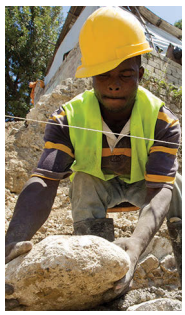

Chapter 6

Occupation and Risk for Injuries

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INTRODUCTION

The world of work has changed dramatically. Globalization affects the structure of workplaces, the way work is performed, and occupational safety and health (OSH). Despite great strides in improving OSH during the past century, an estimated 317 million nonfatal occupational injuries and 321,000 occupational fatalities occur globally each year, that is, 151 workers sustain a work-related accident every 15 seconds (ILO 2013a). Poor workplace safety and health place a substantial economic burden on individuals, employers, and society. Estimates from the International Social Security Association (ISSA) suggest that costs associated with nonfatal workplace accidents alone equal approximately 4 percent of world gross domestic product (GDP) each year (ISSA 2014; SafeWork 2012).

Although virtually every job entails some risk for injury, the magnitude of risk varies widely across jobs, sectors, geographic regions, and individuals. Occupational injury rates have been rising in low- and middle-income countries (LMICs), but declining in high-income countries (HICs), although the effect of globalization has been mixed. The steady decline in Australia, North America, and Western Europe is due, at least in part, to the export of labor-intensive and often more dangerous industrial production to regions where salaries are lower, workplace regulations are less stringent, and working conditions are generally poorer. However, in HICs the number of small firms and informal sector jobs has grown markedly. These firms and jobs are underserved by OSH regulations and enforcement; are difficult to reach with traditional OSH services; and have greater, but largely hidden, risk for accident and injury. Consequently, although the true burden of occupational injury in HICs remains uncertain, an estimated 6.9 million worker injuries occurred in the European Union (EU) during 2006 and 8.5 million occurred in the United States during 2007 (Chau and others 2014; Leigh and Marcin 2012). Occupational injuries and fatalities take an even greater toll in LMICs, where a large portion of the population works in the informal sector or in high-hazard sectors, including agriculture, construction, fishing, and mining, with associated costs as high as 10 percent of GDP.

The great recession of 2007–09 had a negative effect on OSH in many countries. Corporations downsized, restructured, and outsourced or transferred work to third-party employers, temporary employment agencies, or independent contractors. As of 2011, 22.3 million fewer adults and 6.4 million fewer youths participated in the labor force than anticipated according to global trends before the downturn. From 2007 to 2010, the ratio of jobs to population declined sharply—from 61.2 percent in 2007 to 60.2 percent in 2010 (ILO 2012c)—and the number of workers in precarious or vulnerable employment reached an estimated 1.52 billion, an increase of nearly 23 million since 2009 and 136 million since 2000. Latin America and the Caribbean, the Middle East, South Asia, South-East Asia and the Pacific, and Sub-Saharan Africa experienced the largest increase in

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vulnerable employment. Women were disproportionately affected in the Middle East, North Africa, and Sub-Saharan Africa.

This chapter discusses the many changes in work and work-related injuries in seven sections. Following this introduction, the second section reviews the current state of occupational injury and safety in HICs, with an emphasis on recent developments and observations, and the third focuses on the situation in LMICs, again with an emphasis on recent developments. The fourth section reviews the effect of global supply chains on global business practices. The fifth section discusses the economic effects of these changes and interventions used in ameliorating the problems raised, drawing heavily from observations in the preceding sections to the extent possible. The sixth section provides a brief synopsis of the contributions that workplace physical, chemical, and biologic exposures may make to the occurrence of acute and chronic medical conditions. A final section provides conclusions.

OCCUPATIONAL INJURY IN HICs

Several developments have the potential to raise occupational injury rates. In HICs, temporary work and other forms of flexible employment have risen, including contingent work, home-based work, part-time contracts, unregulated work, and other nontraditional work. Most of these arrangements are precarious; they are unstable, offer little social protection, and pay low wages. Consistent evidence has shown that workers in precarious or vulnerable work arrangements experience more health and safety hazards and poorer health and safety outcomes than do other workers. Labor statistics often capture only precarious workers in temporary employment, underestimating the true burden of precarious employment on OSH (Benavides and others 2006; Virtanen, Janlert, and Hammarström 2011). Temporary workers have twice the risk for occupational injury as permanent workers, but the reasons for this higher risk are poorly defined. They are likely to include less job experience, less recognition of workplace hazards, and inadequate or ineffective safety training (Virtanen, Janlert, and Hammarström 2011). Despite substantially higher rates of occupational injury, temporary workers have lower absence rates, perhaps fearing the loss of their job (Benavides and others 2006; Virtanen, Janlert, and Hammarström 2011).

Economic and employment growth in many regions relies to a great extent on small and medium enterprises (SMEs). More than 90 percent of businesses in the EU and the United States employ fewer than 20 employees, and SMEs account for an estimated 82 percent of all occupational injuries (Ecorys 2012). SMEs are extremely diverse, covering many sectors and work activities and often offering flexible work environments. Given their small size, many SMEs have limited resources and lack formal OSH programs and training. Results from a national survey of U.S. firms with fewer than 250 employees found that few had an employee safety committee, 50 percent had no formal safety policies, and only 60 percent provided safety training to new employees (NFIB 2002). Moreover, a survey of major health insurers in Germany indicated that SMEs in the manufacturing sector had reduced their OSH management since the economic recession, a concerning trend (Kraemer 2010).

Employees of small business enterprises are exposed to higher health and safety risks than are employees of larger enterprises (Fabiano, Currò, and Pastorino 2004; Sinclair, Cunningham, and Schulte 2013). They also have much greater difficulty assessing and controlling these risks (Eakin, Champoux, and MacEachen 2010; Sørensen, Hasle, and Bach 2007).

Furthermore, most OSH laws and regulatory agencies are designed for large enterprises in the formal economy and either exempt or do not cover the informal economy and SMEs. Hence, there is little reporting on these sectors or enforcement of laws and regulations even in HICs. Employees who work in small enterprises far outnumber those who work in larger enterprises in many countries, so addressing these gaps is critical (Hasle and Limborg 2006).

The substantial increase in outsourcing in recent decades has shifted some work to workers' homes and other informal settings. Whereas many home-based workers are self-employed, others may work under some form of outsourcing arrangement and fall under the broad umbrella of precarious employment.

Studies examining the health and safety effects of outsourcing or subcontracting and home-based work have reported poorer OSH outcomes, using a range of measures (Quinlan and Bohle 2008). Questions regarding the mechanisms by which outsourcing and home-based work negatively affect health remain, but several factors may contribute (table 6.1).

There is no universally accepted definition of migrant workers. However, evidence from several press investigations and published reports suggests that regardless of their legal status, migrant workers experience various forms of exploitation at work, although conditions are typically worse for undocumented workers (McKay, Craw, and Chopra 2006). Migrant workers are less likely to receive workplace health and safety training in many sectors. When such training is provided, language barriers may prevent workers from understanding basic safety procedures or knowing how or where to report safety or health concerns.

Table 6.1 Negative OSH Consequences Potentially Arising from Home-Based and Outsourced Work

Contributing factor	Hazard
Economic and reward pressure	• Work intensification and compromised OSH
Disorganization of management systems	• Limited worker training or supervision • Poorly designed work settings • Inadequate safety protocols • Obscured mechanisms for workers to raise concerns
Dispersed workforce with complex management structures	• Less regulatory oversight and enforcement • Workforce logistically difficult for inspectorates to reach • Less worker understanding of employer OSH obligations and worker rights

Source: Lippel 2005.
Note: OSH = occupational safety and health.

Although migrant workers face similar workplace hazards as local workers in similar sectors and jobs, their safety and health may be at greater jeopardy for reasons specific to their situation. Migrant workers are more likely to be employed in hazardous work, work longer hours with fewer breaks, perform shift work, and be temporary workers or subcontractors and are less likely to report accidents (Premji, Lippel, and Messing 2008; Premji and others 2010). Migrant workers are often overqualified for the work they perform in host countries, and workplace injury may limit their occupational mobility, perpetuating the education–job mismatch. There is a great need to address barriers to suitable employment and to improve health and safety strategies targeting recent immigrants.

Workplace Hazards

Research conducted in HICs is the predominant source of information about the contribution of workplace hazards (physical, psychosocial, and work organization) and individual factors (gender, age, and health status) to occupational injury risk as well as ways to mitigate risk.

Physical Exposures

Physical exposures related to job tasks, workplace environment, use of tools and materials, machine operation, and machine-paced work affect workers in different occupations and employment sectors (Chau and others 2009; Vandergrift and others 2012). The following physical workplace exposures are strongly associated with injury risk:

- Manual handling
- Forceful exertions
- Highly repetitive motions with short work cycles
- Awkward postures of the neck, trunk, and extremities
- Whole-body or segmental vibration
- Mechanical contact stress from work positions or handling of tools and equipment
- High levels of ambient noise
- Extreme temperatures
- Work performed from heights
- Work performed around operating machinery.

Although many jobs in HICs continue to require manual labor, exposure to workplace physical hazards is not limited to manual workers. Results from the 2010 European Working Conditions Survey indicate that 33 percent of European workers handle heavy loads for at least 25 percent of their working time and 23 percent are exposed to workplace vibration (Eurofound 2010). Additionally, 30 percent of European workers are exposed to tiring positions 25–75 percent of their working time, and 16 percent of workers are exposed to tiring positions 100 percent of their working time (Eurofound 2010).

In the United States, approximately 27 percent of working adults are exposed continually to repetitive motion, 25 percent spend more than half of their time at work either bending or twisting, an estimated 10 percent are exposed to cramped workspaces that require them to assume awkward postures every day, and 2.7 percent are exposed to whole-body vibration (Tak and Calvert 2011). Workplace physical hazards clearly persist in HICs, underscoring the importance of mitigating these hazards even as countries move toward becoming largely service-based economies.

Psychosocial Exposures

Significant changes in technology and management ideologies, combined with increases in global competition, are responsible for the trend toward more difficult,

faster, more productive labor with less control over tasks (Green 2005). Workplace psychosocial hazards arising from evolving work demands, in conjunction with changing economic and social contexts of work, are emerging threats to physical and mental health (EU OSHA 2007; NIOSH 2002). Evidence has been amassed suggesting an association between stressors and the risk for work-related injury (Glasscock and others 2006; Kim and others 2009; Nakata and others 2006) and musculoskeletal disorder (MSD) (Bongers and others 2006; da Costa and Vieira 2010; Ghaffari and others 2008).

Psychosocial stressors include the following:

- Work intensification
- Highly monotonous work
- Time pressure or deadlines
- Significant mental workload
- Ambiguous or conflicting roles
- Lack of decision-making authority
- Machine-paced work or piecework
- Isolation
- Weak supervisor support
- Demand or reward imbalance
- Job insecurity.

Physical and psychosocial workplace exposures increase the risk for injury and MSD. In combination, they create even greater risk (Lapointe and others 2009; Magnavita and others 2011), with important implications for OSH interventions.

Work Organization

The modern 24-hour society has greatly affected the timing of work hours. The development of new technologies and global economic competition require that goods and services be made available at all hours of the day and night (Costa 2010). The traditional schedule of regular, mainly daytime working hours has given way to a variety of work patterns for many workers in HICs. Results from the 2000 European Working Conditions Survey indicate that only 25 percent of employed workers and less than 10 percent of self-employed workers have traditional work schedules. The vast majority work irregular hours, including some combination of compressed work hours, variable work hours, shift work or night work, weekend work, part-time work, and on-call work (Costa and others 2004). A large body of evidence suggests that shift work and night work interfere with circadian rhythms, decrease efficiency, and strain social and family relationships (Costa and Di Milia 2010).

Workers with rotating shifts often experience sleep deficits and fatigue, which decrease their mental agility, reduce performance efficiency, and increase error rates. Evidence suggests that night workers have higher risk for injury than do day workers, with successive night shifts further elevating the risk (Folkard and Tucker 2003). Increased risk for injury has also been associated with working overtime, long hours, and 12-hour shifts (Dembe, Delbos, and Erickson 2008; Folkard and Lombardi 2006). Shorter sleep duration and longer work hours are independently associated with the risk for work-related injury, mainly because fatigue impairs cognitive functioning and slows response time (Lombardi and others 2010). The understanding of the effect of fatigue on performance is complicated by the existence of individual differences in vulnerability to fatigue. These differences may be critical for workers in round-the-clock operational settings (Van Dongen, Caldwell, and Caldwell 2011).

As women increasingly participate in the labor force and men assume a progressively larger role in domestic duties in most HICs, in combination with substantial changes in family composition and labor force demographics, balancing work and family demands has become more challenging (Valcour 2007). Work–life conflict has been associated with adverse outcomes, including work-related MSDs (Hämmig and others 2011), sleep disorders and fatigue (Wirtz, Nachreiner, and Rolfes 2011), and reduced labor force participation and its economic consequences (Jansen and others 2010). Associations between work–life conflict and adverse outcomes extend beyond the high-risk sectors. For example, in the retail sector, Sunday work significantly increases the risk for accidents (Wirtz, Nachreiner, and Rolfes 2011). Workplace interventions that reduce conflicts between work and private life and address other risk factors are needed to prevent workplace injury and MSDs.

Individual Factors

Individuals have varying susceptibilities to workplace injury, and this variability is related to occupational and individual characteristics (Clarke 2011; Schulte and others 2012). Many reports have found a consistently elevated risk for injury among younger workers (Breslin and others 2007; Breslin, Smith, and Moore 2011) and workers with lower educational attainment (Breslin 2008; Strong and Zimmerman 2005).

The increased risk for injury among novice workers compared to their longer-tenured counterparts remains despite adjustment for confounders, including age, sex, and job (Kubo and others 2013; Morassaei and

others 2013). The reasons include a combination of unfamiliarity with job tasks or work environment, failure to recognize workplace hazards, ineffective or inadequate safety training, and differential exposure to more hazardous tasks at the beginning of a job (Breslin and Smith 2006; Morassaei and others 2013).

Workers with lower levels of education appear to be particularly vulnerable, possibly because of their greater exposure to physical demands or other hazards (Breslin 2008). Additional evidence suggests that experienced (and older) workers plan ahead in order to limit fatigue and avoid stressful emergency situations much more than do their less experienced coworkers (Pueyo, Toupin, and Volkoff 2011). Experienced workers also engage in more verbal communication with their colleagues.

These findings illustrate the potential benefit to be gained from targeted job training.

Gender

The gender gap in labor force participation is closing globally. Women's participation has held steady at roughly 52 percent for the past few decades, and men's participation has declined from 81 percent in 1990 to 77 percent in 2010. A wide gap remains in some regions. Women's participation has fallen well below 50 percent in Northern Africa, Western Asia, and Southern Asia (UN DESA 2010). Although women predominantly and increasingly work in the services sector, the proportion of women employed in traditionally male-dominated sectors such as manufacturing has risen.

Injury and fatality statistics by industry suggest that women are at lower risk for workplace injury (Lin, Chen, and Luo 2008, 2011). However, many of these reports fail to account for the differential distribution of men and women among jobs or even tasks within jobs. Evidence is emerging that women are at elevated risk for acute injury and MSD, controlling for job and individual confounders (Taiwo and others 2009; Tessier-Sherman and others 2014). Qualitative research also suggests that male workers—in traditionally male- and female-dominated jobs—have more control over their job and often receive more safety training than do their female coworkers (Kelsh and Sahl 1996; Turgoose and others 2006). Further, research examining gender differences in the performance of repetitive tasks suggests that identical, force-demanding tasks may be considerably more strenuous for females than for males (Nordander and others 2008), which could increase the risk for injury and MSD among women.

These findings, combined with the increasing labor force participation of women globally and the large proportion of women in precarious employment, suggest that future attention should focus specifically on understanding the physical, psychosocial, and training needs of women.

Age

Among younger workers, differential distribution by type of job, workplace environment, and organizational structure plays an important role in their elevated risk for injury, because younger workers are more likely to work in more hazardous jobs (Breslin and Smith 2005) and are overrepresented in small enterprises, which have limited OSH resources (Eakin, Champoux, and MacEachen 2010; Headd 2000). Moreover, almost half of working adolescents receive no safety training, suggesting that workplaces where young workers are employed pay less attention to OSH (Knight, Castillo, and Layne 1995).

As life expectancy increases, the population ages, and many workers extend their working life beyond traditional retirement age, interest in the consequences of injury among older workers has grown (Smith and others 2014). Although older workers may have a lower risk for injury (Chau and others 2014; Smith and others 2014), they may suffer worse consequences if they are injured, requiring longer periods for recovery and higher associated costs (Pransky, Loisel, and Anema 2011; Silverstein 2008).

However, little is known about the changing OSH needs of workers beyond ages 55–60 years, because most occupational analyses denote 55+ as the oldest age category (Farrow and Reynolds 2012). More research is crucial to inform OSH for aging workers.

Health

A few reports have linked chronic health problems to occupational injury, but substantial gaps remain in the evidence. Several reports suggest that hearing impairment increases the risk for occupational accidents and injury (Cantley and others 2015; Girard and others 2009). Diabetes, chronic heart disease, and depression may also confer increased risk for acute occupational injury, although the evidence is more limited (Kubo and others 2014; Palmer, Harris, and Coggon 2008).

Employment Sector

Globalization has subjected the manufacturing sector in HICs to intense international competition. As a result, high-hazard technologies have moved to LMICs, and the services sector has become increasingly important. Although occupational injury is a risk in the services sector, the riskiest sectors are agriculture, forestry, fishing, construction, manufacturing, and transportation. These sectors account for approximately half of the

serious accidents at work and the largest share of fatal accidents. According to estimates from the Survey of Occupational Injuries and Illnesses conducted by the U.S. Bureau of Labor Statistics, among the 2.8 million nonfatal occupational injuries reported by private industry in 2012, 75 percent occurred in service-providing industries, which employed approximately 82 percent of the private industry workforce. The remaining 25 percent occurred in goods-producing industries, which employed 18 percent of the private industry workforce (BLS 2013).

Agriculture, Forestry, and Fishing

Work in the agricultural, forestry and fishing sector is among the most hazardous, and comparatively weaker health and safety regulations, in combination with growing numbers of immigrant workers and a paucity of surveillance data, have resulted in widespread underrecognition of worker injury risk. And although occupational health and safety research is limited overall for this sector, research for the forestry and fishing subsectors is particularly sparse. Recognizing the dual needs for more accurate surveillance data and development and implementation of effective OSH interventions, a formal research and public health practice agenda for this sector is underway (NIOSH 2008).

Agricultural production not only employs the largest number of workers worldwide (about 1.3 billion), but also consistently ranks as one of the most hazardous sectors It has high rates of both fatal and nonfatal injuries and fatality rates several times higher than the average for all industries combined in the EU and North America (BLS 2014; Frank and others 2004; Vijayvergiya, Bohra, and Jhanwar 2012).

Agricultural injuries are less well documented in developing countries, where the vast majority of this workforce is located (Lehtola and others 2008). Even in HICs, which have only 9 percent of the global agricultural workforce, many agricultural accidents and injuries are not captured because of the high rates of self-employment and large number of small farms, temporary workers, and migrant workers.

The unique nature of many farms helps explain the increased risk for injury among agricultural workers. Many farms are small and family owned, with economic pressures fostering use of less-expensive methods and equipment that may increase injury risk. Many farms are also family homes, where children and young adults live and work at least part-time and safety training is likely learned through personal experience and from family members rather than through more structured processes. Farm work is seasonal and labor intensive; workers are exposed to adverse weather conditions and subjected to concentrated periods of work that lead to time pressures, stress, and fatigue, which are linked to increased risk for accidents and injuries. Leading risk factors for agriculture-related injuries and fatalities include operation of farm equipment and machinery, work with animals, work performed at heights, and falling objects (Pfortmueller and others 2013). Tractor use is associated with a large number of fatalities.

Construction

Construction is one of the most physically demanding and dangerous sectors in both LMICs and HICs. Workers are regularly exposed to ergonomic and safety hazards from manual handling, power tools and equipment, noise, confined spaces and electricity, work performed from heights, excavation, irregular work hours, and exposure to weather extremes. A construction worksite is also complex and dynamic. Often it comprises multiple employers with potentially divergent safety cultures and a high proportion of self-employed workers, adding to the challenge of effectively disseminating safety information and interventions for effective uptake. This sector also employs a disproportionate number of immigrants, independent contractors, on-call or day laborers, contract workers, temporary workers, and young workers—all subgroups with higher injury risk, which presents major challenges for OSH in this sector (CPWR 2013).

In HICs, construction workers have higher-than-average risk for injury and MSD, and the leading causes of injury involve contact with objects and overexertion. More than half of injuries sustained by self-employed workers require five or more days away from work compared to only a quarter of the injuries sustained by workers employed by firms (HSE 2014a).

In HICs, construction workers have a three- to fourfold risk for a fatal accident at work compared to workers in other sectors, while in LMICs the risk is as much as sixfold (ILO 2014b). Even among HICs, however, fatality rates differ, although the reasons for this disparity are poorly understood (Mendeloff and Staetsky 2014).

Manufacturing

Although the manufacturing sector comprises a diverse array of industries worldwide, the majority of manufacturing jobs are labor intensive. Workers who are engaged in transforming materials, substances, or components into products are at risk for injury from physical exertion; contact with machinery and equipment; long work hours; changing work shifts; slips, trips, and falls (STFs); and new methods or organization that may increase job strain.

The manufacturing sector employs approximately 10 percent of the workforce in both the United Kingdom

and the United States but accounts for a disproportionate number of injuries. In the United Kingdom, the manufacturing sector accounts for 18 percent of nonfatal workplace injuries requiring more than seven days away from work and 17 percent of major specified injuries. STFs on the same level (29 percent), contact with machinery (14 percent), and a blow by an object (13 percent) are the most frequently cited causes of major or specified injury (HSE 2014b).

Wholesale and Retail Trade

Although workers in the wholesale and retail trade sector are generally perceived as having lower risks for injury than are workers in other sectors, many trade jobs are physically demanding, which places workers at risk for back and upper-extremity disorders. Given the large number of workers and continued growth in this sector, a wide range of workplace hazards may pose a risk for injury among a considerable number of workers. In addition, psychosocial and organizational factors may contribute to the burden of injury. Historically, the causes of and potential interventions for safety hazards within this sector have received little attention, but this is one of eight sectors for which a research agenda has been developed to address existing gaps (Anderson and others 2010).

Health Care and Social Services

The health care and social services sector is a large employer in HICs, with projections suggesting continued growth as populations age. Workers in this sector are mainly female and experience high rates of injury, especially musculoskeletal injury. Injuries resulting from overexertion and STFs are particularly problematic (Bell and others 2008; Collins, Bell, and Gronqvist 2010). Frequent lifting, transferring, and repositioning of patients are leading causes of musculoskeletal injury among health care workers in both acute and longer-term care settings, whereas STFs are particularly prevalent among facility support workers and community health workers (Drebit and others 2010). Because sharps injuries are extremely common among these workers, targeted preventive efforts have been undertaken in recent years.

Transportation and Warehousing

The transportation and warehousing sector, which enables the movement of passengers and goods via air, rail, water, and road, is vitally important to the economies in HICs and encompasses a very diverse group of workers, jobs, and job-related hazards. The risk for accidents causing human injury and fatality is widely recognized. However, the range of hazards—including risks associated with the handling of dangerous substances, the performance of physical jobs in isolation, long and variable working hours, frequent need for vigilance, and psychosocial and organizational factors—that combine to increase injury risk among workers in this sector are less recognized. Exposure to whole-body vibration and prolonged sitting or standing, interspersed with the physically strenuous work of loading and unloading goods, increase the risk for MSDs, especially back disorders. The shift in manufacturing from inventory-based systems to leaner, just-in-time production processes has created very narrow margins for timely delivery. Transport workers are also exposed to high levels of noise in and around vehicles.

OCCUPATIONAL INJURY IN LMICs

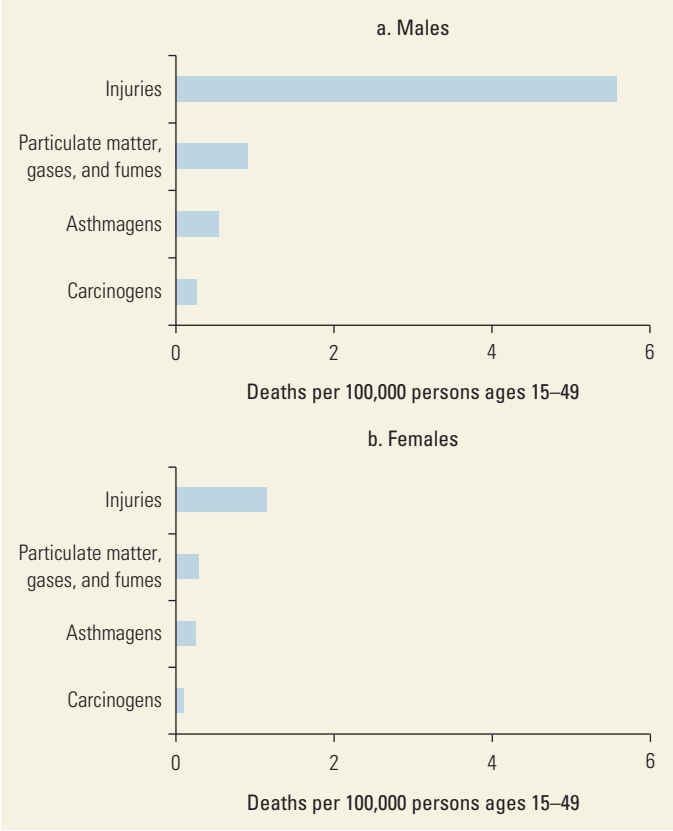
According to the latest estimates from the 2013 Global Burden of Disease (GBD) study, more than 80 percent of occupational injury–related deaths in the world occur in LMICs (Murray and others 2014), where the death rate is higher than in HICs. Occupational risk factors for injuries are also the leading cause of occupational fatalities among men and women ages 15–49 years (figure 6.1) and the leading cause of disability-adjusted life years (DALYs) resulting from occupational risks in LMICs. Almost half of these deaths and DALYs are attributable to transport injuries.

Covering only unintentional injuries, these estimates exclude workplace violence, which is increasingly being documented in LMICs. Table 6.2 summarizes the literature on the incidence of physical violence in the workplace.

LMICs clearly need to address the alarmingly protracted trend in occupational injuries. However, intricately related factors—economic adversity, competing priorities, resource mismanagement, workforce migration, conflict and internal displacement, and urban-to-rural influx, among other factors—foster a dearth of financial and human resources devoted to such efforts, while crafting an industrial landscape that features a vulnerable workforce. Those factors, in turn, underpin most of the challenges facing implementation of OSH in LMICs. Although some of these challenges are not unique to LMICs, their pervasiveness impedes a simplistic transfer of potentially successful occupational health interventions from HICs. An overview of these challenges follows.

Evidence on the proximal work- and worker-related risk factors in LMICs suggests that they are not substantially different from those documented in HICs. Table 6.3 gives some examples of risk factors.

Figure 6.1 Mortality Attributable to Occupational Risks in Low- and Middle-Income Countries, 2010



Source: Based on Global Burden of Disease Study 2013 estimates (Murray and others 2014).

Many LMICs have health and safety legislation in place, but capacity for enforcement is weak (ILO 2012b). A common feature in several LMICs is a slower increase and sometimes a decrease in the ratio of trained labor inspectors to workers. This situation suggests inadequate institutional capacity to enforce provisions for safe work environments, although comparisons over time are limited by the poor quality of the data. Moreover, underfunding of government departments mandated with statutory inspection, as reported in Zambia (ILO 2012a), weakens the infrastructure required for carrying out inspections.

The World Health Organization (WHO) and its partners have called for integrating occupational health with primary health care (WHO 2001, 2012). However, health care workers are too few in number and poorly distributed, particularly in LMICs, where the crisis is fed by inadequate infrastructure, insufficient investment in health care and training, and outmigration of health care workers (Chen and others 2004).

Trade unions can be strong partners and advocates for worker safety. Recent agreements have been signed in the Asia-Pacific region to increase the participation of trade unions in promoting safe workplaces by organizing campaigns and participating in national OSH strategies and plans, among other activities (ILO 2014a). However, trade union density is low in some countries in Latin America and the Caribbean, and Sub-Saharan Africa (Hayter and Stoevska 2011). This situation limits

Table 6.2 Exposure to Physical Violence in the Workplace in Some Low- and Middle-Income Countries

Region and location	Study	Study population	Number exposed	Year	Percentage per year
Asia					
Taiwan, China	Chen and others 2008	Nurses, nurse aides, and clerks in a psychiatric hospital	222	2003	35
	Pai and Lee 2011	Registered clinical nurses	521	—	19.6
Thailand	Kamchuchat and others 2008	Nurses	545	2005	3.1
	Sripichyakan, Thungpunkum, and Supavititpatana 2003	Health care workers	1,090	2001	11.0
Middle East and North Africa					
Egypt, Arab Rep.	Abbas and others 2010	Nurses in Ismailia governorate	970	2010	3.0
Latin America and the Caribbean					
Brazil	Alonso Castillo and others 2006	Working women ages 18–60	109	—	39.0
	Palácios and others 2003	Health care workers	1,569	2001	6.0

table continues next page

Table 6.2 Exposure to Physical Violence in the Workplace in Some Low- and Middle-Income Countries (continued)

Region and location	Study	Study population	Number exposed	Year	Percentage per year
Mexico	Alonso Castillo and others 2006	Working women ages 18–60	669	—	16.0
Peru	Schlick and others 2014	Children and adolescents attending night school in Cusco	375	2010	3.0
Sub-Saharan Africa					
Kenya	El Ghaziri and others 2014	Nurses and midwives	227	2007	8.8
Mozambique	Couto, Lawoko, and Svanstrom 2009	Conductors and drivers	504	—	32.0
	Caldas and others 2003	Health care workers	396	2001	8.0
Nigeria	El Ghaziri and others 2014	Nurses and midwives	159	2008–10	32.1
	Azodo, Ezeja, and Ehikhamenor 2011	Oral health care professionals in Southern Nigeria	175	2009	6.0
South Africa	Steinman 2003	Health care workers	1,018	2001	13.0
Tanzania	El Ghaziri and others 2014	Nurses and midwives	146	2009	22.0
Other Sub-Saharan African countries[a]	El Ghaziri and others 2014	Nurses and midwives	85	2007	21.0

Note: — = not available.
a. Central African Republic, Eritrea, Ethiopia, Malawi, Namibia, Togo, Uganda, Zambia, Zimbabwe, and others.

Table 6.3 Risk Factors for Workplace Injury and Violence in Various Worker Populations in LMICs

Population	Risk factors of occupational injury	Study
Miners in Zimbabwe	Underground work, long working hours, targets per shift (work pressure), inadequate personal protective equipment	Chimamise and others 2013
Machine operators in Ethiopia	Work pressure, malfunctioning machines, unfamiliar techniques, unfamiliar tasks, failure to wear gloves	Ahmed 2008
Textile factory workers in Ethiopia	Lack of training, sleep disturbance, job stress, long hours, manual work, work requiring visual concentration	Aderaw, Engdaw, and Tadesse 2011; Yessuf Serkalem, Moges Haimanot, and Ahmed Ansha 2014
All workers in a representative household sample in Vietnam	Regular or daily alcohol consumption	Phung and others 2008
Health care workers in Cairo University hospitals	Time on the job	Zawilla and Ahmed 2013
Nurses in Mulago National Hospital in Uganda	Lack of training on needlestick injuries, long working hours, recapping of needles, failure to wear gloves	Nsubuga and Jaakkola 2005
Commercial motorcyclists in Nigeria	Lack of formal education, alcohol consumption	Adogu, Ilika, and Asuzu 2009
Workers in Thailand	Low income, long working hours, heat stress	Berecki-Gisolf and others 2013; Tawatsupa and others 2013
Workers in a commune in Vietnam	Overlapping employment (full-time in industry, part-time in agriculture)	Marucci-Wellman and others 2011

table continues next page

Table 6.3 Risk Factors for Workplace Injury and Violence in Various Worker Populations in LMICs (continued)

Population	Risk factors of occupational injury	Study
Nurses in the Philippines (needlestick injuries)	Night shifts	de Castro and others 2010
Nurses and midwives in Sub-Saharan Africa (workplace violence)	Risky client characteristics, long working shifts	El Ghaziri and others 2014
Frontline workers in 60 factories in China	Educational level, mental stress, previous injury, working hours	Yu and others 2012
Cleaners in the city council's health services department in Zimbabwe	Lack of preemployment training	Gonese and others 2006

Note: LMICs = low- and middle-income countries.

the scope for workers to engage in organized action to promote their safety (although high union density does not necessarily mean strong bargaining power).

Employers in SMEs can be an important informal source of information on OSH for their employees. In Ghana, a positive perception of organizational support was associated with a positive perception and practice of safety and a lower rate of injury among workers (Gyekye and Salminen 2007). Yet some employers, especially in small enterprises, have little knowledge of OSH and rarely adopt OSH practices, although the evidence is limited (Hu and others 1998).

Estimating and tracking the burden of occupational injuries in LMICs is crucial but challenging. Many countries lack an acceptably complete system for registering fatalities. The informal sector is usually excluded from the mandatory reporting of occupational injuries, and injuries often are not reported even where formal channels of reporting exist, for example, sharps injuries among health care workers (Hanafi and others 2011; Mbaisi and others 2013; Shiao and others 2009). Health facility data and some national surveys in LMICs collect data on injuries, but these data often are of poor quality or incomplete, failing either to identify their relation to work or to analyze and report on this dimension. Attempts to estimate the global burden are useful for highlighting the problem internationally, but they may not be fit for supporting local decision making or for tracking trends at the subnational level.

The informal sector grew tangibly over the past four decades in many LMICs. In most countries in Sub-Saharan Africa with time-series data, the share of informal sector employment (including both informal and formal jobs in the informal sector and informal jobs in the formal sector) in total nonagricultural employment is rising. A similar trend is seen in Latin America and in Southern and South-East Asia. Notable exceptions are Mexico, South Africa, and Thailand and countries in Western Asia (Charmes 2012). Informality levels also vary, ranging from one-half of nonagricultural employment in North Africa to almost three-quarters in Sub-Saharan Africa (ILO 2002). Some regional differences are evident in the contribution of the informal sector to GDP. The highest level is in Sub-Saharan Africa, where the informal sector contributes almost two-thirds of GDP and one-half of nonagricultural gross value added. Agriculture alone comprises up to 60–65 percent of total informal employment except in Latin America and the Middle East and North Africa, where construction and manufacturing constitute the bulk of nonagricultural informal employment (Charmes 2012).

The relation between informal employment and occupational injury risk is difficult to characterize mainly because of scarce data on occupational injuries and working conditions in the informal setting. Many workers in informal employment are poor, work in adverse physical conditions, and lack social insurance protection and benefits that could mitigate the consequences of occupational injury (Muntaner and others 2010). Table 6.4 highlights some of the risks in informal employment situations.

The few studies on this topic have found that informal sector workers did not have higher injury rates than formal sector workers. For example, a study in Costa Rica reported a relative risk of only 1.06 (Mora and others 2011), while in Nicaragua, injury rates in the informal sector were half those in the formal sector. These reports likely reflect high levels of underreporting among informal workers rather than lower injury rates (Noe and others 2004). In Vietnam, work-related injuries were 72 percent more frequent among informal workers (falling to 45 percent when adjusting for sociodemographic factors) than among formal workers, but the role of chance could not be ruled out statistically (Phung and others 2008). Severe injuries were even found to be more frequent among formal workers.

Table 6.4 Occupational Hazards Identified in Various Informal Industries in LMICs

Informal industry	Hazard	Study
Agriculture	Hand tools (spades and sickles), machinery (harvester and threshers), venomous animals, pesticides, falls, exposure to sun and heat	Loewenson 1998; Mohan and Patel 1992
Street vending	Traffic injuries, fire, assault, weather extremes	Alfers 2009; Alfers and Abban 2011
Textile	Fire, chemicals	Regoeng 2003
Auto repair	Fire, chemical solvents and acids, mechanical injury	Buhlebenlosi and others 2013; Regoeng 2003
Waste management and recycling	Medical waste including syringes, broken glass	Cunningham, Simpson, and Keifer 2012
Welding	Radiation	Buhlebenlosi and others 2013
Carpentry	Sharp tools	Regoeng 2003
Manufacturing	Sharp tools, exposure to sun and heat, chemicals	Loewenson 1998
Domestic work	Violence (verbal, physical, sexual); repetitive strain, household chemicals	Alfers 2011

Note: LMICs = low- and middle-income countries.

However, the severity of injury was defined by type of health care received. Thus, the finding probably reflects differential access to health care, because case fatality was higher among informal workers. These studies did not account for differences in the duration of actual exposure to injury risk.

OSH in the informal sector is particularly challenging. The magnitude of the injury problem is difficult to measure because of lack of routine mandatory reports. This prohibits injury from taking its deserved position on the list of priorities for policy makers and, in turn, contributes to the shortage of resources devoted to addressing it. Minimal contact with the health and safety authorities suggests that monitoring and enforcing safe working conditions are almost impossible tasks (Muntaner and others 2010). The informal economy, dominated by agriculture, construction, and manufacturing, often relies on low-cost manual technologies. Potentially effective control measures such as engineering controls and elimination or substitution of hazards may be too costly and thus problematic to implement in LMICs.

Personal safety measures, such as the use of personal protective equipment, can therefore be a principal means of OSH in such settings. Workers in the informal sectors reportedly have high levels of knowledge about hazards and personal protection methods, but compliance with health and safety precautions can be exceptionally challenging in the absence of enforcement. For example, 73 percent of the Jua Kali informal sector in Kenya knew that eye injury could be prevented by the use of personal protective equipment. However, only about 12 percent said that they actually used such equipment, mainly because of a perception of low risk and a sense that the equipment interferes with work precision (Chepkener 2013). Similarly, 90 percent of welders in Southwestern Nigeria were aware of protective eye gear, but less than half owned them and only 10 percent actually used them, citing similar reasons for nonuse (Ajayi and others 2011). Among vegetable farmers in Ghana who use chemicals in farming, almost three-quarters did not use protective cover when handling insecticides and about 80 percent disposed of empty containers unsafely (Ntow and others 2006). Sugarcane crushers in India thought that hand injuries sustained during work were just "bad luck" or "God's will," more than 60 percent blamed injuries on carelessness, a minority thought that safe machines were needed, and less than 33 percent indicated that they would use protective equipment even if it were provided for free (David and Goel 2001).

Economic hardship and conflict have long fueled cross-border labor migration and rural-urban migration in Africa, Asia, and Latin America. Temporary workers, farm laborers, female traders, and professionals have been moving between countries of West Africa along gradients of economic opportunity, mainly to Côte d'Ivoire and Ghana and more recently to Nigeria, slowing their pace at times of economic and political crises in those countries (Adepoju 2005). Political turmoil and poverty in Zimbabwe led many Zimbabweans to enter neighboring South Africa, where they found work as farm laborers (Vigneswaran 2007). In Latin America, Argentina attracts the most significant amount of immigration from within the region. The most significant migration corridors are Paraguay–Argentina, Bolivia–Argentina, and Colombia–República Bolivariana de Venezuela. Other corridors of lesser importance are Peru–Argentina and Peru–Chile

(Texido and Warn 2013). In China, rural-urban migration has been on the rise and forms the bulk of internal migration (Wang 2008).

Similar to migrant workers in HICs, migrant workers in LMICs are at risk for social exclusion, exploitation by employers, informal employment, and poor working conditions (ILO 2013c; Marilda and Maciel 2014; Texido and Warn 2013; Vigneswaran 2007). In China, where access to public services relies on the *hukou* system of household registration, internal migrants who leave their place of registration cannot use health insurance and other benefits and services (Mou and others 2013). Rural migrants may lack proper training for the job (Pringle and Frost 2003) and work long hours in poor conditions with low wages and limited benefits (ILO 2011b). Studies suggest that migrant workers in China have a higher rate of injury than do registered urban residents and are more likely to engage in hazardous occupations (Xia and others 2012).

The percentage of children at work—a special subset of informal workers—in LMICs ranges widely from 2.5 percent of children ages 7–14 years in Costa Rica and India to as high as 74 percent in Benin (World Bank 2014). The percentage of working children who do not attend school also varies widely, from around 2 percent to 89 percent, but does not exceed 50 percent in most LMICs. The vast majority of working children are employed in agriculture. Others are employed in a range of industries—fisheries, domestic work, mining and manufacturing, and construction—where adults are also employed, and some are soldiers in war-affected zones. The problem of child workers is waning worldwide but is still alarming in Sub-Saharan Africa, where one in five children is working (ILO 2013b). Child workers are at higher risk for injuries and may suffer greater consequences because their bodies are still growing. Working children often emulate unsafe behaviors of adults, lack adequate safety training, are at higher risk for exploitation, and endure long working hours and minimal pay, often superimposed on a background of deprivation (ILO 2011a). Eliminating child labor remains the ultimate international goal, but a child's work in LMICs can be instrumental for the family's livelihood and sometimes the child's own education. Until child labor has been eliminated, efforts to mitigate hazardous working conditions for children are needed (Siddiqi and Patrinos 1995).

In summary, LMICs bear the brunt of global occupational fatality and disability, yet many lack the resources and infrastructure to tackle them effectively. Challenges related to workforce shortages, compliance of employees and employers with OSH, lack of sound data, and predominance of a vulnerable and hard-to-reach informal workforce preclude the direct transfer of successful interventions from HICs to LMICs. Therefore, progress in OSH is inseparable from overall progress in many domains: economy, governance systems, data systems, education, employment prospects, and social justice. Addressing the problem will require community-based public health initiatives that transcend the traditional well-demarcated workplace, scale up participatory intervention, invest in the local workforce, and improve the quality and use of data.

THE GLOBAL SUPPLY CHAIN

Over the past three decades, globalization has changed the way goods are manufactured and exchanged internationally. International supply chains offer a flow of materials from natural resource to final product in a manner that is cost-efficient and easily scalable to produce high-quality goods for affordable prices. The supply chain is governed by a focal company, often a multinational, which receives goods and materials from suppliers that use subcontractors to develop raw materials into finished products (Ustailieva, Eeckelaery, and Nunes 2012).

Firms in the EU and the United States have developed global supply chains spanning a variety of industries, ranging from apparel and toys to electronics (Locke 2013). Lambert and Cooper (2000, 70) define the members of a supply chain as "all companies/organizations with whom the focal company interacts directly or indirectly through its suppliers or customers, from point of origin to point of consumption." Many foreign manufacturers of U.S. goods (contract manufacturers) are not just subcontractors; they are supply-chain facilitators, providing U.S. firms with everything from production facilities and engineering expertise to logistics (Eltschinger 2007). One advantage of using foreign factories is the unmatched scalability of their labor. A sense of how globalized the supply chain has become can be gained by considering a Nike cross-trainer shoe: the outer rubber sole is refined in the Republic of Korea; processed into large rubber sheets in Taiwan, China; and shipped to an assembly plant in Indonesia, where it is attached to the shoe (Locke 2013). Intermediate exports grew from US$2.867 trillion in 2000 to US$7.723 trillion in 2012, and the share of intermediate goods as a percentage of total nonfuel exports is 55 percent, the highest in global history (WTO 2013). The number of intermediate goods integrated into global supply chains has reached a record high.

Industrial nations (prominently the United States and EU countries) continue to outsource a significant portion of the goods and services of their primary (agriculture, fishing, and mining) and secondary (manufacturing) sectors to LMICs, creating economic benefits and reducing the number of fatal occupational accidents

occurring in HICs (Takala and Hämäläinen 2009). Their integration into global supply chains has provided LMICs with promising economic opportunities and a prominent place in the world economy, while providing HICs with low-cost labor (Rivoli 2009).

Focal companies have a clear profit incentive to acquire low-cost ready-for-market goods. In turn, suppliers contracted by the focal company strive to keep costs low and to deliver products quickly and reliably because of volatility in production orders and intense competition with rival firms. Because the contracted factories in LMICs tend to be under intense economic pressure to deliver intermediate products at a low cost, work-related injuries and occupational hazards persist. In order to respond to large fluctuations in the quantity of production in a short span of time, temporary employment has become very common in factories in LMICs (Smith, Sonnenfeld, and Pellow 2006).

The majority of workers integrated into global supply chains are migrants who move from poor rural areas to the rapidly developing and industrializing urban areas within their country seeking employment with higher pay, because rural job opportunities are often sparse and pay below subsistence-level wages (Welford and Frost 2006). From 1995 to 2000, 79 million migrant workers in China alone moved to prominent manufacturing cities in search of higher-paying employment (Wang and others 2011). Most of these migrant workers are young (ages 17–39 years), have little to no formal education, and lack experience in an industrial environment. Consequently, they tend to have a poor understanding of workplace risks and labor rights. They are placed in the highly hazardous workplaces of construction, mining, and manufacturing often without training, resulting in high rates of injury, sickness, and death at the workplace. The excessive competition for temporary work means that they are reluctant to report minor injuries on the job for fear of losing employment. These subcontracted laborers have one and a half times the occupational accident risk of their full-time counterparts (Quinlan 1999).

This growth of contract work is not a temporary trend. Rather, the number of workers with precarious employment is rising in LMICs, leading to a global gap in OSH standards and regulation (Nossar, Johnstone, and Quinlan 2003; Quinlan, Mayhew, and Bohle 2001). In China, 80 percent of the recorded on-site deaths were of migrant workers (Wang and others 2011). Currently, 50–70 percent of workers in LMICs define their employment as "vulnerable"—work that is low in pay, lacks security and safety, and provides few to no labor rights (Locke 2013).

Additionally, there is little to no professional OSH oversight to ensure the safety of workers, especially among large manufacturing plants in China, where 15,000–20,000 workers are at risk for injury at any given moment (Brown 2007). Moreover, these employees are hired and fired on short notice. This rise in nonpermanent labor has been associated with poorer OSH outcomes in developing areas such as Bangladesh, China, Lebanon, South Africa, and Thailand, as well as Central America (Baldwin 2011). Finally, forced overtime in excess of 6-day, 72-hour work weeks is all too common (Locke and Romis 2007), resulting in increased risk for accidents and repetitive motion injuries (Brown 2007).

Another issue of concern is the limited availability and accessibility of OSH training and education in source countries undergoing rapid industrialization (Ahasan 2003). The occupational health services coverage in China, for example, is estimated to be in the 10 percent range, whereas in HICs, the average is in the 20–50 percent range (Barboza, Lattman, and Rampell 2012). Moreover, the intergovernmental organization overseeing the occupational health services of manufacturers in LMICs—the International Labour Organization (ILO)—has reported less than 1 percent of occupational accidents in nations such as China and India because occupational records in these countries are either nonexistent or inconsistently maintained (Hämäläinen, Takala, and Saarela 2006).

Regulation of Occupational Health

Fragmented production in the global supply chain has resulted in the establishment of a flurry of regulatory bodies meant to control the OSH and labor rights of each supplier. However, the complexity of the chain often prohibits effective regulation. In the twentieth century, OSH and labor rights were regulated at the national level for many LMICs. The ILO and WHO provided similar regulation at the international level, publishing reports on worker conditions and employment demographics for each sector globally. However, a previous effort to include social clauses within global trade agreements was struck down by WHO when both LMICs and HICs voiced their strong dissent (Locke 2013). Thus, the advent of the global supply chain left a void in the regulation of OSH and labor rights, because authority was dispersed in a complex web of buyers and sellers. Compounding this situation are the economic incentives for governments to ignore factory OSH violations in order to keep the cost of production low (Locke 2013).

To bridge the gap in OSH oversight, nongovernmental organizations (NGOs)—privately owned labor-watch groups—have emerged as so-called regulators of the working conditions of factories by articulating

international expectations for OSH conditions, wages, and gender equality. These organizations conduct random audits of factories and publish reports on their performance.

NGOs have been unable to regulate suppliers or the focal company itself. Monitoring alone has had marginally small results, according to a case study by Locke and Romis (2007) that analyzed audits from more than 800 factories in Nike's 51-country supply chain.

A newer development in global supply chain regulation is the notion of corporate social responsibility; the focal company has a direct responsibility to protect the interests of society by upholding OSH and labor equality standards throughout its supply chain. Many multinational corporations, such as Adidas, Apple, Gap, Nike, and Walmart, have defined criteria that their suppliers must meet and then conducted factory audits as part of a yearly report analyzing current labor conditions in their supply chain (Apple 2014; Burke, Scheuer, and Meredith 2007; Gap 2012; Verbeek and Ivanov 2013; Yu 2007). Little research has been conducted on the effectiveness of these initiatives (Ustailieva, Eeckelaery, and Nunes 2012). The paradoxical demand for both high OSH standards and low-cost labor creates conflicting incentives for recording occupational injuries (Brown 2007).

Common OSH Risks

The distinctive economic incentives and pressures operating in the global supply chain give rise to numerous OSH risks. Although the specific risks are not unique to the global supply chain, the combination of hazards presents particular challenges. To examine the OSH risks engendered by the global supply chain, this section reviews the common sources of risk in the microelectronics and textile goods workplaces, prominent industries using the supply chain of LMICs.

Electronics Industry

The electronics industry is one of the fastest-growing sectors in the world, with a vast network of suppliers (Locke 2013). Beginning in the 1980s, prominent multinational firms in Canada and the United States, such as Apple, IBM, Lucent, Maxtor, and 3Com, gradually adapted their supply chain management to a new form of outsourcing that granted licenses to suppliers from factories across the globe, prominently China, Malaysia, Mexico, and Singapore (Locke 2013). The contract manufacturers that received the most business were Flextronics, Hon Hai/Foxconn Technology Group, and Jabil, all of which have factories in LMICs around the world (Locke 2013). Many of these companies generate electronic products spanning the "6 Cs": computers, communications equipment, consumer products, car parts, content (e-book readers), and health care products (Ngai and Chan 2012). Today, 75 percent of computer products are manufactured by contract manufacturers as opposed to original equipment manufacturers (Brown 2009). By 2000, the most successful of these companies had production facilities in as many as seven countries, mostly LMICs (Locke 2013).

The magnitude of employment that these contract manufacturers manage can be illustrated by Foxconn: in 2013, it employed 1.4 million workers in China alone (Chan, Pun, and Selden 2013). The common structure of a factory in the global supply chain is a large assembly line consisting of hundreds of workers performing a single 20- to 30-second operation repetitively until their shift ends (Sandoval and Bjurling 2014). This level of repetition is mentally taxing (Butollo, Kusch, and Laufer 2009) and is accompanied by reports of suicides and attempted suicides (Ngai and Chan 2012). The common OSH risks in the electronics manufacturing industry include fatigue resulting from long work shifts and physically demanding work with very few or no breaks and no proper safety equipment (Sandoval and Bjurling 2014).

Serious occupational injuries are common in electronics factories. According to a study that gathered 500 audit reports from 276 factory suppliers of Hewlett-Packard from June 2004 to January 2009, 59 percent of the factories were in violation of legal working hours, 40 percent were in violation of emergency preparation, 32 percent were in violation of hazardous material storage, and 22 percent were in violation of occupational safety (Locke 2013). Of these suppliers' workers, 95 percent were performing repetitive tasks while standing in an assembly line, and most were female migrants (Locke 2013). A similar study published by a coalition of NGOs, referred to as ProcureITfair, found that workers for the Excelsior Electronics plant in Dongguan, China—a computer and digital electronics manufacturing facility for Apple, Intel, and Sony components at the time of investigation—were working for 10–12 hours on a poorly ventilated shop floor and inhaling industrial alcohol, cleaning agents and thinners at the printed circuit board processing area (Butollo, Kusch, and Laufer 2009; ProcureITfair 2008). According to statistics gathered from Shenzhen factories that were released by mainland authorities, an average of 13 workers lose a finger or an arm daily, and 1 worker perishes onsite every 4.5 days (Murdoch and Gould 2004).

Another serious issue is the unsafe handling of flammable materials, leading to deadly factory fires. On Foxconn's campus in Chengdu, three workers perished

in a polishing department fire (Sandoval and Bjurling 2014). In Zhejiang Province, a factory fire killed five workers (Murdoch and Gould 2004).

Textile, Clothing, and Footwear Industry

On April 24, 2013, the Rana Plaza factory building collapsed in Dhaka, Bangladesh, killing 1,129 workers and injuring more than 2,000, making it the deadliest industrial disaster to date (Adler-Milstein, Champagne, and Haas 2014). Just five months before the Rana Plaza disaster, 112 workers were killed in a factory fire in Dhaka at Tazreen Fashions, an apparel supplier for Disney, ENYCE, Sean Combs, Sears/Kmart, and Walmart (Adler-Milstein, Champagne, and Haas 2014). Between 1990 and 2010, 33 major fires occurred in garment factories, as well as 200 smaller fires in Bangladesh alone, injuring more than 5,000 workers (Brown 2010). These textile factories—stationed in poorly structured high-rise buildings—lack safety exits and proper electrical wiring (Adler-Milstein, Champagne, and Haas 2014). Table 6.5 shows a select number of fire accidents that occurred in Bangladeshi garment factories from 2000 to 2006.

The ready-made garment sector in Bangladesh accounts for 78 percent of the country's export earnings (Ahamed 2013). Since liberalizing its economy in the 1980s, Bangladesh has integrated its ready-made garment industry, which includes mass-produced textile products, into the global supply chain, exporting more than US$5 billion worth of products each year (Akhter and others 2010; Rahman 2004). In 2009–10, Bangladesh's knitted and plain-weave garment industries grew 46 and 40 percent, respectively, as a direct result of rising production costs in China for brands such as H&M and Walmart (Jun and others 2012).

A recent study gathered data from audit reports of 210 factories supplying a major global apparel firm that span Bangladesh, China, the Dominican Republic, Honduras, and India (Locke 2013). The study revealed that the apparel firm's compliance program, regarded by private regulatory programs as the most effective in the industry, had an overall compliance rate of 51 percent. The criteria for compliance covered compensation, working conditions, and overtime hours. The worst compliance was found in the factories in South and East Asia, where 56 and 72 percent of the factories, respectively, were not approved.

China has the strongest presence in the supply chain of the footwear industry; 86 percent of all footwear sold in the United States comes from factories in Southern China (Locke 2013). Guangdong is the hub of the athletic footwear industry because of its well-designed ports, access to large numbers of cheap laborers, and lack of government regulation (Frenkel 2001). According to recent publications, work in the Chinese shoe manufacturing

Table 6.5 Selected Fire Accidents in Garment Factories in Bangladesh, 2000–06

Date	Place	Number killed	Number injured	Cause of fire	Cause of death
February 23, 2006	KTS Textiles, Chittagong	91	400	Electric short circuit	Only exit locked; fire, suffocation, stampede
March 6, 2006	Industry, Gazipur	3	—	Fire panic	Only exit blocked by boxes, smoke, stampede
March 2006	Salem Fashion Wear Ltd.	3	50	Unknown	Stampede
May 3, 2004	Misco Super Market, Dhaka	9	50	False fire alarm	Stampede
August 1, 2001	Kafrul	26	76	Unknown	Smoke, stampede
August 8, 2001	Mico Sweater Ltd., Mirpur	28	100	Unknown	Single exit locked
2000	Near the capital	48	70	Burst boiler	Trapped in locked, burning building
2000	Chowdhury Knitwear, Norshingdi	53	100	Short circuit	Fire, smoke, stampede
August 28, 2000	A garment, Banani	12	45	Unknown	Suffocation, stampede

Source: Akhter and others 2010.
Note: — = not available.

industry is fraught with excessive overtime, managerial neglect of OSH conditions, and sexual harassment (Locke 2013).

Much like trends in the electronics industry, contracted temporary work in the textile, clothing, and footwear industries has been growing, leading to dangerous OSH conditions for workers (Nossar, Johnstone, and Quinlan 2003). In a study examining the comparative dangers of contingent work in the clothing and manufacturing industries (Mayhew and Quinlan 1999), contracted employees in the clothing industry had three times the number of occupational injuries as did contracted workers in the manufacturing sector. One possible explanation for this disparity in injury experience is that garment workers are often paid by an incentive system that pushes them to work faster than their manufacturing counterparts, who are paid by the hour, and increases the risk for injury.

OCCUPATIONAL INJURY INTERVENTIONS

Because working conditions significantly influence worker performance and productivity, optimizing the conditions for improved health and safety has far-reaching implications for individuals, employers, and economies globally. Identifying and implementing effective health and safety interventions at the policy level and in individual workplaces to foster sustainable and safe work environments are important. However, there is no one-size-fits-all strategy for reducing the risk for occupational injury. LMICs are especially diverse in their type and amount of resources, strength of their regulatory institutions, industrial profile, and levels of informality, among other relevant features. Therefore, the range of viable options for a country in Sub-Saharan Africa, for example, may not be the same as that for a country in Latin America. Nonetheless, considering comprehensive solutions that integrate multiple strategies for improving not only primary prevention, but also injury care, rehabilitation, workforce training, and data systems is important.

Primary Prevention

Given the challenges in LMICs, prevention of occupational injury should consider two distinct but related questions: What is known to work? How can it be applied successfully and sustainably? These questions can be rephrased as technical measure effectiveness versus implementation or program effectiveness.

Because of resource constraints in LMICs, applying the more effective, but also more expensive, technical measures from the top of the hierarchy of hazard controls—elimination, engineering, administration, or personal protection (in order of decreasing effectiveness)—may not be feasible except perhaps in large, well-resourced enterprises. Very few studies have evaluated the effectiveness of technical measures in LMICs. In India, the use of protective eye equipment reduced the incidence of eye injury among agricultural workers (Chatterjee and others 2012), while the installation of mirrors above tandoor ovens showed potential for reducing burns among oven operators in Pakistan (Nasrullah and Awan 2012). These remain very isolated islands of evidence.

Injury Care and Return to Work

Prehospital, hospital, and ambulatory care for occupational injury in some LMICs is part of the general capacity for trauma care. Although basic health units in the workplace or the community can manage minor trauma, a sophisticated prehospital and hospital trauma care system is crucial for saving lives and mitigating the effect of severe occupational injuries. Much room exists for improvement in such systems in LMICs (Baker and others 2013; Dunser, Baelani, and Ganbold 2006; Goosen and others 2003), but not without resources that could be beyond reach in such settings. In a nonrandom control study, Murad, Larsen, and Husum (2012) reported a lower injury mortality rate among patients managed by field-trained first responders than among those not managed by first responders. Applying a similar approach in workplaces or communities may be an affordable alternative for improving outcomes, particularly in the informal sector.

Access to rehabilitation services following injury cannot be dissociated from the general problem of limited access to quality health services in LMICs. Similar to emergency medical services, there is much room for building and improving rehabilitation services in LMICs (Haig and others 2009; Tinney and others 2007). Data on the duration of disability after injury in LMICs are very scarce, and such data are critically needed for an evaluation of initiatives that aim to minimize disability and enhance early return to work.

Capacity Building and Retention

Scaling up training programs to develop a competent occupational health workforce, including primary health care workers, needs to be coupled with simultaneous and serious retention efforts. The disproportionate concentration of the health workforce in urban areas is a global phenomenon (Chen and others 2004), but it is accentuated in LMICs by the rural-to-urban influx as a

result of poor investment in rural development. The most common reasons for "brain drain" are better remuneration, safer environment, and better living conditions in the receiving country and lack of facilities in the sending country. Adjusting training to local needs—for example, by providing enough training to enable locals to serve their own populations—coupled with efforts to improve working and living conditions, may curb outmigration in LMICs (WHO 2006a).

To overcome OSH resource scarcity, models have highlighted the use of intermediary organizations designed to bridge the gaps between public health and safety organizations and SMEs and to deliver occupational health and safety services (Soares and others 2012). Because SMEs are diverse and often insular, straightforward information is needed regarding OSH initiatives that can offer specific, tangible benefits and be readily adapted to their organizational structure. Through regular interactions with individual SMEs, intermediary organizations may offer the best opportunity to influence OSH decision making, providing short-, medium-, and long-range benefits (Gervais and others 2009).

Data for Planning, Monitoring, and Evaluation

Effective and targeted prevention efforts are impossible without viable local data. A recent review of an audit of suppliers to Apple revealed that fewer than one in seven recorded any injury or health events in the past year (Apramian and Cullen 2015). The ILO guidelines for improving national reporting of occupational injuries acknowledge the challenges of expanding reporting to cover small enterprises, migrant workers, the self-employed, and the informal sector (Ehnes 2012). Among the recommended solutions are legalizing migrant work and creating administrative connections through which small enterprises are obliged to report to a national database, for example, in the same way they report information for tax purposes or social insurance.

However, more pragmatic solutions may be needed for these hard-to-reach groups. One possible solution is ensuring that occupational injury modules are part of periodic household or establishment surveys (Taswell and Wingfield-Digby 2008). Enhancing routine health information data with identifiers of the relation to work and the occupation and industry of the injured person is a promising approach. Marucci-Wellman and others (2013) tested an active surveillance system that builds on the health information system in one commune in Vietnam and compared its outcomes with those from a range of unenhanced and enhanced passive surveillance models also based on the existing system. Although active surveillance performed better than passive surveillance, such an approach could be expensive and difficult to monitor and sustain. As a middle ground, passive surveillance that is enhanced with data on place and activity during injury, supplemented with active surveillance in high-risk settings, has been suggested.

Determining whether prevention programs that rely on participatory approaches, particularly those overseen by primary health care workers, could be a suitable platform for active surveillance will be useful. Ensuring the quality and completeness of data is crucial for the success of such approaches.

Regulation and Enforcement

Governments in HICs protect workers against health and safety risks through OSH legislation, regulation, and enforcement via workplace inspections that may result in citations and penalties. These approaches are often considered the cornerstone of workplace safety and health risk management (Mischke and others 2013; Tompa, Trevithick, and McLeod 2007). However, these policies are lacking or inconsistently applied in many parts of the developing world.

Studies examining the effect of OSH inspections, citations, and penalties have shown varying results (Foley and others 2012; Friedman and Forst 2007; Levine, Toffel, and Johnson 2012). Some evidence shows that inspections resulting in penalties are associated with lower rates of lost workday injuries in the years immediately following inspections (Gray and Mendeloff 2005). Other evidence suggests that penalty inspections extend their influence beyond the injuries closely related to the specific regulations for which citations and penalties were levied (Gray and Mendeloff 2002; Mendeloff and Gray 2005); that is, penalties may prompt employers to enhance general safety efforts and to respond to cited deficiencies (Haviland and others 2010). Verbeek and Ivanov (2013) appraised systematic evidence for effectiveness of basic OSH interventions in settings similar to those prevailing in LMICs and found that enforcement of regulations reduced injury rates.

In the most comprehensive report to date, a Cochrane review assessed evidence on the enforcement of OSH regulations and the prevention of occupational diseases and injuries. Mischke and others (2013) found that inspections likely reduce the risk for injury in the long term, although the magnitude of effect remains unclear. Further, focused inspections appear to have greater effect than more general inspections, although the current evidence is low quality. Unfortunately, because inspections are costly and resources are limited, the enforcement or threat of enforcement fails to reach all workplaces equally.

Additionally, the changing political, economic, and legal landscape of work is creating new stressors and potential hazards with consequences that not yet understood. Although regulations and enforcement activities are designed to protect worker safety and health, employer obligations have not yet been fully realized (Niskanen and others 2010). Given the limited number and unequal distribution of labor inspectors worldwide, more effective mechanisms are needed to translate OSH regulations into widespread practice.

Achieving sustainably safe work environments within the organizational structure of supply chains will require both private voluntary and public mandatory regulation. The involvement of local government can be crucial to upholding proper labor standards and, historically, it has underused its own capacity to impose worker standards on foreign investors in global supply chains (Amengual 2011). However, the fluid, fast-evolving structure of international supply chains means that static governmental law alone cannot sufficiently protect worker rights and health.

Rather, a joint effort with NGOs and government intervention is necessary. An example of such joint regulation involves the protection of the rights of workers in *maquiladoras*—Mexican manufacturing plants that operate in a free-trade zone (Locke 2013). The NGO CEREAL (Centro de Reflexión y Acción Laboral, or Centre for Reflection and Action on Labour Issues), the Guadalajara Chamber of Commerce, and electronics suppliers in this zone developed a dispute system known as the Accord to handle issues regarding worker compensation and benefits. Workers file complaints within the courts of the Accord, and cases are resolved directly with the factory's human resources department, bypassing the slow, often ineffective, Mexican judicial system (Locke 2013). Before the Accord, workers were subject to government neglect largely because of a weak union presence in maquiladoras and a general lack of understanding of Mexican law. Since the advent of the Accord system, workers can file labor violation cases in court and have them resolved within a few months.

Worker Training

Training workers as well as managers in hazard recognition and control, safe work practices to reduce risk, proper use of personal protective equipment, safety and health information, and emergency procedures is a widely recognized, essential component of OSH programs (Burke, Scheuer, and Meredith 2007; Redinger and Levine 1998).

Systematic reviews of research pertaining to the effectiveness of OSH training found strong evidence for positive effects on worker safety and health behaviors, but insufficient evidence that training alone improves health or safety outcomes (Amick and others 2010; Robson and others 2012). A review of evidence on the effectiveness of OSH interventions in agriculture, SMEs, and informal sector settings did not find educational interventions to be effective in reducing injury risk (Verbeek and Ivanov 2013). However, worker perceptions of safety training may positively affect safety by increasing worker recognition of potential risks, thereby enhancing workers' ability to identify near misses and increasing the likelihood that they will report injuries at all levels of severity (Lauver and Lester 2007). Contemporary learning theory suggests that incorporating structured dialogue and action-focused reflection into OSH training may enhance the effect of training on workers' engagement in safe work behaviors and confidence in their ability to handle unanticipated events safely (Burke and others 2006; Burke, Scheuer, and Meredith 2007).

Given the increasingly diverse workforce and demographic disparities in injury risk, OSH training programs need to target workers with language barriers and low literacy and incorporate cultural and societal aspects to be effective. Failing to address these aspects can deepen the OSH disparities (Steege and others 2014).

Safety Climate and Safety Culture

A general belief holds that management commitment plays a fundamental role in developing a strong safety climate and culture and that strong management commitment to and support of safety enhance employee adherence to safe work practices and ultimately reduce workplace injuries.

However, evidence showing a direct link between safety culture and climate and injury outcomes is limited. Having a strong safety culture may have a positive effect on workers' use of safe behaviors, injury and illness rates, or reporting of injuries and illnesses, but the evidence is mixed or inconclusive (GAO 2012). A meta-analysis found support for an association between safety climate and safety performance, but also found a much weaker link between safety climate and injury (Clarke 2006).

Subsequent work examined the effect of government subsidies designed to improve occupational safety by changing safety culture. Research found that only half of the subsidized interventions evaluated were deemed successful in improving reporting of hazards, reducing unsafe behaviors, or reducing accidents, indicating the challenge of promoting organizational culture change (Hale and others 2010).

Factors associated with successfully improving safety culture included a planned, systematic approach that generates sufficient energy and support for deployment of multiple safety interventions, engagement and empowerment of workers in the learning and change process, and training and motivation of managers at all levels (Hale and others 2010). Evidence from the restaurant industry suggests that employees' perceptions of management's commitment to safety and safety training are separate dimensions of the work environment, the former a proximal predictor of future injury and the latter a more distal predictor (Huang and others 2012).

Safety Incentive Programs

Safety incentive programs are popular and widespread, yet little research has been done regarding their effect on the occurrence and reporting of injuries (GAO 2012). Such rate-based and behavior-based incentive programs are intended to entice workers to work safely, but safety incentive programs may discourage injury reporting.

Studies evaluating incentive programs have reported varying conclusions about their effect on workplace safety. Some have reported that rate-based safety incentive programs have no effect on injury reporting (Brown and others 2005). Others have concluded that safety incentive programs reduce injuries (Alavosius and others 2009; Gangwar and Goodrum 2005), and still others have shown that workers whose employers enact policies involving discipline as a consequence of injury are less likely to report injuries for fear of punishment than are those whose workplaces have no such programs (Lipscomb and others 2013). The bulk of evidence is equivocal. These discrepancies may be due, in part, to the widely varying components of safety incentive programs. Some offer incentives for reporting near-miss incidents, reporting other safety concerns, or wearing protective equipment, and others reward work groups for having fewer injuries.

Behavioral interventions such as monetary incentives, praise and feedback, and team competition may reduce injuries in settings similar to those prevailing in LMICs, but the evidence is limited (Verbeek and Ivanov 2013). Effective implementation of behavioral interventions may require a greater degree of organizational regulation than currently exists in LMICs.

Ergonomic Interventions

Because ergonomic hazards vary markedly between industries and jobs within specific industries, the optimal means to mitigate those hazards likewise vary. Despite this variation, ever-growing evidence suggests that participatory ergonomics may be an effective strategy for identifying and addressing workplace biomechanical, psychophysical, and psychosocial risk factors (Niu 2010); reducing injury and MSD risk (Cantley and others 2014); maximizing the involvement of workplace stakeholders; improving production, worker perceptions, worker morale, and job satisfaction (Dennerlein and others 2012; Vink, Koningsveld, and Molenbroek 2006); and embedding ergonomics within organizational processes (Driessen and others 2011; Pehkonen and others 2009; Törnström and others 2008).

However, critical prerequisites for a successful ergonomics program are a well-established system for identifying and assessing risk factors and implementing solutions; communicating effectively with workers and management; and actively engaging workers, management, and technical personnel in the ergonomics process (Broberg, Andersen, and Seim 2011; Niskanen and others 2010; Pehkonen and others 2009; Zink, Steimle, and Schröder 2008).

Evidence showing a positive effect of ergonomic hazard control on reducing injury risk across groups of workers and jobs has been rather limited and conflicting (Fujishiro and others 2005; McSweeney and others 2002; Palmer and others 2012). However, several studies have reported an association between reduced risk for MSDs and acute injuries associated with manual handling and ergonomic job modification (Carrivick and others 2005; Marras and others 2000; van der Molen and others 2005). A recent report illustrated the benefits of identifying ergonomic hazards and controlling risk for any type of acute injury or MSD among a population of manufacturing workers, and risk was reduced further with each hazard control implemented (Cantley and others 2014). Furthermore, the application of an ergonomics process for identifying and mitigating organizational and psychosocial demands that contribute to both injury and MSD risk at work has been the subject of some recent research (Bentley 2009).

The body of scientific evidence supports the financial case for ergonomic programs. Ergonomic programs have been shown to be cost-effective, particularly in manufacturing, and ergonomics best practices focus on integrated approaches to hazard control rather than on specific ergonomic tools and procedures (Amick and others 2009).

Other Participatory Approaches

Some countries in Asia are increasingly using action-oriented participatory approaches to deliver OSH interventions, particularly in difficult-to-reach or

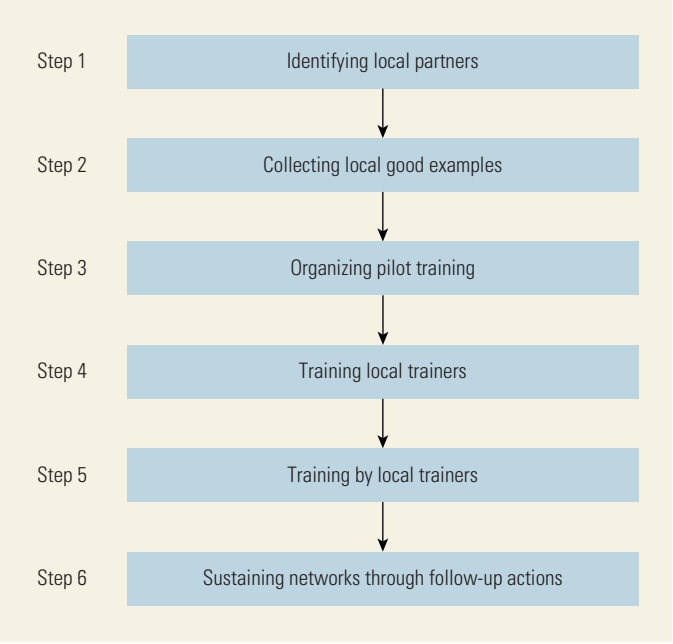
difficult-to-regulate settings such as small enterprises and the informal economy (Kawakami 2007). Also widely deployed in HICs, this approach involves the target population in identifying hazards and developing and implementing safety interventions (figure 6.2), thus ensuring a more appropriate fit between an intervention and a particular workplace setting. Interventions using a participatory approach could even help eliminate hazards and substitute them with appropriate, low-cost, and safe alternatives. This approach promotes ownership, improving the potential for compliance and sustainability.

In Cambodia, the Work Improvement in Safe Home program focused on home workers and small businesses. OSH trainers mobilized by government, worker, and employer organizations assisted participants in identifying practical safety solutions using a simple action checklist (Kawakami and others 2011).

In a slightly different version in Thailand, primary care unit (national hospital system) staff members were retrained as OSH service providers, assessing OSH risk and giving low-cost improvement advice through participatory group discussions (Kawakami 2007). In Vietnam, the Worker Improvement in Neighborhood Development program has been extensively applied in agriculture. Supported by provincial government officials, farmers were trained to use illustrated checklists to propagate examples of good practice among established networks of their peers. The approach could potentially be used to address child labor in hazardous agricultural work (ILO 2012d). The program has expanded since the launch of Vietnam's first national OSH program in 2006.

A few studies have employed an uncontrolled pre- and post intervention design to test the effectiveness of these approaches. In Thailand, reductions in toluene and carbon monoxide levels were recorded following the application of participatory training in the informal sectors of artificial flower making and batik processing (Manothum and others 2009). Similar benefits were observed after applying the same approach in the informal weaving, ceramic, and blanket-making industries (Manothum and Rukijkanpanich 2010). Knowledge, attitude toward occupational safety, and use or provision of personal protective equipment were improved after participatory training of 525 welding workers in 25 SMEs in China. However, improvements in implementation of engineering controls were inadequate (Fu and others 2013).

Figure 6.2 Steps for Promoting Participatory OSH Training in Workplaces in the Informal Economy



Source: Kawakami 2007.
Note: OSH = occupational safety and health.

Prevention of Falls from Heights and Slips, Trips, and Falls

Falls from heights are a serious hazard for many workers, especially in the construction sector. Same-level STFs pose a substantial hazard for workers in nearly every sector, but especially in health care, food services, and wholesale and retail trade.

Much has been learned about the causes and prevention of injuries resulting from these hazards, and resources have been developed to assist employers and workers in recognizing and controlling them. However, barriers continue to limit the dissemination of knowledge and use of interventions in the field. For example, gaps in knowledge persist regarding how to use fall protection measures (Committee to Review the NIOSH Construction Research Program 2008).

Management systems designed to ensure the use of fall protection measures have been shown to reduce falls among construction contractors (Becker and others 2001). Implementing comprehensive STF prevention programs that include analysis of common causes of STFs, general awareness campaigns, workplace hazard assessments, changes in housekeeping products and procedures, consistent removal of ice and snow, changes in flooring, and provision of slip-resistant footwear for high-risk employees can substantially reduce the risk for STF injuries among hospital workers (Bell and others 2008). These results

should be readily transferable to other sectors at similar risk for STFs.

Sector-Specific Interventions

Health Care

Mechanical patient-lifting devices have been shown to reduce the back compressive forces on nursing personnel by approximately 60 percent, reduce the lifting required during patient transfers, and improve patient perceptions of comfort (Garg and Owen 1992; Zhuang and others 2000). Working with national and international researchers, the National Institute for Occupational Safety and Health in the United States conducted research into comprehensive safe patient-handling policies involving the use of mechanical lifts and repositioning aids, a zero-lift policy, and employee training on the use of lifting devices. This approach was highly effective in reducing back injury risk among health care workers of all ages and lengths of work experience, regardless of the type of facility (Collins and others 2004). Additionally, clinical use and scientific studies have documented the effectiveness of blunt-tip suture needles in reducing needlestick injuries, and multiple resources have been developed to disseminate this information to health care workers (CDC 2010; NIOSH 2007).

Very few controlled studies demonstrate the effectiveness of different measures in preventing sharps injuries in LMICs. Cross-sectional comparative effectiveness analysis conducted in the Alexandria University hospitals in the Arab Republic of Egypt found that factors such as access to safe injection devices, adherence to infection control guidelines, access to written protocols on prompt reporting, and training on safe injection practice were associated with a lower probability of needlestick injury (Hanafi and others 2011).

Studies on the effectiveness of educational programs elicited inconsistent results. In contrast to an educational program, an official imperative program with monetary penalty for unsafe practice reduced syringe recapping among nurses in the Islamic Republic of Iran (Dianati and others 2012). A controlled study in China and an uncontrolled study in Taiwan, China, among student and intern nurses showed improved practices and reporting of sharps injuries following education interventions (Wang and others 2003; Yang and others 2007). In Cairo University hospitals, education combined with improved access to safe injection devices in intensive care units was associated with a reduction in the incidence of sharps injuries (Zawilla and Ahmed 2013). Countries such as the Syrian Arab Republic also report improvements in injection practice and reductions in sharps injuries after implementation of multifaceted strategies combining the provision of safe injection devices, development and circulation of national guidelines, education campaigns, and training of health care workers (WHO 2011).

Construction Worksite Safety

A great deal has been learned about engineering solutions to address major safety issues, including fall protection equipment, nail gun safety, and protection from contact with overhead power lines. However, overcoming the barriers to knowledge dissemination is needed to facilitate wider recognition of hazards and implementation of available solutions (Committee to Review the NIOSH Construction Research Program 2008). Efforts to increase awareness of construction worksite hazards should target vulnerable work groups, including immigrant workers, young workers, and contract workers, who are at substantially higher risk for injuries and fatalities in this sector.

Little research has systematically examined the effect of safety culture and OSH management systems on reducing injury and improving working conditions in the construction industry. However, evidence suggests that when owners, contractors, contractor associations, insurance carriers, and appropriate unions collaborate to establish and promote a safety culture, the risk for injury and fatalities can be reduced.

To enhance the uptake of safety training among the many immigrant workers in this sector, using training workers from representative cultural groups to deliver safety training may be more effective than using professional trainers. To promote effective integration of health and safety management into construction project planning, communication, and control, a project funded by the U.K. Health and Safety Executive developed several integrated tools for use. These include a responsibility chart, an option evaluation chart, health and safety hazard workshops, drawings presenting safety information, red-amber-green lists, health and safety milestones, and a process for controlling design changes (Cameron and Hare 2008; Hale and others 2010).

Agriculture

Various safety interventions have been implemented within the agriculture sector in HICs, but their effect remains poorly understood. Farm safety hazards in LMICs, where the vast majority of agricultural workers are employed, have received much less attention.

Results from a meta-analysis found no evidence that educational interventions were effective at reducing injury risk, which is consistent with evidence suggesting that training alone is insufficient to prevent injuries. In contrast to earlier reports, limited evidence was found

that rollover protective structures on tractors reduced injuries (Lehtola and others 2008). However, the dearth of high-quality studies illustrates the continued need to develop and evaluate farm injury interventions, particularly in LMICs.

National coordination of efforts across agriculture sector stakeholders is under development in several countries, including New Zealand, Sweden, and the United States (Lundqvist and Svennefelt 2012, 2014). In addition, initiatives to address injuries and fatalities associated with tractors and other farm machinery have been developed, including an electronic system to warn farm equipment drivers when someone enters the hazardous zone near their vehicle (EU-OSHA n.d., "Case Studies").

Pesticide poisoning is a major hazard in the agriculture sector in LMICs. Occupational exposure causes unintentional harm, while easy access is a key factor in intentional self-harm. In accordance with expert opinion, the WHO recommends a range of promising interventions regarding the safe storage of pesticides in households, communal storage, training of farm workers and schoolchildren, training of pesticide vendors, and use of community leaders to disseminate information on safe handling of pesticides (WHO 2006b). The effectiveness of these measures is yet to be demonstrated.

Social marketing—the use of commercial marketing strategies to raise awareness and promote safe behavior—has been advocated for tackling unsafe behaviors among young people (Lavack and others 2008; Monaghan and others 2008; Smith 2006). Although they are difficult to evaluate, social marketing campaigns have been associated with a reduction in occupational injuries in Germany (Mustard 2007). The effectiveness of such campaigns in LMIC settings remains to be seen, but the campaigns are probably suitable as components of participatory programs.

Machine Safety

Worker contact with machinery or equipment presents a major risk for severe injury, particularly in the manufacturing and mining sectors. Some recent risk mitigation efforts include the application of capacitance-sensing technology (Powers Jr., Anmons, and Brand 2009) and the use of intelligent video technology to detect worker presence in hazardous locations near machinery. Although these efforts show promising results for preventing future injuries (Ruff 2010), they are less readily transferable to LMICs.

Fatigue

Although fatigue is widely accepted as a public and workplace safety concern, critical gaps exist in the understanding of strategies to mitigate its causes and adverse health and safety effects (Noy and others 2011; Williamson and others 2011). Because both work and nonwork activities can greatly affect fatigue, fatigue risk management requires the involvement of employers and workers alike.

Regulatory limits on hours worked are evolving into multidimensional fatigue risk management systems that incorporate additional risk mitigation strategies, such as education and training; regular monitoring of fatigue levels; and systematic assessment of the role of fatigue in accidents and injuries in many sectors, including transportation and health care (Gander and others 2011). Development of effective and comprehensive fatigue risk management systems will require enhanced understanding of the complex relationship between fatigue and safety, because risk may be greatest at intermediate levels of fatigue, when operators may be less attentive (Folkard and Åkerstedt 2004).

Workplace Violence

International commitment to preventing workplace violence is mirrored in the ILO's code of practice for preventing violence in the services sector (ILO 2003). Most of the proposed interventions apply to service organizations such as health care institutions. Evidence from areas such as government policy and strategy development could apply to other sectors where risks are not clearly defined, such as street vending and domestic work. However, awareness-raising and prevention initiatives still need to be part of participatory occupational health approaches that target all sectors.

Psychosocial Risk Management

The association between baseline psychosocial workplace stressors and ill health and injury was documented recently among construction and municipal utility workers before the performance of a random control trial of a workplace safety intervention (Bodner and others 2014). The results from this trial will be useful for informing future interventions.

An analysis of data from the European Survey of Enterprises on New and Emerging Risks identified six aspects associated with psychosocial risk management. Establishment size, industry, and country predicted the degree of psychosocial risk management. Larger enterprises were associated with better psychosocial risk management. Manufacturing and construction sectors were associated with the least comprehensive psychosocial risk management, while the education, health, and social work sectors were associated with the most comprehensive. Countries in Northern Europe offered

more psychosocial risk management than did countries in Southern and Eastern Europe (van Stolk and others 2012). Although room exists for improvement globally, this trend toward taking systemic approaches to managing workplace psychosocial risks in Europe is encouraging.

Diffusion of OSH Interventions to SMEs

Much effort has been focused on developing OSH management systems for large enterprises, but similar development, implementation, and evaluation have been lacking for smaller enterprises (Hale and others 2010; Robson and others 2007). Given the barriers to disseminating OSH information to SMEs across many employment sectors, smaller businesses may require assistance from external organizations and other sources to fulfill their responsibility to protect the health and safety of their workers.

To address this concern, several EU member states have launched programs to support OSH in SMEs. Adequate risk assessment is a key component of OSH, but it can be costly and difficult for small businesses that lack resources for the task. To address this problem, EU-OSHA introduced the Online Interactive Risk Assessment (OiRA) project to encourage and help micro and small businesses assess their workplace risks via a cost-free Web application designed for ease of use. Sector-specific OiRA tools are being developed (EU-OSHA n.d., "Safeguarding Europe's Micro and Small Enterprises").

Cost-Effectiveness of OSH Interventions

Although some evidence highlighting the economic benefits of OSH interventions has emerged in recent years, substantial gaps remain. Existing analyses focus primarily on benefits achieved via ergonomic interventions in four sectors: administrative and support services, health care, manufacturing and warehousing, and transportation. Strong evidence supports the financial merits of ergonomic interventions for the manufacturing and warehousing sector, moderate evidence was found for the administrative and support services and health care sectors, and limited evidence was found for the transportation sector (Guimaraes, Ribeiro, and Renner 2012; Tompa and others 2010). Studies have found that ergonomic and other musculoskeletal injury prevention interventions in manufacturing and warehousing environments are cost-effective and improve health and safety outcomes, and paybacks are realized over a time period ranging from just over three months to slightly more than two years (Tompa and others 2009).

Implementation of a participatory ergonomics process consisting of both proactive and reactive components yielded a benefit-to-cost ratio of 10.6 for an auto parts manufacturer; although the number of worker compensation claims was not reduced, the duration of claims was shortened, suggesting a reduction in injury severity (Tompa, Dolinschi, and Laing 2009). Similarly, economic evaluation of a participatory ergonomics process implemented in a clothing manufacturing plant, which introduced primarily low-cost, low-tech interventions, showed a benefit-to-cost ratio of 5.5; significant reductions in first aid incidents, modified-duty episodes, and short- and longer-term sickness absences; and improvements in efficiency and product quality (Tompa, Dolinschi, and Natale 2013).

Economic evaluations of OSH interventions in SMEs are difficult to find, although SMEs represent a significant force in the global economy and the cost of injuries to these establishments could be catastrophic (Targoutzidi and others 2013). Economic evaluations may be lacking, in part, because smaller enterprises rarely have a separate budget for OSH and routinely collect only very limited OSH data, which makes complete economic analyses quite a challenge (Lahiri, Gold, and Levenstein 2005). In light of research suggesting that each near-miss or non-injury accident costs at least 654 euros (US$740), the infrequent collection of information by SMEs on these incidents suggests inadequate diffusion of information, making the business case for OSH interventions and another gap to be filled (Binch and Bell 2007; Targoutzidi and others 2013). To identify and address factors relevant to SMEs and encourage investment in OSH interventions, Targoutzidi and others (2013) recently developed several case study examples as a tool for SMEs to calculate the costs and consequences of OSH interventions.

If one recognizes that the economic benefits derived from OSH interventions may extend beyond traditional outcomes to include improved profitability and worker engagement, then considering a range of outcomes when evaluating OSH interventions is critical to ensure that the true benefits of interventions are understood (Verbeek, Pulliainen, and Kankaanpää 2009). SMEs often perceive that performing work more safely would be costly. For this reason, highlighting the business case for OSH could facilitate the broader diffusion of OSH interventions globally.

OCCUPATION AND RISK FOR ACUTE AND CHRONIC MEDICAL DISEASES

There is a vast literature on the contributions that physical, chemical, and biologic exposures at work may make to the occurrence of acute and chronic medical

conditions (Rosenstock and others 2005). Indeed, almost every pathological condition has one or more possible occupational causes. Some conditions may have myriad causes, although deciphering the role of workplace exposures in each case is problematic. For others, the consequences of workplace exposures are unique, such as the poisonings caused by lead, mercury, arsenic, and other heavy metals; the pneumoconioses caused by coal, silica, or asbestos; or the rare syndromes caused by dioxins and vinyl chloride. These latter causes can, at least in theory, be diagnosed individually.

Other consequences present as very common, such as chronic obstructive lung disease caused and exacerbated by exposure to irritant dusts, coronary artery disease caused by exposure to particulate matter or workplace stressors, or the more common forms of cancer caused by exposure to several dozen common carcinogens. In individuals with these common ailments, the contribution of work can be assessed only by looking at patterns of disease in the population in aggregate.

However, broad debate continues about the burden of chronic disease that may be attributed to work even in well-studied HICs, ranging from as little as 1–2 percent to perhaps as high as 10 percent (Sorensen and others 2011). Far fewer data are available on LMICs. Moreover, although acute overexposures to toxins are commonplace (WHO 2004), their role in morbidity and mortality is unlikely to approach that of injury, which is the reason this vast subject is relegated to a brief overview.

Exposure Classes

More than 100,000 chemical substances and numerous biologic hazards are found in workplaces around the globe. The control of occupational disease has focused on three major categories of hazard—physical, biological, and chemical:

- ***Physical hazards*** include noise, heat and cold, ionizing and nonionizing radiations, and stressors such as vibrations. Although the range of effects of these factors remains incompletely studied, hearing loss (noise), cardiovascular disease (noise, heat), and cancer (ionizing radiation) are the major concerns even in HICs.
- ***Biologic hazards*** include both infectious and allergenic microbes, highly allergenic plant and animal products such as latex rubber, and agents with direct biologic activity such as tobacco leaves and some pharmaceuticals. In general, biologic hazards pose significant risks for the small fraction of any workforce sensitive to them. They probably contribute little to overall disease burden in either HICs or LMICs.
- ***Chemical hazards*** include pesticides, organic solvents, heavy metals, fibrogenic dusts, and plastics and other reactive chemicals.
- ***Pesticides*** include several classes of intentionally biocidal materials. Their poor control is an established cause of substantial physiologic effect on persons regularly exposed and may cause permanent neurological and other effects.
- ***Organic solvents*** remove oils and grease and dissolve chemicals. Ubiquitous in every metal-working or plastics operation, they are potent liver toxins. Isolated members of the group can cause leukemia (benzene), severe neuropathy (n-hexane), and heart disease (carbon disulfide).
- ***Heavy metals*** include both naturally occurring (arsenic) and human-extracted (lead, mercury) materials. Many of these materials are extremely toxic, and human epidemics associated with exposure are well described (Dorne and others 2011; Jaishankar and others 2014). The degree to which modest exposures contribute to overall morbidity and mortality, including cardiovascular disease, cancer, and renal diseases, among others, is uncertain.
- ***Fibrogenic dusts*** include silica—present in every ore and stone—coal, and asbestos. Although coal has proved less hazardous than the others, millions of workers have been exposed to these lethal dusts, which cause lung scarring and cancer. Part of their importance is the enormous economic scope of mineral mining, refining, and fabrication and the general absence of any acute reaction to exposure, leaving many with the erroneous impression that the reactions are little more than a nuisance. In the aggregate, these dusts have contributed measurably to the world's burden of chronic lung disease and cancer, despite progress in control of exposure in most HICs.
- ***Plastics and other reactive chemicals***, including dyes, explosives, and pharmaceuticals, are becoming increasingly problematic in LMICs because many workers move from rural agricultural areas to cities and manufacturing environments. The biologic consequences of exposure to this large and heterogeneous class of materials have been studied, but their potential for adverse effects is difficult to ascertain. Although a few members of this class of agents, such as formaldehyde, are relatively ubiquitous, most are associated with specific processes and tasks. For this reason, population-level risks tend to be modest.

Prevention

Although the fraction of chronic diseases to which workplace factors contribute remains unknown, there is

compelling reason to believe that some progress on prevention has been made in HICs. All evidence suggests that high-level exposures of the sort historically associated with acute disease have become far less common in the past four to five decades. This improvement is likely the result of a combination of regulations enforced in all HICs; successful litigation against manufacturers of products known to cause harm, such as asbestos; and a far higher level of awareness of workplace hazards by employers and employees alike, especially in unionized sectors of the workforce. Jurisdictions with reporting laws, including the United Kingdom and many U.S. states, have documented the marked decline in these sentinel cases (Stocks and others 2015). Although exposure to noise, heat, and fine particulate matter continues to be very widespread, potentially adding to the still-high burden of cardiovascular disease, average exposures to metals, pesticides, and carcinogens have improved (Kauppinen and others 2013; Symanski, Kupper, and Rappaport 1998).

The same cannot yet be said for the situation in most LMICs. The picture is clouded by severe impediments to control, with strong parallels to the issues affecting injury control:

- Because HICs have banned certain harmful materials, such as asbestos or polychlorinated biphenyl, stockpiles have made their way into countries without such regulations, a cycle affectionately referred to as chemical "dumping."
- Few professionals are trained in occupational exposure or disease control, and those with training often take advantage of the better employment prospects at multinational companies and in HICs.
- Few employers and workers receive training.
- Personal protective equipment is either too expensive or unavailable.
- Regulations, including social programs such as workers' compensation, are weak, because governments try to woo foreign investors with a so-called "race to the bottom."
- Even where regulations exist, they are often unenforceable because of political reasons or the absence of trained inspectors and laboratories, among others.
- The absence of unions or laws protecting the rights of workers creates difficulty in enforcing safer work practices.

Combined with the dearth of research, the sparseness of strategies for controlling exposure or preventing acute and chronic diseases is not surprising. For this reason, the discussion combines control of these conditions with injury control, for which the need is more immediate, the risks are well documented and recognized, and the available information is at least slightly more tractable.

CONCLUSIONS

The most effective means to prevent occupational injuries globally is far from certain, and universally effective intervention strategies are improbable. Nevertheless, sufficient evidence exists to recommend widespread implementation of several approaches.

Developing and retaining a competent health care workforce is critical for LMICs. Community-based initiatives to promote OSH in conjunction with public health have the potential for broader reach in regions with few resources for health care workers. Empowering workers to advance change through wider implementation of participatory approaches could speed the identification and mitigation of hazards across many regions and sectors. Targeted and effectively delivered training for vulnerable workers, such as young workers, inexperienced workers, immigrant workers, and workers in SMEs, is needed to reduce the burden of occupational injury among these subgroups of workers worldwide. Efforts to formalize segments of the informal workforce are also needed to protect these vulnerable workers.

NOTE

World Bank Income Classifications as of July 2014 are as follows, based on estimates of gross national income (GNI) per capita for 2013:

- Low-income countries (LICs) = US$1,045 or less
- Middle-income countries (MICs) are subdivided:
  a) Lower-middle-income = US$1,046 to US$4,125
  b) Upper-middle-income (UMICs) = US$4,126 to US$12,745
- High-income countries (HICs) = US$12,746 or more.

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