	20,250	8,760	8,040	2,720	48.7	21.1	19.4	6.5
Installation, maintenance, and repair	49	16,570	6,010	6,970	2,960	38.9	14.1	16.4	6.9
Production occupations	51	17,490	2,950	10,920	3,170	22.6	3.8	14.1	4.1
Transportation and material-moving occupations	53	40,760	9,970	21,420	7,340	56.5	13.8	29.7	10.2

^a BLS, Table R12. Number of nonfatal occupational injuries and illnesses involving days away from work by occupation and selected events or exposures leading to injury or illness, private industry, 2013. US Bureau of Labor Statistics, Washington, DC. 2015e. <http://www.bls.gov/iif/oshwc/osh/case/ostb3993.pdf>.

^b BLS, Table R100. Incidence rates for nonfatal occupational injuries and illnesses involving days away from work per 10,000 full-time workers by occupation and selected events or exposures leading to injury or illness, private industry, 2013. US Bureau of Labor Statistics, Washington, DC. 2015f. <http://www.bls.gov/iif/oshwc/osh/case/ostb4081.pdf>.

TABLE 1.5

Fall Deaths among General Population in the United States in 2013

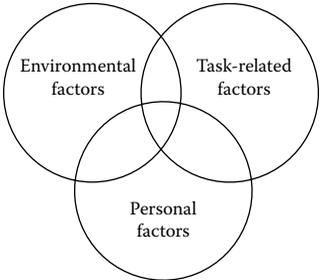
Fall Deaths	Males (N = 15,957)			Females (N = 15,283)		
	Number of Deaths	Population	Rate Per 100,000	Number of Deaths	Population	Rate Per 100,000
Age Group						
0–9	32	20,661,392	0.15	20	19,777,277	0.10
10–19	93	21,398,713	0.43	35	20,410,705	0.17
20–24	197	11,678,965	1.69	51	11,116,473	0.46
25–29	223	10,959,879	2.03	39	10,620,319	0.37
30–34	204	10,681,612	1.91	58	10,582,777	0.55
35–39	211	9,785,269	2.16	59	9,818,501	0.60
40–44	310	10,359,992	2.99	100	10,488,928	0.95
45–49	475	10,498,118	4.52	167	10,710,188	1.56
50–54	684	11,070,966	6.18	252	11,488,260	2.19
55–59	783	10,282,382	7.61	329	10,912,048	3.02
60–64	893	8,674,373	10.29	430	9,447,628	4.55
65–69	1054	6,913,190	15.25	560	7,695,527	7.28
70–74	1178	4,884,452	24.12	861	5,723,597	15.04
75–79	1684	3,390,347	49.67	1379	4,287,534	32.16
80–84	2511	2,370,170	105.94	2444	3,398,468	71.91
85 and up	5424	2,041,782	265.65	8498	3,999,007	212.50

TABLE 1.6

Nonfatal Fall Injuries among the General Population in the United States in 2013

Fall Injuries	Males			Females		
	Number of Injuries	Population	Rate per 100,000	Number of Injuries	Population	Rate per 100,000
Age Group						
0–9	915,912	20,661,392	4432.96	696,791	19,777,277	3523.19
10–19	543,167	21,398,713	2538.32	425,791	20,410,705	2086.12
20–24	208,626	11,678,965	1786.34	201,749	11,116,473	1814.87
25–29	182,695	10,959,879	1666.94	191,746	10,620,319	1805.46
30–34	176,944	10,681,612	1656.53	195,617	10,582,777	1848.45
35–39	151,875	9,785,269	1552.08	190,946	9,818,501	1944.76
40–44	164,931	10,359,992	1592.00	199,357	10,488,928	1900.64
45–49	185,302	10,498,118	1765.10	232,901	10,710,188	2174.57
50–54	221,028	11,070,966	1996.47	277,180	11,488,260	2412.72
55–59	205,777	10,282,382	2001.26	288,244	10,912,048	2641.52
60–64	172,517	8,674,373	1988.81	264,954	9,447,628	2804.45
65–69	158,611	6,913,190	2294.32	259,089	7,695,527	3366.75
70–74	148,605	4,884,452	3042.41	238,223	5,723,597	4162.12
75–79	139,697	3,390,347	4120.43	259,104	4,287,534	6043.19
80–84	150,821	2,370,170	6363.30	300,292	3,398,468	8836.10
85 and up	233,265	2,041,782	11424.58	608,099	3,999,007	15206.25
Unknown	276			141		

TABLE 1.7
Risk Factors Associated with Slips, Trips, and Falls

Model	Primary Factors	Elements
 <p>There are intersections of some elements under each of the three primary factors between or among primary factors, although they are classified as belonging to a single primary factor</p>	Personal factors	Age, gender, race, body size, work experience, physical strength, chronic illness, substance use, cognitive capacities, constraints of PPE, visual acuity, contrast sensitivity, discrepant vision between the eyes, and expiratory flow rate
	Environmental factors	Restricted support surfaces, inclination of support surfaces, lighting, building design, material properties of support surfaces (e.g., friction, contaminants, evenness, loose fixtures, and firmness), elevation perception, moving visual scenes, depth perception, visual ambiguity, and visual detection of obstacles and their properties
	Task-related factors	Load handling, physical exertion and fatigue, footwear, complexity of tasks, social interactions, and community resources

Source: Hsiao H. and Simeonov P., *Ergonomics*, 44 (5), 537–561, 2001.

1980; Paulus et al., 1984; Peterka and Benolken, 1995; Clark et al., 1996; Lasley et al., 1991). The task-related factors include load handling, physical exertion and fatigue, footwear, complexity of tasks, social interactions, and community resources (WHO, 2007; Hsiao and Simeonov, 2001; Commissaris and Toussaint, 1997; Seliga et al., 1991; Zohar, 1978; Patla, 1997). Many of the above-mentioned elements within each of the primary factors relate to the interaction between or among primary factors, although they are classified as belonging to only a single primary factor.

National and global research efforts to prevent STF vary among government agencies, 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 improve workplace safety and quality of life as a whole, countering fall hazards and risks faced by community dwellers and workers on the job, at home, and in the public area becomes more inseparable. Workers use ladders at work. People use ladders in their homes for household chores as well. Community members access building floors through stairways at home as well as at workplaces and public facilities. Adequate material properties of walkways and proper lighting are equally critical at work and at home for walkway-related fall control. Moreover, an STF injury typically affects a person’s ability to perform tasks at the workplace and in 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 are similar. Global entities, whether their specific foci are on workplace safety, home safety, or public safety, can integrate current knowledge and research efforts among all aspects to advance the identification of risk factors and innovations for STF control, and transfer realistic and effective STF interventions into practice.

1.2.4 Intervention and Implementation

In STF prevention using the public health approach, *intervention* refers to the design and evaluation of risk-factor controls to understand what works and the level of effectiveness.

Implementation refers to bringing STF prevention measures to a broad segment of the population and reducing STF at a population level. Both intervention and implementation require active partnerships and research-to-practice engagements for their effective impact. *Active partnerships* refers to collaborative partnerships among labor, industry, government agencies, academic institutions, and other stakeholders. Collaborative partnerships ensure the input from partners at all stages of the public health model to facilitate the linkage of research with the development of practical injury-control solutions. *Research-to-practice actions* refers to the transfer and translation of research findings into effective use. Organizations may focus their efforts on knowledge or technology transfer to achieve an impact on reducing fall risks, injuries, and deaths among workers or the general population.

1.3 Strategic Goals to Address Global STF Burden

The incident surveillance data described in Section 1.2.2 provide a means to highlight program activities and directions that are likely to have the greatest impact on preventing fall injuries and deaths among high-risk industries, occupations, and population groups. Some industry targets indicated by the surveillance data are the construction industry, the retail trade, and the health services industry. Occupational targets include the transportation and material-moving occupations. General population targets include focusing on fundamental knowledge and practical solutions for STF prevention in homes and communities, especially for older populations. These primary STF prevention targets are further elaborated in this chapter, and this book is organized around these subjects.

1.3.1 Reducing STF in the Construction Industry and among Construction Trade Workers

The construction industry has the highest count of STF-related fatalities of all industries in the United States, and the construction, building- and grounds-cleaning, and installation and repair occupations have encountered the highest number of STF-related fatalities. Efforts that can be made to address the burden include (1) inventory of existing fall protection technologies and identification of gaps where technical engineering guidance needs to be developed or modified further for fall prevention and protection (such as fall protection anchorage systems); (2) development and evaluation of engineering interventions and guidelines to address fall prevention gaps (such as aerial lift safety guidelines); (3) partnership with insurance companies and consultation organizations to identify the implementation obstacles to small contractors associated with existing fall prevention and protection measures (such as fall prevention in residential construction); (4) inventory of existing research, regulations, guidance, and practitioner materials on ladders, scaffolds, and roofing safety, and identification of key gaps and needs (such as graphic-based ladder safety guidelines); and (5) conducting and evaluating national or regional construction fall prevention campaigns.

1.3.2 Fall Injury Control in the Health Services Industry

The health-care and social assistance sector has the highest count of nonfatal STF-related injuries among industrial sectors. Health-care practitioners and health-care support

technical occupations together are among the groups with the highest rates of falls on the same level. The literature has reported STF control strategies for the health services industry, and many of them have been adopted by the industry. In addition, STF prevention toolkits for the health-care sector are being developed and adopted by many hospitals in the United States. There is a need for the health services industry, insurance companies, occupational safety professionals, safety equipment manufacturers, government, and fall prevention research organizations to promote widespread implementation of comprehensive STF prevention programs in health-care settings.

1.3.3 Reducing STF in Retail Trade Settings

The retail trades have the second highest nonfatal STF injury counts among industrial sectors after the health-care industry. Their associated food preparation and serving occupations account for the second highest number of STF injuries, following the transportation and material-moving occupations. The retail trades are known to have some unique STF issues. Organized efforts toward STF research and prevention among the retail trades, however, are not well reported in the literature. The implementation of effective, evidence-based fall prevention and protection designs, technologies, programs, and communication materials for the handling, storage, and retrieval of merchandise is needed. Among the critical topics are (1) developing and evaluating innovative fall preventive/protective solutions (strategy, technology, or PPE) addressing merchandise storage and retrieval-associated fall incidents; (2) testing the feasibility of advanced technologies for integration into existing elevation-access devices; (3) transferring fall prevention innovations (or existing effective fall prevention solutions) and the related fall prevention knowledge into industrial practices in the retail trade, such as trucking/transporting and goods retrieval practices; and (4) providing scientific evidence and business case support for comprehensive STF prevention programs to reduce STF injuries among food service workers.

1.3.4 Reducing Fall Injuries among Transportation and Material-Moving Occupations

Transportation and material-moving occupations account for the highest number of nonfatal STF injuries among all occupations. Vehicle and equipment manufacturers, standards committees, occupational safety professionals, and government agencies can work together to improve the design of delivery trucks and material-moving procedures to reduce the risk of injuries and fatalities associated with falls from these vehicles and falls during the material-moving process. Among the main topics are (1) evaluating vehicle configuration and access system designs of delivery trucks, and working with equipment manufacturers to review and consider design enhancement; (2) working with national standards groups to update or develop vehicle configuration and access system standards for delivery vehicles; (3) developing and disseminating guidelines for vehicle configuration, access system use, and material-movement assistance systems to reduce STFs among truck drivers and material-moving workers.

1.3.5 Fall Injury Control among Vulnerable Populations

Workers of specific age, social, and economic characteristics may have unique vulnerabilities to 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 on aging workforces in coping with injury risks. Injury data systems have shown that 42%

of fatal STF victims in the workplace in 2013 were aged 55 and above (BLS, 2015g). Data on fall deaths among the general population in the United States in 2013 also showed disproportional STF fatalities in the 55–85+ age category, accounting for 85% of male and 95% of female victims (NCIPC, 2015). One topic would be to study older workers' physical and psychosocial characteristics associated with falls and the mechanisms through which older citizens are at increased risk for fall injury, and develop guidance to address risks for falls among older populations.

1.3.6 Fall Injury Protection among Diverse Populations

Populations of a given age, gender, ethnicity, and occupation may have unique body size and shape compositions. Workplaces, community environments, and PPE need to be adequately designed to accommodate diverse populations. 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 research community. In addition, safety research organizations, trade associations, insurance companies, and employers can identify, characterize, and reduce fatal and serious injuries associated with falls to a lower level among Hispanic construction workers. Hispanic workers have disproportional STF-related fatalities in the construction industry (Dong et al., 2009).

1.3.7 Understanding Human Characteristics for Effective Fall Control Measures

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 PPE (Hsiao and Simeonov, 2001). Understanding human characteristics, social-organizational characteristics, and biotechnology-based fall control measures will generate fundamental knowledge and practical solutions for STF prevention in the workplace, the home, and the 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 factors or craft engineering solutions and organizational interventions to reduce the incidence of STF. 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. Among the important topics are (1) exploring the effects of physical variations, neurological traits, cognition processes, social-organizational and cultural factors, and safety attitudes on fall risk; (2) publishing information on the effectiveness of new strategies, technologies, and sensory-enhancement approaches to reduce fall-initiation risk; (3) transferring recommendations to industrial practice on improved sizing systems and configurations of fall protection devices to accommodate current worker populations; (4) developing improved devices or accessories for impact energy or stress relief (such as swing falls and suspension-trauma relief during and after a fall incident) and

establishing rescue guidelines to further protect workers; (5) developing knowledge databases for improving digital human models on fall dynamics, including the phases of fall initiation and fall termination, for use in efficient evaluation of new fall prevention and protection methods and strategies, in fall incident investigations (reconstruction), and in workers' hazard-recognition training; and (6) transferring knowledge databases to digital model developers to develop scientifically comprehensive yet easy-to-use digital modeling modules for use in workplace planning for fall prevention, workers' hazard recognition training, and fall incident investigations.

1.3.8 Emerging Issues in Fall Injury Control

In this new era of changing technology, there are unique issues in the booming green energy and digital communication businesses in which fall protection measures are important (e.g., safe erection of wind turbines and communication towers). Preplanned fall protection measures are necessary for both erection and maintenance stages. Next, smartphone-based safety software applications (apps) represent an emerging area of education and communication 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 National Institute for Occupational Safety and Health (NIOSH) ladder safety mobile app is a successful example (Simeonov et al., 2013). Furthermore, a paradigm shift by adopting technology from other fields may offer a creative solution for STF control. For instance, the concept of wearable airbags may be useful to combat fall injuries. With advancements in durability and reduction in 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 and worker fall injury risk in health-care or home care settings during daily activities.

1.4 Summary

STF research has long been recognized as one of the most important and necessary areas of occupational and nonoccupational injury prevention research. The complex and multifactorial nature of STFs in workplaces, homes, and communities demands a proactive and systematic approach to prevention. Considering STF prevention as a public health matter 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 this 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. This chapter describes injury data, critical research topics, and practical suggestions for global STF control, which correspond to the overall organization of this book: from fall injury risk factors to fall prevention research, evidence-based fall prevention practices, fall injury case studies, and emerging issues in fall prevention and protection in homes, communities, and workplaces.

1.5 Disclaimer

The findings and conclusions in this chapter are those of the author and do not necessarily represent the views of the NIOSH. Mention of company names or products does not constitute endorsement by NIOSH.

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Section I

A Public Health View of Fall Problems and Strategic Goals