Journal of Preventive and Population Health
https://jpphealth.com/

REVIEW ARTICLE

Long-term disability and mortality following severe occupational injuries: narrative review

Wael Mohamed Suleiman[1*], Ahmed Mustafa El-Shiekh Idrees[2], Amer Atta Almanan Mohammed Haroun[3]

Full list of author information is available at the end of the article.

ABSTRACT

Workplace injuries are a major public health concern with significant social and economic effects. As a result of workplace injuries, approximately 5 million people die each year. Job-related injuries are common in a variety of occupations, including mining, construction, the healthcare sector, and transportation. Workers' long-term well-being, family life, and financial security are all significantly impacted by these injuries in addition to their immediate health. Thus, the major problems caused by industrial injuries around the world make workplace safety regulations and post-injury treatment crucial issues that need constant attention. This review article provides a comprehensive overview of occupational injuries, highlighting the various causes associated with job-related injuries, their fatal socioeconomic implications on workers, and the importance of safety policies.

Keywords: Disability, mortality, occupational injuries.

Introduction

The "Law on Occupational Health and Safety" defines occupational injuries as incidents that take place at work or while performing duties and result in death or compromise of physical or mental integrity [1,2]. Workplace accidents that cause personal injuries, illnesses, or fatalities are serious public health problems with far-reaching social and economic ramifications. In 2021, there were 91,181 work accidents reported in Austria, translating to an incidence of 1018/100,000 [3]. Furthermore, around 6,300 people die every day from accidents or occupational illnesses [4]. In addition to numerous other injuries, around 25% of all work-related fatalities occur in the construction industry [5]. For example, the percentage of construction workers injured during work was 74% in Kenya [6].

Around the world, hundreds of millions of people work in dangerous conditions [7]. Yosef et al. demonstrated that workplace injuries in construction have been associated with a number of factors. These factors include job satisfaction, sex, marital status, use of personal protective equipment, and occupational safety training [8]. Males, those between the ages of 20 and 34, and those employed in the construction, production, farming, and forestry sectors are the categories most likely to get eye injuries relative to other types of injuries [9]. Moreover, occupational health and safety services that help prevent accidents and injuries at work are frequently inaccessible to temporary employees [10].

Different professions frequently include occupational injuries. For example, mining has long been a dangerous profession, particularly underground coal mining. All miners must deal with the serious occupational risk of injuries, even fatal ones. Krstić et al. [11] Reported that injuries are generally regarded as unpredictable and unintentional. The high injury rates are caused by the way the job is organized, the age or skill level of the employees.

In addition, a variety of common injuries are a part of the healthcare sector. It was detected that 53%

Correspondence to: Wael Mohamed Suleiman
*Orthopedic General practitioner, Care Medical Hospital, Riyadh, Saudi Arabia.
Email: Wael_Sa@hotmail.com
Received: 12 October 2025 | **Revised:** 20 November 2025 | **Accepted:** 08 December 2025

of occupational injuries in Austria were among orthopedic and trauma surgeons [12]. This is attributed to frequently working with sharp or electrical devices, stand for extended periods of time, and perform repetitive motions [13-16]. Particularly, injuries from sharp objects present serious hazards for infectious diseases like HIV, Hepatitis B, and Hepatitis C [17,18]. The likelihood of getting hurt at least once in one›s career might reach 79%, depending on the risk factors at work [3]. Furthermore, according to a 2022 study, healthcare workers who experienced physical aggression, verbal harassment, a negative perception of the workplace culture, and a lack of support from their bosses were more likely to consider suicide [19]].

In the United States, the annual incidence of carbon monoxide (CO) poisoning is estimated to be 50,000 (16.0 cases per 100,000 population) [20]. According to the Global Burden of Disease (GBD) risk factor framework, one of the two risk factors currently linked to mortality from unintentional carbon monoxide poisoning is occupational injuries [21]. It was shown that the risk of CO exposure for dermatosis, eye inflammation, and respiratory disorders was 24.95%, 65.77%, and 61.12%, respectively [22].

Because of medical expenses and employee absence, occupational injuries cause both direct and indirect financial losses [23]. Around 20,000 industrial eye injuries occur in the US each year, with an estimated cost of $300 million [24]. It is estimated that occupational accidents cost the world economy USD 1.25 trillion, or 4% of its GDP [25,26]. Employers should therefore place a high priority on providing safety training, and promoting the use of personal protective equipment while working. Moreover, they should carry out regular workplace inspections, and make sure that their employees are content by creating comfortable workspaces in order to decrease the occupational injuries' rate [8].

This comprehensive research examines the mortality rate, long-term disabilities following occupational injuries, and factors related to them. Additionally, it illustrates socioeconomic burden and the impact of safety training programs.

Mortality rates after severe occupational injuries

Mortality rates are statistical measures that describe the frequency of deaths in a specific population during a certain period of time. They help understand how common or severe death is in relation to a defined group of people [27]. Research on mortality rates after severe occupational injuries has emerged as a critical area of inquiry because of its substantial impact on public health and workforce sustainability in the United States. Occupational injuries contribute significantly to global morbidity and mortality, affecting millions of workers annually, with fatality rates varying widely across regions and industries [28].

The number of fatal workplace injury deaths is frequently organized and analyzed based on different categories like age, sex, race, ethnicity, and industry. This is done to identify trends and understand how these categories relate to the data being examined [29-31].

Global prevalence of occupational injury mortality

The World Health Organization (WHO) estimates that occupational injuries cause over 5 million fatalities each year, contributing approximately 10% to the global mortality burden [28]. Between 2014 and 2019, the number of yearly deaths from work-related illnesses and injuries rose from 2.3 million to 2.9 million, a 26% rise [32]. COVID-19 has killed 1004 health care workers (HCWs) worldwide as of May 13, 2020. Some 550 of these deaths were physicians, with an average age of 62.49 years and 52.62 years for non-physicians. U.S. HCW deaths were 64.1% male, with 26.9% of physician deaths being general practitioners and family care physicians. HCW fatalities were highest in the US, as in other wealthy nations [33].

Martin et al. [27] examined North Carolina's fatal workplace accidents between 1992 and 2017. Almost 2645 unintended fatal job-related injuries occurred among those who were 18 years of age or older. Fatal occupational injury rates declined by 0.82 injuries per 100,000 person-years . In another quantitative epidemiological analysis, between 2015 and 2019, the number of fatal occupational injuries dropped from 380,500 to 312,000 [32]. This reduction might be partly because fewer deaths are reported in densely populated regions of the world, such as China and India, where employment statistics are lower, rather than indicating a true improvement in accident prevention [32]. The estimated number of non-fatal occupational injuries was 402 million, a significant increase since 2015. This increase can be partially ascribed to 2019's fatal/non-fatal rate estimations being more precise than those from prior evaluations [32].

Injury-specific mortality patterns

According to ATECO, jobs were divided into three sectors: primary (A and B, like farmers and breeders), while secondary (C-F, like construction workers, maintenance/technicians, like electricians and plumbers, carpenters and foremen, metalworkers, and unskilled workers), and tertiary (G-U, like couriers, white-collar workers, law enforcement, and healthcare workers) [34].

It was found that falls from above remain a significant cause of fatal accidents. It is common in construction due to the nature of work involving activities at heights and among older workers. Falls account for a large proportion of both fatal and nonfatal injuries, with higher mortality in cases involving head trauma or internal organ damage [34-37]. Thus, head injuries, particularly polytrauma and fatal head traumas, are common in work-related accidents with percentages of 36.4% and 19.2%, respectively, according to Antonangeli et al. [34].

While commuting accidents, especially in the tertiary sector, represent a substantial portion of fatal injuries, necessitating a better understanding and preventive measures due to workers' increased vulnerability on the roads [34]. Conversely, occupationally acquired infections such as hepatitis C virus (HCV), hepatitis B (HBV), and human immunodeficiency virus (HIV) are the most common pathogens of concern. Significant morbidity and death are linked to them. Accidental punctures are frequently the cause of bloodborne illnesses in most work or laboratory environments. Every year in the US, an estimated 400,000 people are hurt by sharp objects in medical settings [38].

Road injuries are a leading cause of occupational injury deaths globally, including motor vehicle accidents. It affects all age groups and is especially prevalent in transport and construction sectors [39]. On the other hand, Crush Injuries, Asphyxia, and Drowning are notable in mining, civil engineering, underwater work, and construction work; these mechanisms are associated with high fatality rates [37]. Another injury pattern related to mortality is the heat-related injuries. Heat exposure causes significant mortality, especially among agricultural and construction workers, with a higher risk in men, Hispanics, and small businesses [40]. Moreover, Work Conditions includes night shifts, lack of supervision, absence of personal protective equipment, and long working hours, are independent risk factors for fatal outcomes [36,41,42].

Factors influencing long-term mortality post-injury

Age and sex differences

Age is one of the most important factors affecting both immediate and long-term mortality following occupational injury. Unintentional fatal occupational injuries are dominant in males aged ≥ 18 years [27]. A global burden analysis showed that the age group 25 to 44 years recorded the highest burden of fatal occupational injuries [39]. Fatality rates increase considerably with age, as older workers are more vulnerable to severe injury consequences, such as cancer and cardiovascular disease (CVD), which account for 70%–80% of total mortality in individuals aged 40 years or older [43].

Worldwide, the gender difference in labor force participation is getting less, but it is still rather big. In 2023, males were in the labor force at 73.0% and women at 48.7%. The participation disparity ranges from 46 to 54 percentage points in Southern Asia, Northern Africa, and Western Asia. In contrast to the service sector, where women predominate, manufacturing is seeing a rise in the proportion of female employees [44]. Pronounced sex differences appear in occupational injury death rates. Male workers typically experience higher fatality rates (up to 10 times in some regions) and years of life lost due to workplace injuries than females, mainly because men are more often employed in high-risk jobs [43,45,46].

Industry and occupational factors

The type of industry has a significant impact on post-occupational mortality risk. Construction, mining, agriculture, and transportation have the highest fatality and severe injury rates [39,46,47]. This can be attributable to various conditions associated with these industries, such as low salaries, poor working environments, lack of protective equipment, and exposure to different occupational hazards [39,47].

Migrant status and vulnerable populations

Migrant workers consistently face higher risks. This is because of limited language proficiency, lack of formal training, and limited access to healthcare or compensation [48]. For instance, Chinese migrant workers in South Korea have higher fatal injury risks due to the restricted employment permit system [49]. In China, 80% of onsite deaths were migrant workers [50]. Additionally, in Saudi Arabia, migrant construction workers suffered more severe injuries and had poorer access to care than local workers [51]. These disparities highlight the intersection of occupational health, immigration policy, and broader social inequalities.

Geographic

Occupational injury mortality rates differ significantly across regions. Countries were classified based on "country income levels" into high-income countries (HICs) and low- and middle-income countries (LMICs) [50,52]. Although fatal occupational injuries have decreased overall, HICs have experienced an increase in the rate. This is likely due to more countries being included in this category and improved reporting systems for fatal occupational injuries compared to highly populated countries, including India and China [32].

Low- and middle-income countries (LMICs) consistently show higher occupational injury mortality rates compared to HICs [31,50]. In 2016, LMICs had a rate of 7.0 per 100,000 people, more than double that of HICs (3.1 per 100,000]. Yet both groups reported a general decline in occupational injury mortality, except for ages 15–49 in HICs [31]. Racial and ethnic disparities were observed in certain states, such as Arizona, North Dakota, and Oklahoma, which had significantly higher fatality rates among various racial and ethnic minority groups compared to their regional averages [27,46]. This variation highlights the intersection between different factors affecting occupational injury mortality rates, necessitating further studies to decrease these variations [31].

Occupational safety and health (OSHA) rules and regulations are lacking internationally due to precarious work in LMICs. Moreover, overtime work and poor OSH monitoring increase accident and repetitive motion injury risk. In increasingly industrializing source countries, OSH skills and education are lacking [50]. A study conducted in 2019 showed that East Asia,

South Asia, and Southeast Asia had the highest rates of occupational injuries, with the greatest burden in China and India [39]. Despite that, due to inconsistent occupational recordkeeping, the International Labour Organization (ILO) reports less than 1% of occupational accidents in China and India [50].

Disability status and mortality

Disabilities resulting from severe occupational injuries are potential risk factors for increased mortality [53]. Disabilities are associated with psychological factors due to the inability to return to work and thus, not maintain economic security, social connections, and psychological well-being [54,55]. This suggests that disability acquired post-injury can be a cause of the increased mortality [45,53]. A prime example is musculoskeletal diseases, which have been reported as a major cause of disability in the US among men and women. This results in increased lost time among workers (lost time is defined as >7 days off work or some permanent disability) [45].

Drug overdose involving opioids, intentional self-harm, cancer, and cardiac diseases have also been associated with increased mortality due to work-related disabilities [54-57]. Opioids are sometimes prescribed as part of pain management following severe occupational injuries, especially those associated with disabilities. This can lead to accidental or intentional overdose and hence increase mortality rates [55]. Moreover, depression from work-related injuries is associated with disabilities due to the financial burden of the injury and difficulty returning to work. It was reported that the influence of work-related disability on mortality is highlighted by the fact that death is typically higher among those who do not work than among those who do [45,54].

Thus, successful return-to-work programs are important for reducing long-term mortality risks by maintaining economic security, social connections, and psychological well-being [45].

Timing and causes of mortality

Increased overall mortality typically begins approximately 3 years after the injury, with cancer-related mortality starting around 6 years post-injury and heart disease-related mortality beginning about 8 years after the injury [45]. Additional causative agents of death identified in some studies include carcinogens, particulate exposures, gases and fumes, as well as injury risk factors [32].

Long-term occupational exposure

Long-term occupational exposure to occupational hazards such as dust, solvent, and pesticide has been investigated in the elderly (75 years). All-dust exposure is linked to higher mortality in women; solvents are linked to higher mortality in men, while pesticides are linked to higher cancer-related mortality in men and, for some groups, in women [58].

Implications for workplace safety policies and post-injury care

Evidence of long-term mortality following occupational injuries emphasizes the importance of primary prevention strategies. Traditional approaches focusing mainly on immediate injury prevention must be expanded to consider long-term health outcomes and worker well-being [54]. Workplace safety policies and post-injury care are critical areas requiring continuous focus due to the significant challenges posed by occupational injuries globally. These injuries not only affect workers' immediate health but also have far-reaching consequences on their financial stability, family life, and long-term well-being [54].

Rates of fatal occupational injuries have been steady since 2009, indicating the need to update current approaches and adopt new preventive strategies [27]. This can be achieved through identifying vulnerable populations and high-risk industries, and developing targeted interventions to improve safety [27,28,59]. While these industrial activities contribute to economic growth, they must also prioritize worker well-being [28].

Promoting stronger safety climates within organizations is an important approach to decreasing fatal occupational injuries. Organizations should endorse a vision that supports safety initiatives. Investment in safety equipment and ensuring proper training, encouraging active employee involvement in safety programs, hazard identification, and reporting are all important approaches leading to increased safety [29,60]. Moreover, policies should aim to empower workers to decline hazardous tasks, report unsafe environments, and ensure that they receive proper training, especially for unfamiliar equipment. This also addresses situations in which workers may feel pressured to accept overtime or unsafe conditions [29].

Although changing employment demographics, such as an aging workforce, influence injury trends, they do not resolve the underlying social issues contributing to injury risk factors. Policies must address these deeper issues [30,61]. Occupational injuries are linked to substantial declines in income, comparable to job loss from mass layoffs [54]. This highlights the need for strong post-injury support systems that address issues of financial stability [62]. In addition to financial costs, injuries lead to medical expenses, limitations in family roles (e.g., household tasks, parenting), and significant psychological distress, such as depression and anxiety [54]. Therefore, post-injury care must be holistic, integrating medical, psychological, and social support. Additionally, it should include measures to prevent recurrence and facilitate a safe return to work.

Long-Term Disability Risk After Occupational Injuries

Occupational injuries have significant long-term adverse impacts on disability, incomes, familial responsibilities, depression, and opioid use [63]. Injuries

resulting from work accidents represent a public health, social, and economic concern [64,65]. They are among the primary contributors of premature mortality, morbidity, and disability in a substantial population [66].

The kind and severity of occupational injuries (OIs) are recognized as significant indicators of trauma outcomes [67,68]. The effect is pervasive throughout all aspects of life, with victims enduring both short- and long-term health repercussions that diminish their quality of life and those of their families [69]. Globally, missed workdays resulting from occupational accidents are estimated to account for over 4% of the world's Gross Domestic Product (GDP), with some nations reporting figures as high as 6% or more [64].

Occupational accidents inflict significant pain and suffering on wounded individuals, while also impacting their families, workplaces, and society at large. They have several repercussions, including the loss of skilled and unskilled labor, medical expenses, and compensation disbursements [70].

The 2013 Global Burden of Disease (GBD) research predicts that LMICs account for almost 80% of occupational injury-related fatalities worldwide [71]. In LMICs, occupational risk factors for injuries constitute the leading cause of DALYs and occupational fatalities among men and women aged 15–49 [50].

Although industry injury and death statistics indicate that women are less likely to sustain injuries at work, these estimates sometimes do not take into consideration the unequal distribution of men and women across jobs or tasks within jobs [72]. Men were more likely to sustain injuries from specific occupations in primary and secondary industry sectors that required physical exposures in addition to certain chemical and biological exposures. However, women were more likely to sustain injuries due to the repetitive tasks and physical demands of employment in the medical area and aluminum production [73].

Functional outcomes and disability prevalence over time

Long-term or permanent repercussions of injuries are particularly concerning, including the inability to resume employment and consequent dependence on social payments to offset income loss. In response to the latter consequence, several research have investigated the prevalence of disability pension (DP) and sickness absence (SA) among wounded patients, finding various injury-related and sociodemographic risk variables [74–76]. A contributing component is poor socioeconomic level (SES), which has been shown to elevate the probability of both long-term sickness absence (LTSA) [77] and permanent disability pension (DP) subsequent to trauma [74].

There are often far-reaching, long-lasting effects that affect not just the affected person's bodily and mental health but also their relationships at home, at work, and financially. Some of the following are common results that victims often report, such as significant physical changes and pain; distressing emotional changes and increased anxiety and depression; diminished ability to carry out daily tasks, higher rates of work absence, and unemployment, or early retirement. Other results were a decline in productivity; decrease or loss of incomes; diminishing financial stability; diminished life contexts and experiences; social isolation; changes in family roles and dynamics; diminished independence and autonomy; and increased need for health care and third-party assistance [78,79].

Post-Traumatic Stress Disorder (PTSD), among other mental illnesses, is the most explored mental illness after stress or injury [80]. PTSD prevalence rates range from 1.5% to 74% in survivors of natural disasters or traumatic events, whereas major depressive disorder prevalence rates are 13% to 52% [81].

Spinal cord injuries (SCIs) are complex illnesses occurring from direct or indirect spinal cord injury. One of the most prevalent causes of SCI is acute trauma from motor vehicle crashes. Spinal cord injuries may lead to persistent impairment, substantial morbidity, and fatality. High spinal injuries generally limit cardiorespiratory function and necessitate immediate therapies [82].

Over and above, burns have prominent physical and mental effects. Around 11 million people suffer from burn injuries that require medical care each year, and over 180,000 die from burns, mostly in low- and middle-income countries. The workplace is one of the common places where burns happen at [83]. Burns inflict bodily injury and mental health issues owing to the unpleasant healing process. Burn patients face several physical and psychological problems, including anxiety and depression throughout recovery [84].

Socioeconomic and psychological impacts of long-term disability

Traffic, sports, occupational, farm, young adult, in-patient, and multiple trauma or serious injury incidents cause long-term injuries and economic losses. These effects can lead to sick leave, rehabilitation, and disability, resulting in reduced quality of life and a heavy burden on the national economy [85]. Occupational injuries can have significant economic impacts, including lost income and long-term health issues. Age differences in injury risk vary, with older workers often experiencing more disability and younger workers more prevalent [86].

Ganger et al. reported the connection between occupational injuries and mental illness, such as depression, anxiety, and post-traumatic stress [87]. Furthermore, Wightman et al. [62] found that mental health illnesses are much worse after the injury happened in the workplace.

Cross-border labor movement and rural-urban mobility have been caused by economic hardship and violence in Africa, Asia, and Latin America. Cross-border trade and seasonal or permanent migration from Burkina Faso, Niger, Guinea, and Mali to more affluent urban and rural areas of the subregion are significant economic and social phenomena to this day [88]. In China, rural-urban migration is increasing and forms the bulk of internal migration [89]. Migrant workers in LMICs face social exclusion, exploitation, poor working conditions, informal employment, and limited access to public services [90].

Workers' compensation (WC) experiences are often perceived as unfair and adversarial [91]. Many workers face obstacles in obtaining rightful benefits, are treated demandingly, and receive minimal assistance from employers and WC insurers. Workers who sustain injuries are frequently ostracized, called malingerers, and struggle to get their conditions accepted as real [92].

Data suggests that injured workers may not disclose work-related injuries for fear of retaliation, thinking that pain is normal with age or work activity, lack of management support after earlier complaints, and a desire to keep their jobs [93]. Furthermore, the purpose of workers' compensation insurance is to replace wages for workers who suffer an injury at work that prevents them from earning their usual income. However, the majority of states restrict the duration and/or quantity of available income replacement benefits, leading to significant economic hardship [93].

Additionally, Over and above, Qiu et al. [94] reported that that disability-related multiple deprivation (IDMD) significantly lowers employment opportunities (EMPOs). It indicates that people with disabilities face a poverty trap as a result of the connection between IDMD and EMPO.

Economic burden (productivity loss, wage replacement, healthcare utilization)

It was estimated that US work injuries and illnesses cost $250 billion, or 1.8% of GDP. Moreover, workplace illnesses and accidents account for an estimated 4% of worldwide GDP, according to the International Labor Organization [95]. According to the Health and Safety Executive (HSE), job-related injuries and illnesses cost the UK £14 billion, or 1% of GDP. Safe Work projected that Australian work injuries and illnesses cost AUS $61 billion, or 4.8% of GDP [96]. On the other hand, according to a recent study conducted by the European Agency for Safety and Health at Work (EU OSHA), the costs associated with occupational illnesses and injuries amount to 3.3% of European GDP and 3.9% of worldwide GDP [97]. The American Burn Association's National Burn Repository reports that surviving burn patients cost $5,500 and dying patients $15,500 [98].

Economic studies show that indirect wasted productivity costs far exceed direct healthcare costs for accidents and diseases. Career displacement and social issues add to disability's financial effects, as a recent study shows that workers lose wages for years following a working accident [99]. Numerous work-related injuries and workers' compensation claims have had enormous effects on workers, employers, insurers, and society [100].

Post-injury rehabilitation and return-to-work support

Research continuously demonstrates that returning to work following an injury is a socially constructed event that is impacted by several elements. These include the personal traits of the employee, the social and economic circumstances of the injured party, the nature of the employment, and the amount of compensation paid. Social support plays a crucial role in moderating the employment re-entry process [101].

Work disability is a complicated, socially based outcome of illnesses and injuries sustained at work. Numerous factors, including the availability of suitable employment, the state of the labor market and economy, and the abilities and experience of the wounded party, all had an impact [94]. Return to work is significantly predicted by pre-injury job satisfaction and motivation [102].

Impact of Safety Interventions and Training Programs on Occupational Accident Rates

Safety culture is a crucial aspect of occupational safety and health (OSH) programs. It entails educating managers and employees about identifying and controlling hazards, safe work practices, using safety and health information, personal protective equipment appropriately, and emergency protocols [103].

Employee perceptions of safety training may have a positive impact on safety by raising awareness of possible hazards. As a result, they are more likely to report injuries of all severity and are better able to recognize near-misses [104]. According to modern learning theory, OSH training should include both action-focused reflection and structured dialogue. It might strengthen the impact of training on employees' confidence in properly managing unforeseen circumstances and their participation in safe work practices [105].

It was reported that engagement among employees is impacted by safety culture. The association between worker involvement and safety culture is mediated by the safety climate. Thus, the safety atmosphere of a construction company is a crucial component in creating a safety management system for that company [106]. Steege et.al reported the significance of comprehending trends in the inequalities of occupational illnesses, injuries, and deaths. By creating programs that better address the requirements of the increasingly diverse U.S. workforce, it can enhance intervention efforts [107].

Overview of safety interventions and training programs across high-risk industries

One of the most efficient methods to decrease workplace risk has been identified as workplace safety training, especially for high-risk sectors including manufacturing, mining, construction, and oil and gas. These sectors are often afflicted by a variety of occupational risks that, if left unchecked, might cause fatalities, severe injuries, or long-term conditions. Programs for workplace safety training are thought to provide individuals with the abilities, information, and consciousness necessary to identify, prevent, and successfully handle any risks [108].

Safety incentive programs are prevalent; yet, less data exists on their impact on injury incidence and reporting. Behavior-based incentives and rate-based programs aim to motivate employees to prioritize safety; nevertheless, these safety incentive programs may deter the reporting of injuries. The impact of incentive programs on workplace safety has been the subject of multiple studies that have reported varying conclusions [50].

Previous research suggests that various modifiable organizational and psychological elements are linked to safe and sustained RTW in injured employees with work-related persistent disability and perhaps all workers. For example, supervisor and coworker support, safety climate, absence of stigmatization, and health and safety committees. Moreover, low job stress, ease in reporting unsafe work circumstances, communication with employers and healthcare providers, and the flexibility to take time off for personal or family problems are part of these factors. Primary prevention is crucial, but secondary prevention to maintain RTW and avoid reinjury may lessen the health, economic, and societal costs of occupational accidents [93].

Effective Occupational Safety and Health (OSH) solutions are a top concern for firms attempting to manage workplace safety [109]. OSH prevents work-related injuries and illnesses and improves workers' health, safety, and welfare by improving working circumstances [110]. Public institutions are investing heavily in OSH management performance, but more research is needed to evaluate these efforts [111-113].

In recent years, experts have stressed the need to analyze intervention efficacy to maximize their impact and improve them [113]. Organizational interventions generally work in subtle situations and depend on many qualitative elements that are hard to trace. Thus, their success is rarely monitored and frequently presumed without careful analysis [114]. The efficacy of OSH therapies has been studied; however, the issue is still unclear. Understanding the existing quo and prospective improvements can assist researchers and practitioners in identifying important concerns and enhancing OSH interventions.

Type of interventions

Cutting the link between exposure at work and the ensuing occupational disease or injury is the goal of primary preventive occupational health interventions. The primary kinds of these interventions are behavioral, clinical, and environmental [115]. The environmental interventions' aim is to modify the workplace; for example, removing sources of noise to stop hearing loss. While behavioral approaches include advocating for personal protection equipment, and focusing on the behavior of individual employees to eliminate exposure. To prevent diseases, therapeutic interventions employ clinical techniques. Due to the underestimated challenges of including management and employers in workplace changes, field research has proven unsatisfactory [111,116].

Although there is little data, behavioral interventions that resemble those in LMICs, such as financial incentives, team competition, and praise and feedback, may lessen injuries [110]. A higher level of organizational regulation than is presently found in LMICs could be required to guarantee the effective implementation of behavioral treatments.

Key components of successful safety training programs

There are different components to succeeded safety programs. A prime example is Leadership and Commitment; top management›s commitment to a safe workplace is crucial. Employees are more likely to take safety seriously when they see safety as a priority [117]. Additionally, Hazard Identification and Assessment, regular risk assessments support determine potential hazards and evaluate their severity. This process helps in prioritizing and implementing effective control measures [118]. Comprehensive safety policies and procedures outline safety expectations, guidelines, and protocols are Key Component of Successful Safety Training Programs. Employees should have easy access to this information and receive training on safety procedures [119].

Over and above, employee training and education are one of the key components, as regular learning on potential hazards, safety protocols, and emergency procedures is essential [117]. Besides that, employees should be provided with necessary safety equipment and personal protective gear [117]. Every organization should have a well-defined Emergency Response Plan, Safety Committees, and Communication [117]. Creating safety committees or involving employees in safety discussions provides valuable insights and feedback [119]. Additionally, documentation and record-keeping of accurate records of safety-related activities, incidents, training, and compliance are legal requirements [117].

Influence of organizational commitment and safety culture

Safety culture underpins this interaction, promoting safety principles, attitudes, and behaviors at all

organizational levels. Safety culture decreases accidents and boosts employee trust and engagement by proactively addressing workplace dangers. Sustainability is enhanced by corporate social responsibility (CSR) concepts, which promote ethical behaviors, improve business reputation, and reduce workplace accidents and regulatory compliance costs [120].

Risk mitigation links safety culture to sustainability by proactively managing threats to long-term business objectives. Strong safety cultures encourage systematic risk reduction techniques, including hazard assessments and personnel training. These techniques prevent financial losses and operational interruptions while meeting sustainability goals. Effective risk reduction optimizes resource allocation, preserves the environment, and safeguards societal well-being, ensuring sustainability [121].

Research conducted by Thompson et al. indicated that firms with strong safety cultures achieve a decrease of up to 30% in workplace mishaps and notable enhancements in employee retention. In contrast, effective risk mitigation measures improve operational efficiency by 25% and promote sustainable practices [120].

Advances in safety training: technology and leadership integration

The industrial sector has historically depended on intricate technology, perilous substances, and extensive operations, all of which heighten the risk of worker accidents. Workplace accidents cause human harm, productivity loss, and equipment damage, often resulting in substantial financial and operational losses. Consequently, corporations have progressively allocated resources to Advanced Safety Leadership Training Programs (ASLTPs) to mitigate safety hazards and ensure dependable assets [122].

A safety-first mentality among managers and staff, risk minimization, effective communication, hazard detection, and continuous improvement are the goals of advanced safety leadership. These programs' leadership is crucial because safety leaders' actions and attitudes affect safety culture [123]. A full, accurate, and exhaustive assessment of an organization's occurrences and accidents is essential for sustainability, safety, and low incident rates [124]. Islam et al. [125] found that human errors cause 80% of occupational accidents.

Because safety leadership promotes a culture that places a high priority on accident prevention and motivates staff to adhere to safety procedures, it is essential in lowering workplace accidents. Supervisors, managers, and executives can lead and guarantee a strong safety culture across the company with the help of Advanced Safety Leadership Training Programs (ASLTPs) [126]. Research has demonstrated a correlation between reduced injury rates and fewer near-miss accidents in industrial settings and excellent safety leadership. To increase workplace safety, it is crucial to have efficient safety supervision and to encourage people to have positive safety attitudes [127].

By improving communication between employees and management, ASLTPs help to reduce accidents by making sure any dangers are identified early and dealt with before they cause accidents. In order to assist leaders in recognizing risky behaviors and taking proactive measures to address them, behavioral safety strategies are frequently incorporated into leadership training [128]. ASLTPs' emphasis on proactive risk management promotes a preventative strategy, which lowers workplace accidents and fosters cultures where staff members feel empowered to raise concerns about possible hazards.

Innovative tools and techniques

It is important to use advanced technologies with safety leadership training, such as predictive maintenance through IoT. LoT sensors monitor parameters in real-time, allowing safety leaders to proactively address maintenance needs [129]. Moreover, Digital Twin Technology, virtual replicas of physical assets, is used to simulate operations and predict potential failures [130]. While Automated Alerts for Safety Protocols, IoT-enabled equipment has the ability to automatically inform safety leaders about the operational parameters deviations [129].

Additional technologies, such as virtual reality and augmented reality, are used in safety leadership training to replicate real-world situations [131]. Additionally, IoT sensor data can be analyzed by AI-Powered Predictive Maintenance Platforms to better accurately identify faults [132]. Another example is the growing use of gamification techniques in the instruction of safety and reliability concepts [133]. Future studies should focus on improving these systems to take into account new technology and customize them to fit the unique requirements of high-risk businesses.

Barriers and challenges to sustainable safety training implementation

A literature review reveals that effective safety management systems (SMSs) implementation in construction, particularly small and medium-scale projects in India, is hindered by financial constraints, cultural resistance, training deficiencies, and regulatory gaps [134]. These issues are prevalent in both developed and developing nations, with resource scarcity being most evident in small construction and industrial enterprises [135].

Empirical studies confirm the link between structured safety practices and improved safety performance, with safety knowledge and motivation significantly mediating the relationship between SMS practices and worker safety behavior. However, Indian SMEs often lack resources and awareness for SMS adoption,

emphasizing the need for strong management commitment and employee engagement [136].

Studies on SMSs in small construction sites in India have shown that barriers to implementation can hinder safety performance. OHSAS 18001, ISO 9001, and non-certified firms score highest in safety practices and behavior, with enforcement of safety rules being a common predictor. Effective SMS use is linked to a high safety culture, but weak justice elements exist [137]. Industrial safety in India faces high death/injury rates, and SMEs lack resources/awareness to implement SMS effectively. Top management commitment and employee engagement are critical, and predictive models, safety intelligence, and sensor-based systems can enhance performance [138].

Cultural impacts on safety performance have also been examined, with cultural differences affecting the perception and adoption of SMS [139]. Cost uncertainty and poor risk management are critical barriers to both SMS and project success in construction [140].

Conclusion

Workplace injuries have effects that extend far beyond the day of the accident. Elevated mortality risks can persist for years and are shaped by worker demographics, industry conditions, organizational safety climates, and access to care.

The large differences observed across regions, industries, and populations indicate opportunities for targeted prevention and support. Migrant workers, older employees, and those in high-risk industries are particularly vulnerable and should be central to policymaking efforts.

Overall, workplace safety policies must broaden their scope to prevent accidents and ensure quality post-injury care, effective return-to-work systems, and long-term health monitoring.

Conflict of interests

The authors declare that there is no conflict of interest regarding the publication of this article.

Funding

None.

Consent for participate

Not applicable.

Ethical Approval

Not applicable

Author details

Wael Mohamed Suleiman[1], Ahmed Mustafa El-Shiekh Idrees[2], Amer Atta Almanan Mohammed Haroun[3]

1. Orthopedic General Practitioner, Care Medical Hospital, Riyadh, Saudi Arabia
2. Emergency Department, Care Medical Hospital, Riyadh, Saudi Arabia
3. Resident, Care Medical Hospital, Riyadh, Saudi Arabia

References

1. Bilir N. Occupational safety and health profile: Turkey. ILO; 2016.
2. Hunegnaw B, Molla M, Mulugeta Y, Meseret M. Assessment of Occupational Injury among Industrial Workers in the Bahir Dar City of Northwest Ethiopia: institution-Based Cross-Sectional Study. J Environ Public Health. 2021;2021:1–8. https://doi.org/10.1155/2021/2793053
3. Prammer-Waldhör MKJ. Jahrbuch der Gesundheitsstatistik. 2021. Available from: https://www.statistik.at/fileadmin/user_upload/Gesundheitsstatistik-JB_2021_Web-barrierefrei.pdf
4. Citaristi I. International labour organization - ILO. In The Europa directory of international organizations 2022. Routledge; 2022. pp 343 -9.
5. Ambegaonkar R. The importance of safety on construction sites. 2020;7:2021.
6. Kemei R, Kaluli JW, Kabubo C. Common construction site hazards in Nairobi County, Kenya. Am J Const Build Mater. 2017;1(1):26 -33.
7. Nenonen N, Saarela KL, Takala J, Kheng LG, Yong E, Ling LS, et al. Global estimates of occupational accidents and work-related illnesses. 2014.
8. Yosef T, Sineshaw E, Shifera N. Occupational injuries and contributing factors among industry park construction workers in Northwest Ethiopia. Front Public Heal. 2022;10:1060755. https://doi.org/10.3389/fpubh.2022.1060755
9. Statistics B of L. EMPLOYEE TENURE IN 2020. 2020. Available from: http://www.bls.gov/cps
10. Debela MB, Azage M, Begosaw AM, Kabeta ND. Factors contributing to occupational injuries among workers in the construction, manufacturing, and mining industries in Africa: a systematic review and meta-analysis. J Public Health Policy. 2022;43(4):487–502. https://doi.org/10.1057/s41271-022-00378-2
11. Ilić Krstić I, Avramović D, Živković S. Occupational injuries in underground coal mining in Serbia: a case study. Work. 2021;69(3):815–25. https://doi.org/10.3233/WOR-213514
12. Clar C, Koutp A, Leithner A, Leitner L, Puchwein P, Vielgut I, et al. Occupational injuries in orthopedic and trauma surgeons in Austria. Arch Orthop Trauma Surg. 2024;144(3):1171–8. https://doi.org/10.1007/s00402-024-05200-0
13. Catanzarite T, Tan-Kim J, Whitcomb EL, Menefee S. Ergonomics in Surgery: a Review. Female Pelvic Med Reconstr Surg. 2018;24(1):1–2. https://doi.org/10.1097/SPV.0000000000000456

14. Strony KCKR. Needlestick. StatPearls [Internet]. 2023; Available from: https://www.ncbi.nlm.nih.gov/books/NBK493147/
15. Epstein S, Sparer EH, Tran BN, Ruan QZ, Dennerlein JT, Singhal D, et al. Prevalence of Work-Related Musculoskeletal Disorders Among Surgeons and Interventionalists. JAMA Surg. 2018;153(2):e174947. https://doi.org/10.1001/jamasurg.2017.4947
16. Verbeek J, Basnet P. Incidence of sharps injuries in surgical units, a meta-analysis and meta-regression. Am J Infect Control. 2019;47(4):448–55. https://doi.org/10.1016/j.ajic.2018.10.003
17. Wolf J. Ivanov I., Mudgal S., Corvalán C., Bos R., Neira M. PUA. Preventing disease through a healthier and safer workplace. World Health Organization, Geneva, Switzerland; 2018.
18. Călugăreanu V. Knowledge, attitudes, and practices of the population regarding viral Hepatitis B and C worldwide: a systematic literature review. Mold J Heal Sci. 2024;11(2):52–61. https://doi.org/10.52645/MJHS.2024.2.07
19. Chan CC, Faherty C, Rahman N, Murrough JW, Benn EKT, Clark U, et al. Suicidal ideation among non-physician hospital system staff: prevalence and workplace correlates. J Affect Disord. 2024;362:638–44. https://doi.org/10.1016/j.jad.2024.07.109
20. Mekkodathil A, El-Menyar A, Al-Thani H. Occupational injuries in workers from different ethnicities. Int J Crit Illn Inj Sci. 2016;6(1):25–32. https://doi.org/10.4103/2229-5151.177365
21. Murray CJL, Aravkin AY, Zheng P, Abbafati C, Abbas KM, Abbasi-Kangevari M, et al. Global burden of 87 risk factors in 204 countries and territories, 1990-2019: a systematic analysis for the Global Burden of Disease Study 2019. Lancet. 2020;396(10258):1223–49. https://doi.org/10.1016/S0140-6736(20)30752-2
22. Jadoon S, Nawazish S, Mahmood Q, Rafique A, Sohail S, Zaidi A. Exploring health impacts of occupational exposure to carbon monoxide in the labour community of Hattar Industrial Estate. Atmos (Basel). 2022;13(3):406. https://doi.org/10.3390/atmos13030406
23. World Health Organization. .Charter health worker safety: a priority for patient safety. World Health Organization, Geneva, Switzerland; 2020;
24. Dang S. Workplace Eye Injuries by the Numbers - Infographic. Am Acad Ophthalmol [Internet]. 2014; Available from: https://www.aao.org/eye-health/tips-prevention/infographic-eye-injuries-at-work
25. Tadesse S, Israel D. Occupational injuries among building construction workers in Addis Ababa, Ethiopia. J Occup Med Toxicol. 2016;11(1):16. https://doi.org/10.1186/s12995-016-0107-8
26. Gebremeskel TG, Yimer T. Prevalence of occupational injury and associated factors among building construction workers in Dessie town, Northeast Ethiopia. BMC Res Notes. 2019;12(1):481. https://doi.org/10.1186/s13104-019-4436-4
27. Martin AT, Mcclure ES, Ranapurwala SI, Nocera M, Cantrell J, Marshall SW, et al. Fatal occupational injuries in North Carolina, 1992-2017. Occup Environ Med. 2023;80(12):680–6. https://doi.org/10.1136/oemed-2023-109050
28. Sau A, Phadikar S, Bhakta I, Chatterjee A. Global and Indian Scenarios of Fatal and Non-fatal Occupational Injuries: a Secondary Data Analysis. Indian J Occup Environ Med. 2024;28(4):282–7. https://doi.org/10.4103/ijoem.ijoem_275_23
29. Richey MM, Golightly Y, Marshall SW, Novicoff W, Keil AP, Nocera M, et al. Trends in fatal occupational injuries in Latino/a workers relative to other groups, North Carolina 2000-2017. Am J Ind Med. 2022;65(4):242–7. https://doi.org/10.1002/ajim.23331
30. Richey MM, Golightly Y, Marshall SW, Novicoff W, Keil A, Nocera M, et al. Trends in fatal occupational injury rates among older workers before and after the Great Recession of 2008. Occup Environ Med. 2023;80(3):154–9. https://doi.org/10.1136/oemed-2022-108587
31. Wu Y, Schwebel DC, Hu G. Disparities in Unintentional Occupational Injury Mortality between High-Income Countries and Low- and Middle-Income Countries: 1990-2016. Int J Environ Res Public Health. 2018;15(10):2296. https://doi.org/10.3390/ijerph15102296
32. Takala J, Hämäläinen P, Sauni R, Nygård CH, Gagliardi D, Neupane S. Global-, regional-and country-level estimates of the work-related burden of diseases and accidents in 2019. Scand J Work Environ Heal. 2019;50(2):73–82. https://doi.org/10.5271/sjweh.4132
33. Gouda D, Singh PM, Gouda P, Goudra B. An Overview of Health Care Worker Reported Deaths During the COVID-19 Pandemic. J Am Board Fam Med. 2021;34:S244–6. https://doi.org/10.3122/jabfm.2021.S1.200248
34. Antonangeli LM, Sbrissa LPE, Casali MB, Bonzini M. Two decades of fatal workplace accidents in Milan and Monza, Italy: trends, Work Sectors, and Causes from Autoptic Data. Med Del Lav. 2024;115(4):5. https://doi.org/10.23749/mdl.v115i4.15872
35. Yadigaroğlu M, Yanik HT, Durmus A, Ocak M, Yücel M, Güzel M. Occupational accidents and injuries: clinical experiences of a tertiary hospital. Intercont J Emerg Med. 2023;1(4):87–91. https://doi.org/10.51271/ICJEM-0022
36. Çağlar A, Kaçer I, Hacımustafaoğlu M, Öztürk B, Öztürk S, Belgin Akıllı N. Factors Related to Mortality in Occupational Injuries: five-Year Experience. Eurasian J Emergency Med. 2022;21(1):20–7. https://doi.org/10.4274/eajem.galenos.2020.80378
37. Jung S, Kim TK, Kim YJ, Kim YK, Kang D, Kim SY. Epidemiology of occupational injuries in construction workers between 2009 and 2018 in South Korea. Am J Ind Med. 2023;66(2):155–66. https://doi.org/10.1002/ajim.23448

38. Denault D, Gardner H. OSHA Bloodborne pathogen standards. StatPearls, Treasure Island (FL); 2025.
39. Lai J, Li X, Liu W, Liufu Q, Zhong C. Global, regional and national burdens of occupational injuries, 1990-2019: a systematic analysis for the Global Burden of Disease Study 2019. Inj Prev. 2025;31(1):52–9. https://doi.org/10.1136/ip-2023-045149
40. Gubernot DM, Anderson GB, Hunting KL. Characterizing occupational heat-related mortality in the United States, 2000-2010: an analysis using the census of fatal occupational injuries database. Am J Ind Med. 2015;58(2):203–11. https://doi.org/10.1002/ajim.22381
41. Rommel A, Varnaccia G, Lahmann N, Kottner J, Kroll LE. Occupational Injuries in Germany: population-Wide National Survey Data Emphasize the Importance of Work-Related Factors. PLoS One. 2016;11(2):148798. https://doi.org/10.1371/journal.pone.0148798
42. Alamneh YM, Wondifraw AZ, Negesse A, Ketema DB, Akalu TY. The prevalence of occupational injury and its associated factors in Ethiopia: a systematic review and meta-analysis. J Occup Med Toxicol. 2020;15(1):14. https://doi.org/10.1186/s12995-020-00265-0
43. Paglione L, Angelici L, Davoli M, Agabiti N, Cesaroni G. Mortality inequalities by occupational status and type of job in men and women: results from the Rome Longitudinal Study. BMJ Open. 2020;10(6):33776. https://doi.org/10.1136/bmjopen-2019-033776
44. ILO. The impact of care responsibilities on women's labour force participation.
45. Martin CJ, Jin C, Bertke SJ, Yiin JH, Pinkerton LE. Increased overall and cause-specific mortality associated with disability among workers' compensation claimants with low back injuries. Am J Ind Med. 2020;63(3):209–17. https://doi.org/10.1002/ajim.23083
46. Dang G, Marsh S, Victoroff T, Hale C, Watson J, Moller K, et al. Descriptive summary of fatal work-related injuries, Western States, 2011-2017. J Occup Environ Hyg. 2024;21(3):189–201. https://doi.org/10.1080/15459624.2024.2302470
47. Melchior C, Zanini RR. Mortality per work accident: a literature mapping. Saf Sci. 2019;114:72–88. https://doi.org/10.1016/j.ssci.2019.01.001
48. Lau K, Aldridge R, Norredam M, Mkoma GF, Kugan M, Lin RCY, et al. Workplace mortality risk and social determinants among migrant workers: a systematic review and meta-analysis. Lancet Public Heal. 2024;9(11):e935–949. https://doi.org/10.1016/S2468-2667(24)00226-3
49. Lee JY, Cho SI. Prohibition on Changing Workplaces and Fatal Occupational Injuries among Chinese Migrant Workers in South Korea. Int J Environ Res Public Health. 2019;16(18):3333. https://doi.org/10.3390/ijerph16183333
50. Abdalla S, Apramian SS, Cantley LF, Cullen MR. Occupation and risk for injuries. In: Mock CN, Nugent R, Kobusingye O, Smith KR, editors. Injury prevention and environmental health. 3rd ed. Washington, (DC): The International Bank for Reconstruction and Development / The World Bank; 2017. Vol. pp 97 -132.
51. Alruwaili M, Carrillo P, Soetanto R, Munir F. Occupational Accidents, Injuries, and Associated Factors among Migrant and Domestic Construction Workers in Saudi Arabia. Buildings. 2024;14(9):2714. https://doi.org/10.3390/buildings14092714
52. Bochen Cao by SGHJMFDCGSBMD et al. Global Health Estimates. WHO [Internet]. [cited 2025 Oct 9]; Available from: https://www.who.int/data/global-health-estimates
53. Martin CJ, Woods S, Bertke S, Pinkerton L, Jin C. Increased Mortality Associated With Disability Among Workers' Compensation Claimants With Upper Extremity Neuropathy. J Occup Environ Med. 2023;65(9):798–802. https://doi.org/10.1097/JOM.0000000000002910
54. Boden LI, O'Leary PK, Applebaum KM, Tripodis Y. The impact of non-fatal workplace injuries and illnesses on mortality. Am J Ind Med. 2016;59(12):1061–9. https://doi.org/10.1002/ajim.22632
55. Applebaum KM, Asfaw A, O'Leary PK, Busey A, Tripodis Y, Boden LI. Suicide and drug-related mortality following occupational injury. Am J Ind Med. 2019;62(9):733–41. https://doi.org/10.1002/ajim.23021
56. Busey A, Asfaw A, Applebaum KM, O'Leary PK, Tripodis Y, Fox MP, et al. Mortality following workplace injury: quantitative bias analysis. Ann Epidemiol. 2021;64:155–60. https://doi.org/10.1016/j.annepidem.2021.09.015
57. Boden LI, Asfaw A, O'Leary PK, Tripodis Y, Busey A, Applebaum KM, et al. Opioid-related mortality after occupational injury in Washington State: accounting for preinjury opioid use. Occup Environ Med. 2024;81(10):515–21. https://doi.org/10.1136/oemed-2024-109606
58. Alif SM, Benke GP, Kromhout H, Vermeulen R, Tran C, Ronaldson K, et al. Long-term occupational exposures on disability-free survival and mortality in older adults. Occup Med (Chic Ill). 2023;73(8):492–9.
59. Breslin FC, Dollack J, Mahood Q, Maas ET, Laberge M, Smith PM. Are new workers at elevated risk for work injury? A systematic review. Occup Environ Med. 2019;76(9):694–701. https://doi.org/10.1136/oemed-2018-105639
60. Alsabaani A, Alqahtani NSS, Alqahtani SSS, Al-Lugbi JHJ, Asiri MAS, Salem SEE, et al. Incidence, Knowledge, Attitude and Practice Toward Needle Stick Injury Among Health Care Workers in Abha City, Saudi Arabia. Front Public Heal. 2022;10:45. https://doi.org/10.3389/fpubh.2022.771190
61. Hendricks KJ, Hendricks SA, Marsh SM. Workplace Injury and Death: a National Overview of Changing Trends by Sex, United States 1998-2022. Am J Ind

Med. 2025;68(2):194–201. https://doi.org/10.1002/ajim.23687

62. Wightman A, Gawaziuk JP, Spiwak R, Burton L, Comaskey B, Chateau D, et al. Workplace Injury and Mental Health Outcomes [Internet]. JAMA Netw Open. 2025;8(2):e2459678. Available from: https://jamanetwork.com/journals/jamanetworkopen/fullarticle/2830225
63. Boden LI, Asfaw A, Busey A, Tripodis Y, O'Leary PK, Applebaum KM, et al. Increased all-cause mortality following occupational injury: a comparison of two states. Occup Environ Med. 2022;79(12):816–23. https://doi.org/10.1136/oemed-2022-108481
64. Takala J, Hämäläinen P, Saarela KL, Yun LY, Manickam K, Jin TW, et al. Global Estimates of the Burden of Injury and Illness at Work in 2012. J Occup Environ Hyg. 2014;11(5):326–37. https://doi.org/10.1080/15459624.2013.863131
65. Forst L, Friedman L, Hebert-Beirne J, Holloway-Beth A, Madigan & D, Swedler D. Illinois Occupational Surveillance Program: 2015-2021. 2021;
66. Abedzadeh-Kalahroudi M, Razi E, Sehat M, Asadi-Lari M. Return to work after trauma: a survival analysis. Chin J Traumatol. 2017;20(2):67–74. https://doi.org/10.1016/j.cjtee.2016.03.008
67. Tournier C, Charnay P, Tardy H, Chossegros L, Carnis L, Hours M. A few seconds to have an accident, a long time to recover: consequences for road accident victims from the ESPARR cohort 2 years after the accident. Accid Anal Prev. 2014;72:422–32. https://doi.org/10.1016/j.aap.2014.07.011
68. Tamene A, Habte A, Derilo HT, Endale F, Gizachew A, Sulamo D, et al. Time to Return to Work After an Occupational Injury and Its Prognostic factors Among Employees of Large-Scale Metal Manufacturing Facilities in Ethiopia: a Retrospective Cohort. Environ Health Insights. 2022;16:24. https://doi.org/10.1177/11786302221109372
69. Hisasue T, Kruse M, Raitanen J, Paavilainen E, Rissanen P. Quality of life, psychological distress and violence among women in close relationships: a population-based study in Finland. BMC Womens Health. 2020;20(1):85. https://doi.org/10.1186/s12905-020-00950-6
70. Shabani S, Moen BE, Deressa W, Mamuya SH. Prevalence of occupational injuries among workers in the iron and steel industries in Tanzania. Ann Glob Heal. 2025;91(1):21. https://doi.org/10.5334/aogh.4503
71. Murray CJL, Ortblad KF, Guinovart C, Lim SS, Wolock TM, Roberts DA, et al. Global, regional, and national incidence and mortality for HIV, tuberculosis, and malaria during 1990-2013: a systematic analysis for the Global Burden of Disease Study 2013. Lancet. 1990;384(9947):1005–70. https://doi.org/10.1016/S0140-6736(14)60844-8
72. Tessier-Sherman B, Cantley LF, Galusha D, Slade MD, Taiwo OA, Cullen MR. Occupational injury risk by sex in a manufacturing cohort. Occup Environ Med. 2014;71(9):605–10. https://doi.org/10.1136/oemed-2014-102083
73. Biswas A, Harbin S, Irvin E, Johnston H, Begum M, Tiong M, et al. Differences between men and women in their risk of work injury and disability: a systematic review. Am J Ind Med. 2022;65(7):576–88. https://doi.org/10.1002/ajim.23364
74. Elrud R, Friberg E, Alexanderson K, Stigson H. Sickness absence, disability pension and permanent medical impairment among 64 000 injured car occupants of working ages: a two-year prospective cohort study. Accid Anal Prev. 2019;127:35–41. https://doi.org/10.1016/j.aap.2019.02.019
75. Kjeldgård L, Ohlin M, Elrud R, Stigson H, Alexanderson K, Friberg E. Bicycle crashes and sickness absence - a population-based Swedish register study of all individuals of working ages. BMC Public Health. 2019;19(1):943. https://doi.org/10.1186/s12889-019-7284-1
76. Uleberg O, Pape K, Kristiansen T, Romundstad PR, Klepstad P. Population-based analysis of the impact of trauma on longer-term functional outcomes. J Br Surg. 2019;106(1):65–73. https://doi.org/10.1002/bjs.10965
77. Von Oelreich E, Eriksson M, Brattström O, Discacciati A, Strömmer L, Oldner A, et al. Post-trauma morbidity, measured as sick leave, is substantial and influenced by factors unrelated to injury: a retrospective matched observational cohort study. Scand J Trauma Resusc Emerg Med. 2017;25(1):100. https://doi.org/10.1186/s13049-017-0444-3
78. Chu PC, Chin WS, Guo YL, Shiao JSC. Long-Term Effects of Psychological Symptoms after Occupational Injury on Return to Work: a 6-Year Follow-Up. Int J Environ Res Public Health. 2019;16(2):235. https://doi.org/10.3390/ijerph16020235
79. Nota SPFT, Bot AGJ, Ring D, Kloen P. Disability and depression after orthopaedic trauma. Injury. 2015;46(2):207–12. https://doi.org/10.1016/j.injury.2014.06.012
80. Bryant RA. Post-traumatic stress disorder: a state-of-the-art review of evidence and challenges. World Psychiatry. 2019;18(3):259–69. https://doi.org/10.1002/wps.20656
81. Lin KH, Shiao JSC, Guo NW, Liao SC, Kuo CY, Hu PY, et al. Long-Term Psychological Outcome of Workers After Occupational Injury: prevalence and Risk Factors. J Occup Rehabil. 2014;24(1):1–10. https://doi.org/10.1007/s10926-013-9431-3
82. Margetis K, Das JM, Emmady PD. Spinal cord injuries. In StatPearls [Internet]. StatPearls Publishing; 2025.
83. WHO. "Burns." 2024. Available from: https://www.who.int/news-room/fact-sheets/detail/burns
84. Panayi AC, Heyland DK, Stoppe C, Jeschke MG, Didzun O, Matar D, et al. The long-term intercorrelation between post-burn pain, anxiety, and depression: a post hoc analysis of the "RE-ENERGIZE" double-blind, randomized, multicenter

placebo-controlled trial. Crit Care. 2024;28(1):95. https://doi.org/10.1186/s13054-024-04873-8

85. Bhavan T. The economic impact of road accidents: the case of Sri Lanka. South Asia Econ J. 2019;20(1):124–37. https://doi.org/10.1177/1391561418822210
86. Varianou-Mikellidou C, Boustras G, Dimopoulos C, Wybo JL, Guldenmund FW, Nicolaidou O, et al. Occupational health and safety management in the context of an ageing workforce. Saf Sci. 2019;116:231–44. https://doi.org/10.1016/j.ssci.2019.03.009
87. Granger S, Turner N. Work injuries and mental health challenges: a meta-analysis of the bidirectional relationship. Pers Psychol. 2025;78(1):11–57. https://doi.org/10.1111/peps.12649
88. Kleist N, Bjarnesen J. Mediating mobility in West Africa: Improvisation, culture, and volatility in migration infrastructures. Int Migr Rev. 2025;59(4):1747-71. https://doi.org/10.1177/01979183231205563
89. Qi Z. An Overview of Rural to Urban Migration in China and Social Challenges [Internet]. Migr Lett Internet. 2019;16(2):273–82. Available from: https://migrationletters.com/index.php/ml/article/view/664
90. Rast E, Lau K, Lin RCY, Loganathan T, Hargreaves S, Zimmerman C. Healthcare services for low-wage migrant workers: a systematic review. Soc Sci Med. 2025;380:118176. https://doi.org/10.1016/j.socscimed.2025.118176
91. Weir J, Fary R, Gibson M, Mitchell T, Johnston V, Wyatt M, et al. Wellbeing After Finalization of a Workers' Compensation Claim: a Systematic Scoping Review. J Occup Rehabil. 2024;34(4):717–39. https://doi.org/10.1007/s10926-023-10168-6
92. King TL, Disney G, Sutherland G, Kavanagh A, Spittal MJ, Simons K. Associations between workers' compensation and self-harm: a retrospective case-series study of hospital admissions data [Internet]. Lancet Reg Heal - West Pacific. 2019;30:31. https://doi.org/10.1016/j.lanwpc.2022.100614
93. Kyung M, Lee SJ, Dancu C, Hong O. Underreporting of workers' injuries or illnesses and contributing factors: a systematic review. BMC Public Health. 2023;23(1):558. https://doi.org/10.1186/s12889-023-15487-0
94. Qiu N, Jiang Y, Sun Z, Du M. The impact of disability-related deprivation on employment opportunity at the neighborhood level: does family socioeconomic status matter?. Front Public Heal. 2023;11:4. https://doi.org/10.3389/fpubh.2023.1232829
95. Tompa E, Mofidi A, Van Den Heuvel S, Van Bree T, Michaelsen F, Jung Y, et al. Economic burden of work injuries and diseases: a framework and application in five European Union countries. BMC Public Health. 2021;21(1):49. https://doi.org/10.1186/s12889-020-10050-7
96. Australia SW. The cost of work-related injury and illness for Australian employers, workers and the community: 2012 - 13. Canberra: Safe Work Australia; 2015;44.
97. Elsler D, Takala J, Remes J. An international comparison of the cost of work-related accidents and illnesses. European Agency for Safety and Health at Work. 2017.
98. Kearns RD, Bettencourt AP, Hickerson WL, Palmieri TL, Biddinger PD, Ryan CM, et al. Actionable, Revised (v.3), and Amplified American Burn Association Triage Tables for Mass Casualties: a Civilian Defense Guideline. J Burn Care Res. 2020;41(4):770. https://doi.org/10.1093/jbcr/iraa050
99. Debela MB, Azage M, Deyessa N, Begosaw AM. Economic costs and Predictors of occupation-related Injuries in Ethiopian sugar industries from the Employer's perspective: top-down approach and friction method. BMC Public Health. 2022;22(1):2103. https://doi.org/10.1186/s12889-022-14519-5
100. Kaur H, Wurzelbacher SJ, Bushnell PT, Bertke S, Meyers AR, Grosch JW, et al. Occupational Injuries Among Construction Workers by Age and Related Economic Loss: findings From Ohio Workers' Compensation, USA: 2007-2017. Saf Health Work. 2023;14(4):406–14. https://doi.org/10.1016/j.shaw.2023.10.003
101. Etuknwa A, Daniels K, Eib C. Sustainable Return to Work: a Systematic Review Focusing on Personal and Social Factors. J Occup Rehabil. 2019;29(4):679–700. https://doi.org/10.1007/s10926-019-09832-7
102. Carlsson L, Lytsy P, Anderzén I, Hallqvist J, Wallman T, Gustavsson C. Motivation for return to work and actual return to work among people on long-term sick leave due to pain syndrome or mental health conditions. Disabil Rehabil. 2019;41(25):3061–70. https://doi.org/10.1080/09638288.2018.1490462
103. Benson C, Obasi IC, Akinwande DV, Ile C. The impact of interventions on health, safety and environment in the process industry. Heliyon. 2024;10(1):e23604. https://doi.org/10.1016/j.heliyon.2023.e23604
104. García-Mainar I, Montuenga VM. Risk self-perception and occupational accidents. J Saf Res. 2024;88:135–44. https://doi.org/10.1016/j.jsr.2023.11.001
105. Guerin RJ, Sleet DA. Using Behavioral Theory to Enhance Occupational Safety and Health: applications to Health Care Workers. Am J Lifestyle Med. 2021;15(3):269–78. https://doi.org/10.1177/1559827619896979
106. Haq IUH. Beyond safety outcomes: impact of safety culture on workers' engagement while using safety climate as a mediator. NUST Bus Rev. 2023;4(2):13. https://doi.org/10.37435/NBR22102001
107. Steege AL, Baron SL, Marsh SM, Menéndez CC, Myers JR. Examining occupational health and safety disparities using national data: a cause for continuing concern. Am J Ind Med. 2014;57(5):527–38. https://doi.org/10.1002/ajim.22297
108. Kelvin Achi Mobosi. The impact of workplace safety training programs on reducing occupational

hazards in high-risk industries. World J Adv Res Rev. 2025;25(3):753–6. https://doi.org/10.30574/wjarr.2025.25.3.0712

109. Zwetsloot G, Schmitt-Howe B, Nielsen KT. Success factors for OSH implementation. Opening the black box of OSH realisation. Policy Pract Heal Saf. 2020;18(2):196–210. https://doi.org/10.1080/14773996.2020.1786994
110. Vitrano G, Micheli GJL. Effectiveness of Occupational Safety and Health interventions: a long way to go. Front Public Heal. 2024;12:16. https://doi.org/10.3389/fpubh.2024.1292692
111. Ada YR, Surono A, Supriyati S, Pribadi AP. Strategies to improve compliance with personal protective equipment use in the textile industry: a scoping review. BMC Public Health. 2025;25(1):2743. https://doi.org/10.1186/s12889-025-24037-9
112. Sámano-Ríos ML, Ijaz S, Ruotsalainen J, Breslin FC, Gummesson K, Verbeek J. Occupational safety and health interventions to protect young workers from hazardous work - A scoping review [Internet]. Saf Sci. 2019;116754160:15. Available from: https://api.semanticscholar.org/CorpusID:116754160
113. Vitrano G, Micheli GJL, Guglielmi A, De Merich D, Pellicci M, Urso D, et al. Sustainable occupational safety and health interventions: a study on the factors for an effective design. Saf Sci. 2023;166:106249. https://doi.org/10.1016/j.ssci.2023.106249
114. Von Thiele Schwarz U, Nielsen K, Edwards K, Hasson H, Ipsen C, Savage C, et al. How to design, implement and evaluate organizational interventions for maximum impact: the Sigtuna Principles. Eur J Work Organ Psychol. 2021;30(3):415–27. https://doi.org/10.1080/1359432X.2020.1803960
115. Sultan-Taïeb H, Parent-Lamarche A, Gaillard A, Stock S, Nicolakakis N, Hong QN, et al. Economic evaluations of ergonomic interventions preventing work-related musculoskeletal disorders: a systematic review of organizational-level interventions. BMC Public Health. 2017;17(1):935. https://doi.org/10.1186/s12889-017-4935-y
116. Kateman E, Verbeek JH, Morata T, Coolsma B, Dreschler W, Sorgdrager B. Interventions to prevent occupational noise-induced hearing loss. Cochrane Database Syst Rev. 2017;7(7):CD006396. https://doi.org/10.1002/14651858.CD006396.pub4
117. CannAmm CA. Key elements of a health and safety. 2023. Available from: https://www.cannamm.com/blog-and-opinions/the-key-elements-of-a-health-and-safety-program/
118. Effective an. Key Elements of an Effective Worker Safety Program. Cole Fisher Cole O'Keefe + Mahoney. 2023.
119. Gingerlane. Key components of successful workplace safety training programs - ignite human resources. 2024. Available from: https://ignitehumanresources.com/key-components-of-successful-workplace-safety-training-programs/
120. Ying M, Allaqtta MAM. The impact of safety culture, risk mitigation, and sustainability on business performance: the mediating role of employee engagement in palestinian small and medium-sized enterprises. Sustainability. 2025;17(10):4361. https://doi.org/10.3390/su17104361
121. Kantabutra S. Research on corporate sustainability. MDPI. 2023. https://doi.org/10.3390/books978-3-0365-8378-5
122. Naji GMA, Isha ASN, Alazzani A, Saleem MS, Alzoraiki M. Assessing the mediating role of safety communication between safety culture and employees safety performance. Front Public Heal. 2022;10:840281. https://doi.org/10.3389/fpubh.2022.840281
123. Samarasinghe H, Heenatigala S. Insights from the field: a comprehensive analysis of industrial accidents in plants and strategies for enhanced workplace safety. Open J Saf Sci Technol. 2024;14(01):1–6. https://doi.org/10.4236/ojsst.2024.141001
124. Blokland P, Reniers G. Safety science, a systems thinking perspective: from events to mental models and sustainable safety. Sustainability. 2020;12(12):5164. https://doi.org/10.3390/su12125164
125. Islam R, Khan F, Abbassi R, Garaniya V. Human error probability assessment during maintenance activities of marine systems. Saf Health Work. 2018;9(1):42–52. https://doi.org/10.1016/j.shaw.2017.06.008
126. Sujan MA, Huang H, Braithwaite J. Learning from incidents in health care: critique from a Safety-II perspective. Saf Sci. 2017;99:115–21. https://doi.org/10.1016/j.ssci.2016.08.005
127. Basahel AM. Safety Leadership, Safety Attitudes, Safety Knowledge and Motivation toward Safety-Related Behaviors in Electrical Substation Construction Projects. Int J Environ Res Public Health. 2021;18(8):4196. https://doi.org/10.3390/ijerph18084196
128. Patrick Olise, Lois Kumiwaa Opoku, Nicholas Mensah. The impact of advanced safety leadership training programs on reducing workplace accidents and enhancing asset reliability in U.S. industrial sectors. Int J Sci Res Arch. 2025;14(1):25–33. https://doi.org/10.30574/ijsra.2025.14.1.2594
129. Soori M, Arezoo B, Dastres R. Internet of things for smart factories in industry 4.0, a review. Internet Things Cyber-Physical Syst. 2023;3:192–204. https://doi.org/10.1016/j.iotcps.2023.04.006
130. Attaran M, Celik BG. Digital Twin: benefits, use cases, challenges, and opportunities. Decis Anal J. 2023;6:100165. https://doi.org/10.1016/j.dajour.2023.100165
131. Lampropoulos G, Fernández-Arias P, Antón-Sancho A, Vergara D. Examining the role of augmented reality and virtual reality in safety training. Electronics. 2024;13(19):3952. https://doi.org/10.3390/electronics13193952

132. Seng KP, Ang LM, Ngharamike E. Artificial intelligence Internet of Things: A new paradigm of distributed sensor networks. Int J Distrib Sens Networks. 2022;18(3):155014772110628-155014772110628. https://doi.org/10.1177/15501477211062835

133. Zainuddin Z, Chu SKW, Shujahat M, Perera CJ. The impact of gamification on learning and instruction: a systematic review of empirical evidence. Educ Res Rev. 2020;30:100326. https://doi.org/10.1016/j.edurev.2020.100326

134. Simon D, Paul VK, Dua S, Kumar K. Fire risk analysis for construction sites. Int J Archit Des Manag. 2022; 5(1):15–31. https://doi.org/10.37628/.v5i1.872

135. Guerra BC, Leite F. Circular economy in the construction industry: an overview of United States stakeholders' awareness, major challenges, and enablers. Resour Conserv Recycl. 2021;170:105617. https://doi.org/10.1016/j.resconrec.2021.105617

136. Kartal G, Bayramoğlu G. The safety management system (SMS) as a tool for building safety culture in aviation: a qualitative research. J Aviat. 2024;8(3):315–24. https://doi.org/10.30518/jav.1493642

137. Murugasamy M, Sakthivel M, Shanmugam VI. Study on barriers in the implementation of safety management system in construction projects. In AIP Conference Proceedings, AIP Publishing LLC; 2020. Vol. 2240(1), p. 040002.

138. K SS. Improving industrial safety in India: the need for effective safety management systems and employee engagement. 2023. Available from: https://www.researchgate.net/publication/370072788

139. Sharma A. Barriers to effective implementation of safety management systems in small construction sites . 2025. Available from: https://www.researchgate.net/publication/394812622

140. Saini A, Khursheed S, Paul VK, Verma K. Analysis of Indirect cost of Construction Projects in India. Int J Sustain Build Technol. 2021;4(2):9–23 https://doi.org/10.37628/ijsdt.v4i2.864