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Slips, Trips, and Falls: A Call to Duty

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Abstract

Slips, trips, and falls are a problem globally. Safety and health professionals must work diligently to protect workers and the public from injury. Property owners and/or occupants have a duty to mitigate hazards and reduce or eliminate risks of injury to visitors, customers, or travelers. Older workers and citizens are at greatest risk. Many types of hazards and conditions have been identified that increase the chances of pedestrian slip, trip and fall injuries. Common indoor hazards include slippery floors due to wax, water, tracked in snow and/or ice, spills, loose carpets or mats, uneven flooring, transition areas, raised edges, worn flooring, or items left on the floor such a cords, tools, equipment, unused material or waste. In the outdoor environment, and in cold climates snow and ice, are the major hazards associated with slips, trips, and falls and should be addressed immediately. Additional outdoor hazards are uneven surfaces, objects, potholes, mud, water, and debris from natural sources or human activity. Preventing slips, trips, and falls can be as simple as evaluating the hazards, determining risks, identifying controls, implementing controls and prevention strategies, and evaluating effectiveness to reduce the burden of slip, trip, and fall injuries and fatalities.

Key Words: Slips. Falls. Injuries. Prevention. Duty to protect.

Introduction and Scope of Work

Slips, trips and falls are a ubiquitous problem throughout the world (Chang, Leclercq, Lockhart and Haslam, 2016; Gao, 2004; Kwan, Close, Wong and Lord, 2011) and a challenge to control for property owners, occupants, public agencies, and safety and health professionals. Fall related fatalities 2012 -2018 caused 32,000 deaths in the United States of America (US) and cost an estimated $50 billion (Moreland, Kakara and Henry, 2020). Fall related injuries may be mild, moderate or severe (Clarke, Yan, Keusch and Gallagher, 2015; Kwan, Close, Wong and Lord, 2011; Yoon and Lockhart, 2006) and/or be a major cause of fatalities for some industries such as in construction (OSHA, 2020). Brady (2015) reported that 54% of slips, trips and falls were due to human factors, 25% due to wet or slippery surfaces, and 16% due to housekeeping issues. Experts estimated that 55% of all slips, trips, and falls occurred on slippery walking surfaces and 25% associated with footwear (Troyer, 2012). Slip, trip and fall hazards are numerous and should be a priority to control when recognized in any environment where people visit, work, or travel across (Di Pilla, 2010; SAIF Corporation, 2016; Workplace Health and Safety Queensland, 2016).

Property owners, occupants, employers, visitors, public agencies, and safety and health professionals are all stakeholders in the health and well-being of workers and the public and thus have a duty to mitigate hazards when recognized (Maynard, Di Pilla, Natalizia and Vidal, 2012). In the US, the law requires that employers maintain a safe and healthy workplace free of recognized hazards (NIOSH, 2012; OSHA, 2020). Property owners and/or occupants have a duty to mitigate hazards that could cause injury to visitors, customers, or travelers (AmTrust, 2020; Eagle Mat, 2019; Minetz, 1981). The scope of this work places emphasis on slips, trips and falls at the same level and provides information from select sources that reflect opinions, practices and models from around the world. The goal of this paper was to inform the reader and increase awareness of the magnitude of the problem and available protection and prevention strategies.

Definitions

Slips occur when the individual loses traction with the travel surface due to many possible factors that cause the surface to become slippery (Safe Work Australia, 2012; Brady, 2015; Chang, Leclercq, Lockhart and Haslam, 2016; Gao, 2004; Gao and Abeysekera, 2004; Hanson, Redfern and Mazumdar, 2010; ISO Services, 2010). Friction is necessary between the shoe and floor to maintain walking stability. The amount of friction is important and measured as a coefficient of friction (COF) or slipperiness. A COF greater than 0.40 offers a safety factor (Kim, Hsiao and Simeonov, 2013; Maynard, Di Pilla, Natalizia and Vidal, 2012). Loss of traction usually occurs during the forward phase of walking, when the heel-strike contacts the surface and slips; whereas the toe-off phase of walking may also slip during the forward stride thrust and the rear foot slips causing a backward event (Abeysekera and Gao, 2001; Gard and Lundborg, 2000; Hanson, Redfern and Mazumdar, 2010). Many substances may alter friction between the person's feet and the walking surface causing increased slipperiness such as the highly polished floor, spilled grease, oil, water, tracked in snow, ice and/or many other possible substances (Safe Work Australia, 2012; Brady, 2015; Di Pilla, 2010; NIOSH, 2012). Common outdoor weather related hazards that increase slipperiness include water, snow, and ice as well as other possible agents (Di Pilla, 2010; Zurich Service Corporation, 2011).

Trips occur when a person unexpectedly catches their foot on an object or on the floor where they are standing, walking, turning, or running (Work Safe Australia, 2012; Brady, 2015; Workplace Health and Safety Queensland, 2016). A raised surface of 3/8" can cause a person to stumble and fall (CMT, 2009). Trip hazards are usually low to the ground and not easily recognized. Common indoor workplace trip hazards include uneven edges in flooring, loose mats, open drawers, untidy tools, equipment, and/or electrical cords (AF Group, 2020; Safe Work Australia, 2012; Workplace Health and Safety Queensland, 2016). Trip hazards outside of buildings can be numerous and include low-level obstacles such as uneven walking surfaces, natural substances including water, snow, ice, rocks, plants, etc. or human debris from poor housekeeping or other activities on or near the travel path (CMT, 2009; Workplace Health and Safety Queensland, 2016).

Falls may occur at the same level or from different heights. Falls at the same level may result from slips, trips or other factors that result in loss of gait or movement control, balance, and/or stability, that cause the person to descend rapidly to the floor or traveling surface (Brady 2015; Kurz, Oddsson and Melzer, 2013; Safe Work Australia, 2012) and are a major source of occupational injury globally (Chung, Leclercq, Lockhart and Haslam, 2016). External causal factors within the built environment include loose carpet, mats, spilled substances, or obstacles low and not seen (AF Group, 2020). Whereas, outdoor falls may come from naturally derived hazards such as rough terrain, debris, loose soil, mud, rain, snow, and/or ice. The use of equipment and tools out of doors including ladders, scaffolding, machinery, and utility poles may all increase the risk for slip and fall injury when used in adverse environments (AF Group, 2020).

Overview and Epidemiology

The National Safety Council (NSC) reported that estimated 34,673 people died in 2016 due to slips, trips, and falls at home and at work in the US (NSC, 2020). The NSC estimated that 25,000 events occur daily (ISO Services, 2010). Slips, trips and falls made-up an estimated 15% of all accidental deaths and 17% (3.8 million) of disabling occupational injuries (Brady, 2015; Accident Fund Insurance Company of America, 2018). A total of 217,392 slips, trips and falls were reported across eight industries with the highest prevalence in government employers followed by education, health services, and retail trades (NSC, 2020). Costs of medical care and compensation were estimated at $70 billion annually in the US (NFSI, n.d.).

Slips, trips, and falls rank second only to transportation accidents as a leading cause of injury among US workers and accounted for 27% of all non-fatal reported injuries (Bureau of Labor and Statistics (BLS), 2020; NIOSH, 2012). Slips and falls are a major cause of injury that result in medical care and account for an

estimated one million emergency room visits per year. All types of falls result in an estimated 8.9 million emergency room visit each year in the US (Brady, 2015; NSFI, n.d.) and are a leading cause of injury in those over 55 years of age and a primary cause of fatality for those over 70 years of age (NSFI, n.d.).

The Centers for Disease Control and Prevention (CDC) estimates that fall related injuries result in three million emergency room visits for those > 65 years of age and 950,000 hospitalizations. Moreland, Kakara and Henry (2020) estimate that 5.5 million seniors > 65 years were injured by falls between 2012 through 2018. By 2050 one-fifth of the world's population will be > 60 years of age and 20% of them will be > 80 years of age (Kwan, Close, Wong and Lord, 2011). Authors investigated the literature on falls among Chinese older people and found the incidence of falls among those > 60 years ranged from 11% to 34% with 33% to 64% occurring in the home (Kwan, Close, Wong and Lord, 2011). The most common places to fall at home are in the dining areas and bedrooms. Falls outside the home are more common during the day and on the street or sidewalk. The most frequently reported causes for falls were slips, trips, legs giving way, and loss of balance (Kwan, Close, Wong and Lord, 2011).

The Zurich Service Corporation (2011) reported that most slip and fall claims associated with invitees involving snow and ice occurred in parking lots or parking areas. The company reported over $1 billion (US) in slips, trips, and fall claims occurred in North America with 25% due to snow and ice. The company further reported that the average liability claim is settled for $15,132 (US) and increased to $35,132 (US) per case if an employee was involved. The Accident Fund Insurance Company of America (n.d.) reported that employee claims cost an average of $40,000 each.

Falls from different heights are commonly due to a loss of footing, stability or other factors that results in a person falling from one level to another. Falls from one level to another tend to be more serious and result in many fatalities each year (CMT, 2009; OSHA, 2020).

Gevitz, Madera, Newbern, Lojo and Johnson (2017) investigated a surge in slips and fall injuries seeking emergency department (ED) care in Philadelphia, USA. The team used syndromic surveillance to identify and evaluate 4,988,985 injury reports collected from a five-year period 2006 through 2011. Their research revealed that 3.7% (185,385 cases) of all ED visits were due to slips and falls. Ages 18 to 64 years were more than two times likely to suffer fall-related injury. The most frequent fall months were December, January, February, and March. Snow was the most predictive of slips and fall with an adjusted odds ratio of 13.4 (95% CI 2.9-61.5). Study findings underscore the increased risk of snow and ice as a high-hazard and the need to be diligent in managing winter precipitation risks where people walk (Gevitz, Madera, Newbern, Lojo and Johnson, 2017).

The State of New Hampshire (NH) convened a taskforce in 2003 to address the slip, trip, and fall problem in their state and identify solutions that would lessen the adverse impacts to citizen health and the healthcare system (The NH Risk Reduction Task Force, 2003). The task force reported that an estimated 1/3 of all persons over the age of 65 years would experience a fall each year and that falls are a leading cause of death for this age group. Data showed that 60% of all falls are at home and prevention strategies are important and should be implemented (The NH Risk Reduction Task Force, 2003).

The European Union reported over 5,500 people die annually due to slips, trips, and falls and 75,000 suffer some permanent disability (Slip No More Canada, 2015). Preventable slips and falls caused more than four million lost workdays each year. The financial impact of slip and fall accidents was estimated to be more than $20 million Euros annually (Slip No More Canada, 2015). Factors associated with slip and fall accidents included inappropriate floor materials, slippery surfaces, poor lighting, and inadequate footwear for the surface traveled (Slip No More Canada, 2015). The most common locations reported in this study were shopping malls, supermarkets, hospitals, and hotels that had floor surfaces not meeting the European Union standards for non-skid surfaces (Slip No More Canada, 2015).

Netherland researchers investigated the frequency of snow and ice related fractures by comparing an unusual duration of heavy snow and ice during a 10-day period from January 2013 to the previous year (van den Brand, van der Linden, van der Linden, and Rhemrev, 2014). The heavy snow and ice resulted in twice the number of fractures compared to the previous year at approximately the same time. Researchers found that 68.3% of fractures were related to slip and fall events outside requiring 1,785 ED visits (van den Brand, van der Linden, van der Linden, and Rhemrev, 2014). Data analysis revealed the greatest number of fractures were in the forearm followed by the hand, ankle and foot, upper arm, chest and spine, and hip. Few fractures were seen in the knee, leg, and head. More females suffered fractures than males, 75.5% compared to 42.9% respectively (van den Brand, van der Linden, van der Linden, and Rhemrev, 2014). Age was not a good indicator of risk: those between 31 years to 60 years had the greatest number of fractures.

Finnish experts estimated that approximately 70,000 citizens are injured in slip and fall events each year that require medical attention with a significant cost estimated at $2.4 billion Euro (Hippi, Kangas, Ruuhela, Routsalainen and Hartonen, 2020). Researchers also found that typical injuries include bruises, sprains, and fractures. They found that distal radius fractures were 2.5 times more frequent in winter months compared to other times in the year (Hippi, Kangas, Ruuhela, Routsalainen and Hartonen, 2020). Individuals between 35 years and 65 years of age were most often injured. Investigators found that sidewalks, outdoor paths, courtyards and parking lots are the most frequent sites for slip and fall events. The slip and fall problem was so significant they expanded their Road-Surf Warning system designed for automobile travel to include pedestrian traffic with slippery walking surfaces information and warnings (Hippi, Kangas, Ruuhela, Routsalainen and Hartonen, 2020).

The United Kingdom reported that slips, trips, and falls comprised approximately 1/3 of all major injuries costing Great Britain an estimated 750 million £ (Pounds) per year (Slip No More Canada, 2015). Slip and fall events were estimated to occur every three seconds throughout the country. The Health and Safety Executive (HSE) evaluated 62 slip and fall injuries and learned that 24% of cases were due to an individual losing their footing and/or balance, 22% due to inadequate floor maintenance, 11% were due to poor housekeeping, 11% due to customer spills, and 9% due to water (Peebles, Wearing and Heasman, 2005).

Swedish researchers reported that slips, trips, and falls were a significant occupational safety hazard (Kemmlert and Lundholm, 2001) and public health problem (Abeysekera and Gao, 2001). Slip, trip, and fall injuries comprised 21.9% of 37,000 occupational injury claims examined (Kemmlert and Lundholm, 2001). Snow and ice were to blame for 70% of all injury claims involving postal workers (Gao, Holmer and Abeysekera, 2008) and accounted for 37% of all costs for injuries among elderly in traffic related environments (Gao and Abeysekera, 2004). Claims associated with those > 45 years of age and engaged in transfer of materials, equipment, or tools comprised up to 36% of accidents (Kemmlert and Lundholm, 2001). Men and women > 45 years had the longest total temporary disability and most lost workdays, 43 and 38 days respectively. The majority of men (87.5%) and women (57%) reported that slip, trip, and fall mechanisms were associated with three conditions:

1) slip due to miss-step, loss of footing on floor or ground,
2) slip on snow or ice, and
3) slip due to lack of housekeeping, spills and/or secure flooring (Kemmlert and Lundholm, 2001).

The most common reported causes for slips, trips, and falls were miss-step or loss of footing, at 28% for men < 45 years and 27% for men > 45 years and 21% for women in both age groups. Snow and ice were also significant risk factors for men compared to women, 25% for men < 45 years compared to 13% for woman and 30% for men > 45 years with 18% for women (Kemmlert and Lundholm, 2001). Gao and Abeysekera (2004) evaluated slip and fall injuries from a systems perspective and found that contributing factors include type of footwear, underfoot surface characteristics, footwear-surface interface, gait biomechanics, human

physiological and psychological aspects, and environmental factors. Their research found that gaps remained in fully understanding the risks of snow and ice and their role in slip and fall injuries (Gao and Abeysekera, 2004).

Spain estimated that 27 slip and fall events occur domestically every hour and that such events make up nearly a third of all workplace accidents (Slip No More Canada, 2015). In addition, slips and falls are the second most frequent cause of paraplegia (Slip No More Canada, 2015).

New Zealanders report that slips, trips and falls are the greatest cause of domestic related injury with an estimated $135 million impact (Slip No More Canada, 2015). More than 70,000 New Zealanders between the ages of 25 years to 55 years suffered a serious injury due to slip and fall events at home each year. Work related slips, trips, and falls commonly occurred in milking sheds, yards, and paddocks (Slip No More Canada, 2015). A number of falls were also related to individuals mounting and dismounting vehicles or other equipment (Bentley, Tappin, Moore, Legg, Ashby, and Parker, 2005).

The Safe Work Australia (2020) reported that slips, trips, and falls were the second most common injury mechanism associated with work-related accidents. In 2019, there were 24,890 injury incidences reported comprising 23% of all work related traumatic events. The top three body areas injured in slips, trips, and falls were knee, ankle, and back (Safe Work Australia, 2020). The Safe Work Australia (2020) also reported that 16 workers died in agriculture and 21 in construction due to falls between 2015 and 2019. Fatal falls were associated with ladders, roof, horses, donkeys, mules, trucks, semitrailers, and lorries.

Workplace Health and Safety Queensland (2016) reported an estimated 13,000 Queensland workers suffered slip, trip, and fall injuries resulting in more than 256,000 lost workdays with economic costs exceeding $60 million in workers' compensation payments each year. Steinberg, Cartwright, Peel and Williams (2000) reported that slips, trips, and falls were common among Australian seniors. Risk factors for fall related events included the decline in physical conditioning, medication use, impairments of nervous system, chronic disease, disorders of the musculoskeletal system, history of previous fall, and being between 60 to 74 years of age. Senior slips and falls create a public health burden and more research is needed to identify effective controls (Steinberg, Cartwright, Peel and Williams, 2000). The investigators developed four interventions aimed at fall prevention among seniors:

1) education,
2) exercise,
3) safety instruction to modify home environments, and
4) health assessment to optimize health.

They recruited 250 seniors from Brisbane Senior Center to participate in their study. One year follow up revealed significant benefit from the interventions with an estimated probability for reductions in slip and fall injury for the intervention groups compared to controls (Steinberg, Cartwright, Peel and Williams, 2000).

Contributing Hazardous Conditions

The National Floor Safety Institute (NFSI) reported certain types of floor materials may pose risk for slips, trips, and falls (NSFI, n.d.). A COF of greater than 0.40 offers a safety factor to reduce chance of slip and fall (Maynard, Di Pilla, Natalizia and Vidal, 2012). A variety of devices (tribometers) are used to measure COF (Maynard, Di Pilla, Natalizia and Vidal, 2012). Finnish researchers defined slipperiness by classifying conditions based on the COF (Hippi, Kangas, Ruuhela, Routsalainen and Hartonen, 2020). Very slip-resistant flooring was >/= to 0.30, slip-resistant 0.20 – 0.29, unsure was 0.15 – 0.19, slippery was 0.05 – 0.14, and very slippery had a COF < 0.05 (Hippi, Kangas, Ruuhela, Routsalainen and Hartonen, 2020). Floor design is important and should minimize changes in floor levels and avoid slopes greater than 1:12 rise over the run (Safe Work Australia, 2012).

Common slip hazards that alter traction in the built environment include liquid spills, cleaners, solid materials in footpaths, sudden changes in floor level, unstable or loose flooring, change from wet to dry surfaces, dusty, or sandy surfaces (Safe Work Australia, 2012; Brady, 2015).

The American National Standards Institute (ANSI) and National Floor Safety Institute (NFSI) standards list low traction as static COF < 0.40, moderate static traction COF 0.40 – 0.60 and high static traction > 0.60 (Thom, 2013). Common trip and fall hazards include ridges in carpets, worn floor materials and broken tiles, potholes and cracks in surfaces, changes in floor levels, thresholds and transition areas, floor mounted sockets, extensions, and other obstacles in a travel path (Safe Work Australia, 2012). Transition areas from smooth floors to carpet may also pose risk for stumbles and falls.

Stairs pose a trip hazards as well (The NH Falls Prevention Task Force, 2003). Stairs have been identified as potential slip, trip and fall hazards (Safe Work Australia, 2012). Risers should be uniform over the flight, any variation in riser height presents a hazard and should be minimized (Safe Work Australia, 2012). The proper design of stairs is important to minimize slip, trip, and fall hazards. The overall elevation of the stairway should not be too steep and the rise of the stairway should be between 15 and 55 degrees (Safe Work Australia, 2012). Landings should be installed no less than every 16 steps. Handrails on both sides of the stairway adds user stability (Safe Work Australia, 2012).

Snow and Ice Hazards

Snow, ice, water and freezing temperatures create reduced COF conditions that significantly increase the risk for slips and falls (Bongrade, 2017; Gao, Holmer and Abeysekera, 2008). Snow management has many possible considerations such as moisture content in the atmosphere, temperature and temperature ranges, wind speed, depth of snow, and rate of snowfall all influence control strategies and effectiveness of removal (Di Pilla, 2010). The Snow and Ice Management Association (SIMA) estimated that North America invests $22.7 billion for snow and ice management. The retail industry spends and estimated $6 billion annually to manage snow and ice on their property (SIMA, 2016). An estimated 90% of all pedestrian slip and fall injuries are on less than one inch of snow (Konst, 2017). The SIMA reported that one in four falls in the US is due to snow and ice, totaling and estimated 2,250,000 incidences per year with 35% occurring in parking lots (SIMA, 2016). In 2014, an estimated 42,480 snow and ice work related injuries resulted in at least one lost workday each in the US (Bongrade, 2017). Snow and ice are the top two weather factors that negatively impact mobility of older adults (Clarke, Yan, Keusch and Gallagher, 2015). Researchers surveyed 502 citizens in Michigan and found that ice was the major deterrent to daily activity 46.51% of the time compared to 21.71% due to snow. For those >65 years, avoidance rises to 51.14% (Clarke, Yan, Keusch and Gallagher, 2015).

The outdoor environment is susceptible to a number of unique hazards that include: sleet, freezing rain, black ice, snow and ice (Accident Fund Insurance Company of America, n.d.). Sleet formation begins as snow that melts in a warm band of atmosphere air and then refreezes in colder lower atmosphere air forming pellets that bounce when hitting the ground (Accident Fund Insurance Company of America, n.d.). Freezing rain begins as snow that melts in warm atmospheric air but then refreezes when it hits the ground due to colder temperatures. Freezing rain is extremely dangerous for walking or driving (Accident Fund Insurance Company of America, n.d.). Black ice is a thin layer of ice that blends into ground surfaces. Black ice forms from water, dew, or fog often in the early morning and then melts with sunshine but may reform on wet surfaces with freezing temperatures (Accident Fund Insurance Company of America, n.d.). Snow is precipitation that freezes in cold atmospheric temperatures and maintains its freezing form to accumulate on the ground or other surfaces. Ice forms when water from many possible sources freezes due to freezing lower atmospheric temperatures (Accident Fund Insurance Company of America, n.d.).

Additional Outdoor Hazards

The ISO Services (2010) identify same level slip, trip, and fall hazards to include uneven or slippery walkway surfaces, contaminants on walkways, inadequate lighting, poor housekeeping, inadequate maintenance, poorly designed or worn-out or degraded walkway surfaces, and adverse weather conditions.

Walkways include parking lots, fields, playing fields, paths, walks, footpaths or a combination thereof. Additional walkway hazards include broken pavement, depressed, raised, undermined, uneven, or cracked surfaces to the extent that pieces may be easily removed (ISO Service, 2010). Parking lots are frequent locations for slip, trip, and fall hazards (State Automobile Insurance Company, 2020). A one-inch hole is enough to cause someone to stumble and fall. Parking lots should be designed and maintained free of uneven pavement, cracks, bumps, or holes that might cause someone to stumble and fall. Adequate lighting is essential for employees, customers and/or visitors. Poor lighting can be a factor in slips, trips, and falls as well as criminal activity, and vehicle collisions (State Automobile Insurance Company, 2020).

Personal Factors

Numerous personal risk factors have been associated with slips, trips, and falls (Chang, Leclercq, Lockhart and Haslam, 2016; Kurz, Oddsson and Melzer, 2013; Mersey Care NHS, 2016). Factors that may predispose individuals to slips, trips, and falls include age (Moreland, Kakara and Henry, 2020), balance and gait problems (Kurz, Oddsson and Melzer, 2013; Lockart, Smith and Woldstad, 2005; Mersey Care NHS, 2016), decreased strength and flexibility (Lockart, Smith and Woldstad, 2005), impaired hearing, dizziness, altered mental status, use of multiple medications, alcohol use, impaired vision, chronic or acute illness and having had a recent fall (Kurz, Oddsson and Melzer, 2013; The NH Falls Risk Reduction Task Force, 2003). Improper footwear has also been identified as a personal risk factor (Gao, Holmer and Abeysekera, 2008).

Prevention and Management Strategies

Prevention of slips, trips, and falls are best accomplished with a systematic approach (Maynard, Di Pilla, Natalizia and Vital, 2012; Safe Work Australia, 2012). The primary steps involve:

1) identifying the hazards,
2) evaluating the risks,
3) implementing, and maintaining controls, and
4) reviewing effectiveness of controls.

Basic prevention strategies target risk reduction through optimizing factors associated with the person, place, environment, or activity performed. The hierarchy of controls provides an excellent framework for improving the safety of individuals at work, in public, or at home (Safe Work Australia, 2012; Workplace Health and Safety Queensland, 2016.)

The **first** and preferred strategy is to eliminate the hazard through removing the slip, trip and fall hazards such as clearing snow, ice, natural debris, low-lying hazards including tools, equipment, cords, and/or waste from walkways (Safe Work Australia, 2012). The **second** control strategy is substitution such as replacing a slippery surface with a slip-resistant coating or new material (Safe Work Australia, 2012). The **third** strategy is to isolate the higher–hazard area and keep people away using signage and/or barriers to restrict access (Safe Work Australia, 2012). The **fourth** strategy is to use engineering to address hazards and reduce or eliminate risks. Examples of engineering controls might include applying floor treatments to increase friction, improved lighting, stop leaks, provide effective drainage, and clearly mark edges for changes in surface heights (Safe Work Australia, 2012). The **fifth** strategy is to use administrative controls such as high standards for housekeeping, cleanliness, and spill clean-up. Using signage is prudent to warn others that hazards are present such as a freshly mopped floor, snow, ice, water, or other substances that reduce the COF. Training is an administrative responsibility and fundamentally should enhance knowledge, skills and competencies of those trained in all aspects of slip, trip and fall prevention (Safe Work Australia, 2012). The **final** strategy is the use of personal protective equipment such as slip resistant shoes and stabilization-assist devices such as canes or walking sticks (Safe Work Australia, 2012).

Brady (2015) recommends a 10 step process for minimizing slips, trips, and falls in the workplace: 1) assess the workplace, 2) mark isles and passageways, 3) provide traction on slippery surfaces, 4) improve stair safety, 5) mark emergency exits, 6) post safety signs and labels, 7) warn of temporary hazards, 8) inspect scaffolds and ladders, 9) control and clean oil and spills, and 10) train employees.

Chang, Leclercq, Lockhart and Haslam (2016) recommend a simple three-step systematic approach that included
1) primary prevention such as good slip resistant flooring, well designed walkways, effective spill mitigation procedures, robust storage capabilities to keep walkways clear of trip hazards, good lighting, and strong maintenance programs,
2) risk reduction through education and training, audits, controls, housekeeping, signage, discourage carrying loads while walking, manage risks associated with inclement weather, and manage risks associated with vulnerable persons,
3) maximize capability of individuals to navigate the workplace environment through recommended footwear, suitable clothing and PPE, vision testing, vision correction if needed, fitness, and management of risks secondary to medications and shiftwork (Chang, Leclercq, Lockhart and Haslam, 2016).

Workplace Health and Safety Queensland (2016) recommends a risk management matrices that include the following risk factor groups: internal floor surfaces and conditions, external ground surface and condition (including access/egress), contaminants, cleaning procedures, cleanliness, housekeeping and obstacles, environmental and lighting, stairs and ramps, activities (tasks), footwear and others. The property owner, operator or responsible person should identify the detailed risk factors within each group and rank them based on probability of injury: hazard is **Low** (least likely), **Moderate** (some risk of injury), or **High** (very likely to cause injury) (Workplace Health and Safety Queensland, 2016). Once the matrices are complete, rank hazards, create an action plan, develop, and implement controls (Workplace Health and Safety Queensland, 2016).

Maynard, Di Pilla, Natalizia and Vidal (2012) underscored the reality that everyone in an organization is a stakeholder in the prevention of slips, trips, and falls. The recommended process for managing risks and hazards follows a systematic approach using a continuous cycle of improvement. Their model includes eleven actions or parts to achieve success:
1) management responsibility, 2) education and training, 3) incident and injury surveillance, 4) hazard surveillance, 5) floor surface selection, 6) floor surface treatments, 7) housekeeping and maintenance, 8) slip-resistant footwear, 9) mats, 10) floor slipperiness assessment and 11) warning signs and instructions (Maynard, Di Pilla, Natalizia and Vidal, 2012). Coordination of organizational components is essential. Priority stakeholders include facilities management, operations management, risk management, safety, purchasing, occupational health, engineering, maintenance, and housekeeping (Maynard, Di Pilla, Natalizia and Vidal, 2012).

The New Hampshire Falls Risk Reduction Task Force (2003) focused on slips, trips, and fall prevention related to senior citizens. The task force concluded that basic elements of a slip, trip, and fall prevention program were the **4 'E's**: **E**ducation, **E**nvironmental modification, **E**xercise and **E**mergency planning. Education materials should be developed that could be taken home by participants, environmental conditions need to be changed to reduce risks, exercise to strengthen core muscles, lower extremities and balance, and emergency planning to minimize severity and improve outcomes. Environmental conditions could be guided by a Safe House Tour checklist that includes assessment of kitchen, hallways and stairways, bathrooms, bedrooms, living room, and general living areas, entrances, and outdoor walkways. The completed checklist culminates in an action plan that residents can use to make their environments safer. The taskforce continues to be active and provide community education with the most recent virtual class held November 3, 2020 to introduce the new Executive Director of the New Hampshire Commission on Ageing and also focused on fall prevention in seniors (The NH Falls Reduction Task Force, 2020).

Troyer (2012) presented a slip, trip, and fall prevention program based on established standards from the American National Standards Institute (ANSI) and National Floor Safety Institute (NFSI). Using the framework of ANSI/NFSI floor safety standards, Troyer

(2012) outlined a Plan, Do, Check, Act (PDCA) continuous process approach.

Step 1 is planning, this invites a risk assessment that includes common risk estimation tools such as the Failure Modes and Effects Analysis (FMEA) for evaluation and identification of hazards and estimation of probability and magnitude of an event (Troyer, 2012).

Step 2 outlines the action plan for interventions to be taken based on step 1.

Step 3 requires checking or evaluating control strategies for effectiveness.

Step 4 is checking and evaluation for dangerous levels of COF needing proactive interventions to return safety to walking surfaces (Troyer, 2012). The author asserts that monitoring walkways is easy using modern tribometers and comparing results to standards. Using the PDCA cycle of continuous monitoring with appropriate action results in a safer environment for pedestrians and is more likely to prevent and/or reduce slip, trip, and fall incidences (Troyer, 2012).

The Accident Fund Insurance Company of America (n.d.) developed the SAFE Campaign: Slip And Fall Elimination (SAFE). Elements of the SAFE campaign include use of weather advisory systems, snow blower and snow removal equipment, hire a contractor for snow removal, a plan for when off-premises work is necessary, maintain a good supply of ice melt products, obtain appropriate slip resistant footwear, post slip, trip and fall advisories around the premises, ensure entryways are clear with mats. The SAFE program reminds businesses to service parking lots and frequently traveled areas and to keep ice melt product well supplied because it is far cheaper than an insurance claim (Accident Fund Insurance Company of America, n.d.).

The Mersey Care NHS Foundation Trust (2016) offers a policy for the management and reduction of work related slips and falls based on established consensus standards for safety, practice, prevention and care of slips, trips, and falls in the healthcare industry. The 47 page policy includes 12 sections: purpose and rationale, outcomes focused aims and objectives, scope, definitions, duties, process, consultation, training and support, monitoring, equality and human rights analysis, implementation plan, and appendices. The aim of the policy is to ensure efficient and effective prevention and management of slips, trips, and falls of patients in healthcare settings. Key to the success of the program is compliance with the United Kingdom's Management of Health and Safety at Work regulations with accountability of those in charge of safety, facilities, staff, and remaining stakeholders (Mersey Care NHS Foundation Trust, 2016). Systematic hazard identification is paramount to risk estimation and abatement. Risk management strategies include a selection of appropriate and effective controls to mitigate or eliminate hazards with documentation. Knowing who is at risk for falling and taking action to protect the vulnerable is equally important. Training stakeholders, monitoring compliance, and evaluation of outcomes leads to successful prevention and/or care of slip, trip, and fall events (Mersey Care NHS Foundation Trust, 2016). The Mersey Care NHS Foundation Trust (2016) policy for slip, trip, and fall prevention is an open-source model for others to use, it includes tools and resources accessible to all parties for use and enhancement of their injury prevention effectiveness.

NIOSH (2010) published a slip, trip, and fall prevention guidelines for the healthcare industry with the express purpose of explaining how hazards contribute to slips, trips, and falls. The NIOSH (2010) guidance document provides information on where hazards may be found with recommendations on how to abate hazards. The document lists ten major classes of hazards and recommends controls. Hazard classes include 1) contaminants on the floor, 2) poor drainage, 3) indoor walking surface irregularities, 4) outdoor walking surface irregularities, 5) weather conditions: ice and snow, 6) inadequate lighting, 7) stairs and handrails, 8) stepstools and ladders, 9) tripping hazards, clutter, including loose cords, hoses, wires, medical tubing, and 10) improper use of floor mats and runners. Each hazard group has recommendations that reduce or eliminate the risk of injury (NIOSH, 2010).

W.W. Granger Incorporated (n.d.) outlined a simple slip, trip and fall prevention plan for employers that includes: 1) create good

housekeeping practices – plan ahead, assign responsibilities, and maintain the program, 2) reduce wet or slippery surfaces – check parking lots, sidewalks, food preparation areas, shower stalls in dorms and floors in general, 3) avoid creating obstacles in aisles and walkways – keep all work areas, passageways, storerooms, and service areas clean and orderly, 4) create and maintain proper lighting – use illumination in walkways, staircases, ramps, hallways, basements, construction and dock areas, 5) wear proper shoes – require or provide footwear that provides good traction and safety for the job, and 6) control of individual behaviors – provide training to teach employees to enhance awareness of slips, trips and falls, stay alert, avoid distractions such as cell phones or carrying objects that might obscure vision, don't wear sun glasses indoors, avoid taking shortcuts, don't hurry, maintain control of motions and activities (W.W. Granger, n.d.).

Snow and Ice Management

Snow and ice on pedestrian walkways, traveled surfaces, and routes should be considered emergency work and managed with the utmost urgency (Di Pilla, 2010). Removal of snow from walkways and parking lots is essential for the safety of employees and visitors (Di Pilla, 2010; Hofmann, 2020; Hossain and Fu, 2015). Snow and ice control can be accomplished using mechanical, thermal, and chemical means (Hossain and Fu, 2015). Optimal snow and ice removal should be determined through field tests (Hossain and Fu, 2015). Application of preferred methods should be focused on entrances, exits, ramps, slopes, stairs and shaded areas (Hofmann, 2020). Business operators and landowners have a 24/7/365 responsibility to manage their snow and ice risks (Hofmann, 2020; Konst, 2017). Don't think that slip and fall risks are not present just because it didn't snow. Dangerous ice can form with moisture and low temperatures. Snow bias is the potential to disregard risks associated with ice formation without snow (Melchior, 2016).

Gao (2004) investigated snow and ice related injury events in his doctoral dissertation and concluded that snow and ice risks are multifactorial and required multiple measures to successfully reduce fall risks. Best Management Practices (BMPs) are effective interventions to reduce and/or eliminate snow and ice hazards and risks and should include monitoring property with emphasis on walkways, posting warning signs of possible slip conditions, and snow and ice removal (Gao, 2004; Konst, 2017).

NIOSH (2010) outlines several safety measures to reduce employees' and customers' injuries associated with ice and snow through the development and implementation of an aggressive program to promptly remove ice and snow from parking lots, garages, sidewalks, entrances and outside stairs. Their recommendations included distribution of weather information to employees, placing freezing monitors in parking areas and entrances, locating ice melt products in a bin near entrances of parking lots and garages with scoops so anyone can apply the product to ice as needed, displaying phone number for maintenance service, encourage employees to report dangerous conditions, posting signage, using mats at entrances and recommending or provide anti-slip footwear (NIOSH, 2010).

Zion Market Research (2018) estimates that snow melting systems will reach $6 billion (US) in sales by 2022. Such systems monitor the environmental conditions, detect precipitation, and freezing temperatures then automatically activate systems to prevent snow and ice build-up on surfaces such as walkways, patios and roadways.

The Minnesota Pollution Control Agency (MPCA) (2015) recommended sand for parking lots to enhance traction for pedestrians and autos. Special attention was recommended for handicap parking. Mixed sand and salt is recommended for freezing rain (MPCA, 2015). The agency outlined BMPs and winter maintenance basics for snow and ice. The BMPs include removal first, remove snow as quickly as possible, protect the environment, apply deicers per manufacturer's recommendations, record quantity used, record effectiveness and outcomes, cover salt and sand piles, use magnesium or calcium chloride as effective alternatives, use wet snow-melt materials for improved efficiency and reduce total quantities used (MPCA, 2015).

Swedish investigators studied slips and falls due to snow and ice using a systematic perspective with an emphasis to identify preventive factors (Gao and Abeysekera, 2004). The researchers recommended the following steps for effective prevention: 1) proper footwear that had anti-skid and anti-slip features, 2) effective snow clearing with anti-slip materials spread on walking and driving surfaces, 3) walking aid, gait and balance exercise, 4) good environmental lighting, 5) prioritizing management of winter weather risks and hazards, 6) signage to warn pedestrians of risks and hazards and 7) training for the general populations on safer walking techniques and behaviors in snow and ice (Gao and Abeysekera, 2004)

Gao, Holmer and Abeysekera (2008) investigated the opinions and recommendations for slip safety among Swedish workers in newspaper delivery, military, mining and construction industries. Respondents ranked controls from most effective to least effective, results were as follows: 1) spreading anti-slip materials on surfaces, 2) use of slip resistant footwear, 3) walking carefully, 4) snow removal, 5) use of anti-slip devices on shoes, 6) walking slowly, 7) taking small steps and 8) not using ordinary shoes.

The Finnish Meteorological Institute (FMI) developed a public broadcast warning system to inform citizens of times of increased risk when walking (Hippi, Kangas, Ruuhela, Routsalainen and Hartonen, 2020). The country began using a road condition warning system in 2000 that was expanded in 2004 to include walking surfaces. The developers classified walking surfaces into five categories based on the COF. Class 1 conditions were very slip-resistant COF >/= to 0.30, class 2 was slip-resistant COF 0.20 – 0.29, class 3 were described as unsure COF 0.15 – 0.19, class 4 conditions were slippery COF 0.05 – 0.14, and class 5 conditions were highest risk with COF < 0.05 (Hippi, Kangas, Ruuhela, Routsalainen and Hartonen, 2020). Their research found that the most slippery conditions were near zero degrees centigrade (32^0F) where freezing and thawing cycles occur forming ice. Public health messages included a colored warning scheme to communicate conditions and encourage adaptions including slip resistant devices worn on shoes/footwear, alternative travel routes or cancellation of planned walk/travel (Hippi, Kangas, Ruuhela, Routsalainen and Hartonen, 2020). The pilot program started in 2004 remains active today. The system runs 24/7/365 providing a 10 day, 5 day, and 3 hour forecasts. The most recent innovation includes the FMI weather app for citizens to use on their mobile phones that collects data from the accelerometer in the phone.

Swedish investigators, Gard and Lundborg (2000), investigated 25 anti-skid devices that attach to footwear using subject trials where participants ranked devices. Study participants were required to don the anti-skid devices and perform basic walking maneuvers on five different ice surfaces: gravel applied, sand applied, snow over ice, salted surface and ice with no coverage. The participants travelled and maneuvered a 10 meter path. Participants were observed, analyzed, and asked to walk normally, turn around, walk rapidly 4-5 steps, stop, walk backwards 4-5 steps, and walk rapidly across the designated area. Study subjects reported their perceived advantages and disadvantages of the different devices. Evaluation revealed two devices that were ranked as good on all types of iced surfaces and one that was good or fairly good on all surfaces (Gard and Lundborg, 2000). The products that received superior ratings for iced surfaces were named ‘Studs’ and ‘Sensi Galoch’ and a third ‘Beaver’ was ranked highest by test subjects for all surfaces. These types of devices are intended to increase the grip between the wearer’s shoes and the underfoot walking surface (Gunvor and Lundborg, 2000).

Parkin, Williams, and Priest (2009) conducted a novel investigation of pedestrians wearing socks on the outside of their shoes to evaluate the slip resistance. The researchers randomized 30 pedestrians to two different group: those wearing socks on the outside of their shoes and those not wearing socks on the outside of their shoes. Pedestrians wearing socks on the outside of their shoes reported significantly improved traction (Parkin, Williams, and Priest, 2009).

The OSH Healthcare System (2020) recommends walking like a penguin. The unique

gait advocated that individuals assume a slightly bent posture, walk flat-footed and move carefully over ice like a penguin. Walking on slippery surfaces such as snow and ice should be deliberate, planned and carefully executed (OSH Healthcare System, 2020). Learning to fall safely may also be a tenable strategy for reducing injury and adverse outcomes from slip and fall events (OSH Healthcare System, 2020). The martial arts offers fall landing techniques that may reduce injury by landing more safely (Black Belt Wikki, n.d.).

Snow and ice removal can prevent costly liability insurance claims due to injury (Melchoir, 2016; Schaefer Enterprises, 2020). If a contractor is hired for snow removal, verify that they are insured by obtaining a certificate of insurance before signing the contract. Documentation of snow and ice management will lessen the chances of slips, falls, injuries, and lawsuits (Perkoski, 2018).

Safety Standards

A significant number of safety standards exist to reduce and eliminate slip, trip, and fall hazards (Maynard, Di Pilla, Natalizia and Vidal, 2012; Troyer, 2012). In the US the occupational safety and health standards are enforced by OSHA (OSHA, n.d.; USDOL, 1970; Thom, 2013), The Occupational Safety Standards for general industry 29 CFR 1910 and construction 1926 outline specific standards to protect workers from slip, trip and fall hazards (OSHA, n.d.; Thom, 2913). Emphasis on fall prevention in construction is paramount to saving lives. The OSHA recommends a static COF of 0.50 or higher to reduce chances to slips, trips, and falls (Fairfax, 2005; Thom, 2013).

The American National Standards Institute (ANSI) and the American Society of Safety Engineers (ASSE) collaborated on a number of standards. For example: ANSI/ASSE A 1264.2-2006 Standard of Slip Resistance on Walking-Working Surfaces. This is a voluntary consensus standard that establishes COF at 0.50 for safety on dry surfaces and specifies four slip evaluation devices. The ANSI/ASSE TR-A 1264.3-2007 Using Variable Angle Tribometers (VATs) for Measurement of Walkway Surfaces details the validity of VATs. The ANSI/ASSE B101.1-2009 test Method for Measuring Wet SCOF of Common Hard Surface Floor Materials provide values of traction ranging from a high of > 0.60 COF to a low < 0.40.

The American Society for Testing and Materials (ASTM) C1028 Test Method for Determining the Static Coefficient of Friction on Ceramic Title and Other Like Surfaces by the Horizontal Dynamometer Pull Meter outline test method. The ASTM D 2047 Test Method for Static Coefficient of Friction of Polish-Coated Surfaces as Measure by the James Machine outlines testing methods. The ASTM F609 Standard Test Method for Using a Horizontal Pull Meter (HPS) details methods for using the Liberty Mutual HPS. The ASTM F1679 Standard Test Method for Using Variable Incidence Tribometers (VIT) details methods for using the English XL VIT. The ASTM F1677 Standard Test Method for Using A Portable Inclinable Articulated Strut Slip Tester (PIAST) details test methods for using the Bungraber MK II Slipmeter. The ASTM F2508 Standard Practice for Validation and Calibration of Walkway Tribometers Using Reference Surfaces is an evidence-based standard that established parameters for validation and calibration of walkway tribometers using reference surfaces.

The ANSI and NFSI sponsored additional standards that include ANSI/NFSI B101.0 specifies the process by which walking surfaces are audited for slip resistance using the NFSI approved tribometers. The ANSI/NFSI B101.3 specifies the process for measuring the dynamic COF. The ANSI/NFSI B101.1 specifies the process for measuring static COF.

Communities often have county or city codes and/or ordinances that require property owners, tenets or agents of the premises to maintain pedestrian safety by removing snow and ice from sidewalks and driveways. For example, in Butte, MT, the county ordinance 12.12.020 – Snow and Ice Removal – Generally (2014), requires snow removal from sidewalks within 24 hours of accumulation or the party faces a $50 fine for the first offense, $100 for the second and $150 for the third (Butte-Silver Bow, 2014; McClendon, 2019).

A Duty to Protect and Prevent Slips, Trips, and Falls

Property owners and occupants have an obligation to protect visitors and/or the public that may enter their property (AmTrust Financial, 2020; Barker and Parry, 1995; Beckman, 2017; Cassisi Law Firm, 2020; Eagle Mat, 2019; Goguen, 2020; Grigg, 2016; Hofmann, 2020; Melchior, 2016; Miller, 2020; Minetz, 1981; Philadelphia Insurance Companies, 2017; Prior and Thompson, 2017; State Automobile Association, 2020). Employers have an obligation to protect employees, contractors (USDOL, 1970; OSHA, 2020), customers and/or visitors who enter their business (Beckman, 2017; Chang, Leclercq, Lockhart and Haslam, 2016; Eagle Mat, 2019; Minetz, 1981; Prior and Thompson, 2017; State Automobile Association, 2020). While this author is not offering legal advice, it is recommended to assume that current laws and precedent exist that compel and/or suggest property owners and/or businesses to take responsibility for their property and exercise diligence to eliminate or mitigate hazards that might cause injury to employees, contractors, customers and/or visitors. Regardless of natural or unnatural accumulation (Schutte and Waldman, 2015) a fundamental ethical and/or legal obligation exists for property owners and/or occupants to ensure reasonable safety.

Step one of the risk reduction process is to identify hazards that could cause injury to employees, customers, or visitors (State Automobile Association, 2020). *Step two* is to act on the presence of recognized hazards by reducing or eliminating the hazard and related risk of injury through self-directed hazard abatement or through contract services. The lack of action to do so is negligent and likely to expose property owners and occupants to claims and liability (Beckman, 2017; Goguen, 2020; Minetz, 1981; State Automobile Association, 2020). An aggressive program to eliminate and/or mitigate slip, trip, and fall hazards is highly recommended to reduce risks (Chang, Leclercq, Lockhart and Haslam, 2016; Philadelphia Insurance Companies, 2017; Troyer, 2012; Zurich Service Corporation, 2011). Property owners or occupants must decide if they wish to manage snow and ice removal or contract the service (State Automobile Association, 2020). A snow management plan begins before it snows and ends with safe and effective snow removal, anti-icing treatment (Limban, 2020) and posting of danger warnings (Hofmann, 2020). There is a duty of care to anticipate dangers caused by snow and ice and to take action to mitigate and/or eliminate hazards (Goguen, 2020). Ignorance is not an excuse (Hofmann, 2020), so people should not be negligent, should take proactive measures to avoid potential injury claims (Schaefer Enterprises, 2020) and manage slip, trip and fall hazards at their business and/or property using a documented, systematic, and effective risk management processes (ISO, 2010).

Conclusion

Slips, trips, and falls are a significant problem worldwide. Stakeholders have considered multiple risk factors, conditions and alternatives leading to sound prevention strategies for employers and property owners/occupants. Taking action to manage and mitigate slip, trip, and fall hazards is prudent, ethical, and a legal obligation in many circumstances.

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