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Prevention through Design-Slips, Trips and Falls

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Introduction

According to published research by the Liberty Mutual Research Institute for Safety, same-level slips and falls represent nearly 11% of all workers compensation claims and over 13% of all claims costs[1]. This is second only to manual material handling, which represents 37% and 40%, respectively. In most industry groups, slips and falls represent the highest, or second highest, type of workers compensation claim. In addition, 11% of low back pain-related claims and 12% of low back pain-related claims costs are attributed to slips and falls[2].

The Liberty Mutual Workplace Safety Index (WSI) ranking of the 10 leading causes of workplace accidents and the initial Liberty Mutual Executive Survey of Workplace Safety in 2001 revealed some interesting statistics about the direct and indirect costs of workers compensation slips and falls, and the perception among business executives about the extent of the problem. In reality, the direct cost of falls on same level represents $8.61 billion (16.9 % of claims), second behind overexertion or back injuries and from 1998 to 2010 falls on same level has shown a 42.3 percent increase or real growth trend[3]. But, according to the 2001 executive survey, most executives perceived falls on the same level to be much less of a problem - the seventh most important cause overall[4].

Why the difference between reality and the perceived importance of slips and falls? Why do same level falls continue to represent one of the most costly safety problems today? The reason might lie in a lack of understanding as to how slips, trips and falls occur and implementation of a managed safety process that targets those complex causes.

Causes of Slip, Trips and Falls

To understand slips, first consider human bipedal gait. Bipedal gait is characterized by two phases: the stance phase and the swing phase. The stance phase begins with heel strike or the initial contact with the floor at the rear edge of the heel. The heel rocks forward to bring the foot into full contact with the walking surface and to support the body as the other foot enters the swing phase. When the swing phase is completed, the supporting foot rocks forward leaving only the forepart of the foot contacting the walking surface. This is called “toe off”. Body weight is then shifted onto the other foot and the original foot enters its swing phase.

A slip occurs just as the heel contacts the floor and the weight is shifted to the heel potentially resulting in loss of balance and stability and a fall. Slips may result in the person falling posterior or backward[5].

A trip occurs when the foot strikes a near ground obstacle that abruptly arrests the movement of the foot when the body's center of gravity is in motion. This causes the center of gravity to rapidly move out of the area of the body's support base (the planted foot), resulting in loss of balance and stability and potentially a fall. Trips may result in the person falling forward.

Factors that contribute to falls are not well appreciated. Human error is too often blamed for causes of falls e.g. person wasn't watching where they were going, they were rushing, they were "careless" etc. The fact is that falls are embarrassing events. Slips without a fall or slips and trips that result in a fall but no injury are rarely reported or recorded. Prevention is too many times reactive or only when there is an expensive lawsuit or when WC claims frequency and severity is significant enough to attract the attention of risk managers.

To prevent falls means to be proactive and being proactive requires an understanding of human behavior and other scientific disciplines that explain why slips, trips and falls can occur. These disciplines include ergonomics, biomechanics, psychology, and tribology.

Tribology is the study of the interaction of sliding surfaces. The word is derived from the Greek "tribos," meaning rubbing. The field of tribology includes the analysis of friction, wear, lubrication, and application of these principles to mechanical design, manufacturing processes, and machine operation. Historically, tribology, a mechanical engineering discipline, has been associated with the electronics, metalworking, and medical industries but more recently, tribology has been applied to slips and falls.

In slips and falls, Tribology can describe causes of slips and falls and prevention. Friction is associated with the interface between the floor and shoe sole, wear of the shoe sole material and floor surface material, and lubrication with contaminates such as grease, water, dirt, etc.

Most same-level falls are the result of slipperiness caused by faulty housekeeping or defects of the floor surface. Faulty housekeeping is described as dirt, grease, water, or contaminates on the floor. Defective floors are described as slippery floor waxes and finishes, inappropriate floor surface materials for the environment, excess surface wear, and uneven or damaged surfaces.

Rough floor surfaces offer more slip-resistant characteristics by offering sharp peaks, which contact the shoe sole material thereby increasing friction or traction. However, grease, dirt, or other contaminates can reduce that benefit by filling in the voids, and the peaks can wear over time, thus reducing the slip-resistance benefit.

Ergonomics is involved in slips, trips and falls in several ways. Tasks performed have a direct effect upon the force characteristics associated with a person's behavior, movement patterns, and gait. Slips and falls occur most frequently in the elderly. Two reasons explain this. First, as one ages, reaction time slows. When younger people sense or perceive a heel slip, they recover quickly. Older people recover more slowly, and that split-second delay is the difference between recovery and a fall[6].

Second is muscular strength. Many different muscle groups are employed to recover from a slip and we take for granted how strong these muscles must be to recover. The elderly have less strength in these muscles and, again, are less physically able to recover from a slip.

Third, vision deficits and corrective lenses, loss of contrast sensitivity, less color sensitivity, poor dark adaptation (slow/incomplete) and reduced glare recovery can make it difficult to see potential hazards on the walkway surface and therefore increase likelihood of a potential fall[7]. This is especially important for detecting height transitions with stairways, sidewalks, curbs, parking stoppers etc. For this reason, the US Access Board Research recommends Safety Yellow for detectable warnings, as it is most visible even to older pedestrians[8].

Ergonomics is the design of work to fit people that includes jobs, tasks, workstations, tools and equipment. Ergonomic design means accommodating as many people as possible. The same is true of facility design to prevent slips, trips and falls. Ergonomic facility design includes recognizing individual differences such as the aging population and eliminating or reducing as many slip, trip, and fall hazards as possible.

Biomechanics is the human factor element of slips and falls and involves the study of the mechanics of the body and how we walk and interface with surfaces as we walk. Biomechanics research in slips and falls provides an understanding of required or utilized COF during the gait cycle and how it varies by age of person, gait pattern, walking speed, footwear worn and more. Force plates are used to capture ground reaction forces with 3D motion tracking technology (cameras and reflective markers) to identify position and motion of the lower extremity, foot and heel.

Biomechanics is helpful in understanding the dynamics of slipping and at what point a fall might occur. For example, research in the early 90's concluded a micro slip of 0-3 cm is generally undetected, while a slip of 3-10 cm may result in corrective action being taken usually without a fall. A slipping distance over 10 cm most often results in a fall[9]. Recent research by the Liberty Mutual Research Institute for Safety showed considerable variation in human perception of heel slip, slip distance and ranking of floor slipperiness[10].

Determination of required or utilized coefficient of friction (COF) is helpful in understanding probability of slips and falls. For example, if available friction measured with a tribometer or slipmeter is lower or more slippery (0.2) than required friction (0.6) then theoretically the probability of a slip and fall is higher[11]. A statistical model published by the Liberty Mutual Research Institute for Safety in calculating probability of slips and falls is described by Chang et al., 2008[12].

Psychology is how we perceive and respond to slippery conditions. Slips and falls happen when you least expect it. For example, when a person perceives a slippery condition (e.g., walking on ice), they will adjust their gait to prevent a slip. A problem often occurs when a person does not perceive a slippery condition, does not adjust their gait, slips unexpectedly, fails to recover and falls. Examples are when there is water or grease on a floor that has not been cleaned up; or transition points from non-slippery floors to slippery floors, such as transitions from carpet to a glazed ceramic tile or vinyl-composition tile floor.

Liberty Mutual researchers have studied human perception of slipperiness with regard to friction, heel displacement and visual cues and, while there is good correlation to perceived

slipperiness with friction and visual cues[13], there is less so with heel slip. Bottom line is people don't usually look at floors when they walk so selection of flooring is very important.

Other factors that increase the likelihood of same level falls include personal factors such use of certain medications and presence of certain illnesses that affect cognition and balance.

Physical factors that increase the likelihood of slips and falls include slippery walkway surfaces (inside and outside), inadequate footwear, poor lighting, transitions from non-slippery to slippery conditions such as carpet to tile, concrete to tile, hot environments to cold, and dry environments to a more humid environments. Floor slipperiness is affected by presence of water and contaminates (grease, oil, dust, particulate soil etc.). Most dry/clean floors are slip-resistant and safe. Outside slips and falls can be due to slippery walkways at building entrances, sidewalks, curb ramps, parking areas and parking garages.

Physical factors that increase likelihood of trips include walkways that are too rough or very high surface texture or too high a coefficient of friction and transitions in height. Most state, local and federal codes and standards describe changes in elevation of ¼ inch or higher in the course of travel as a trip hazard. Trip hazards can be present anywhere inside and outside a facility including sidewalks, curbs, curb ramps and parking areas. To evaluate floor slipperiness requires baseline knowledge of friction and the interface between the shoe outsole and floor surface. The higher the friction, the higher the traction between the walkway surface and the footwear; an important element in prevention to be discussed later.

A Managed Slip, Trip and Fall Process

Managing slip and fall exposures is challenging and requires participation from all in the organization. Stakeholder groups in a slip and fall prevention process include architects, design and construction, facilities management, operations management, risk management, safety, purchasing, occupational health, maintenance, and housekeeping. Figure 1. Describes the elements of a managed slip and fall prevention process[14].

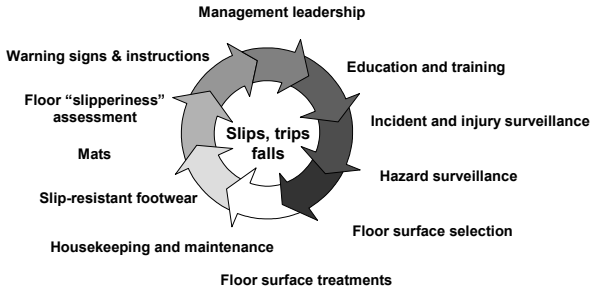

Figure 1. Slip and fall prevention continuum

Facility design, including selection of floor surface materials, is key to this process. If a walkway surface is slippery by design or a trip exposure exists by design then it is a matter of time before a pedestrian could fall victim to the exposure. Installing the wrong floor for the

expected environment, unforeseen transition issues, inadequate cleaning or repairing of defective floors, trip and slip exposures in parking areas, sidewalks, and more are common problems.

Facility Design Guidelines

The International Building Codes, American with Disabilities Act Accessibility Design Guidelines (ADAAG) and other design standards describe the importance of "slip resistant" flooring and stair tread material in design but leave it to the designer to make the best choices on selection of materials. The Building Code Commentary provides additional information on slip resistant surfaces but does not specify standards or performance levels for slip resistance.

ASTM F1646-2012, Standard Terminology Related to Safety and Traction of Footwear[15] offers one of the better definitions of "slip resistance' and "slip resistant" and are as follows:

- Slip resistance, n—the relative force that resists the tendency of the shoe or foot to slide along the walkway surface. Slip resistance is related to a combination of factors including the walkway surface, the footwear bottom, and the presence of foreign materials between them.
- Slip resistant, n—the provision of adequate slip resistance to reduce the likelihood of slip for pedestrians using reasonable care on the walking surface under expected use conditions

In its simplest sense, a slip resistant surface is one that will permit an individual to walk across it without slipping.

Many designers choose flooring on the basis of aesthetics and/or cost rather than slip resistance performance and durability over time. Installing the right floor the first time can potentially save millions of dollars in costly floor treatments, repairs, or even replacement.

There are many different types of flooring, including a variety of tiles, carpeting, epoxy floors, terrazzo and concrete. Determining factors for floor selection should be to install slip resistant floor surface materials for the expected traffic load and environment. If the floor is expected to be wet with contaminants present, then those factors should drive the decision on what floor surface to install. There is more flexibility in the choice for a floor used in mostly dry conditions, since most dry, clean floors are "slip resistant."

Slip resistant qualities of a new floor may be altered due to high traffic, especially if the floor offers little durable qualities. What might seem inexpensive today could be more expensive in the long run if the floor has to be replaced due to excessive wear sooner than expected. Wet or contaminated conditions determine whether the floor offers the best slip resistant qualities.

Surface roughness affects friction; selection of floor surfaces with adequate roughness characteristics may potentially reduce slip and fall accidents[16]. The higher the coefficient of friction, the more slip-resistant the surface. For example, 0.1 is very slippery while 0.8 is relatively non-slippery. Most studies show that people can walk comfortably and safely on surfaces with a coefficient of friction greater than 0.4, but 0.5 offers an additional safety factor[17]. This is called a slip-resistant surface. Measurement of slipperiness using tribometers is beyond the scope of this article.

The selection of flooring should also consider transition areas. A transition from a carpeted floor or non-slippery floor to a glazed tile or more slippery walking surface could increase the likelihood of a slip and fall due to the individual's lack of detection of the transition

(change in slip-resistance) and appropriate gait adjustments. In general, flooring should have similar slip-resistance properties when transitioning between different types of flooring, especially when liquid contaminants may be present.

Entrance design and use of matting is also important to slip and fall prevention. Mats can improve overall floor maintenance by absorbing moisture and scraping soil particles from footwear, thereby, keeping the floor in a clean dry condition and protecting the floor from excessive wear. A rule of safe practice is that footprints or water prints should not be seen beyond the last mat of an entrance. Mats can protect a floor from unnecessary wear and remove water between the shoe and floor.

Stairway Design

Types of missteps on stairs include oversteps, under steps and air steps. In all cases, should a stumble occur on a stairway especially when descending; the presence of a properly designed and installed handrail system is the only thing separating the pedestrian from serious injury. Fortunately, most of the public accessibility guidelines on stairway design including the international building codes, NFPA 101, ADA, and ANSI are fairly consistent on riser and tread dimensions and handrail installations. These same guidelines mention the importance of "slip resistant" treads and the same guidelines above for walkway surfaces selection above applies to stair treads as well. What is or is not a slip resistant tread depends on whether the stairway is inside, outside and exposed to contaminants such as grease, oil, particulate soils, water or any combination.

One and two-step stairway designs are the most difficult to control designs and should be avoided whenever possible. Controls are limited but can include remodeling the elevation to a ramp or installation of handrails. Riser and tread dimensions should follow that of standard stairways. Check the building codes for requirements.

Preventing Trips and Falls

Trip hazards should be eliminated through facility design or maintenance if at all possible. However, if elimination is not possible then other options include:

- For changes of level 1/4 inch to 1/2 inch (6 mm to 13 mm) bevel the edge with a slope no greater than 1:2. Slope is the angle of incline usually given as a ratio of the rise (or vertical height) to the run (or horizontal length). The larger the run the more gentler the incline angle.
- For level changes greater than 1/2 inch, (13 mm) install a ramp with maximum slope 1:12.
- A third but less desirable option is to make hazard visually noticeable through appropriate detectable warnings.

Outdoor Falls

Slips, trips, and falls in outdoor environments can be caused by rain, sleet, ice and snow, and particulate soil that cause surfaces to become slippery or produce poor traction. While we cannot control environmental conditions that increase slipperiness of outdoor walkway surfaces, we can certainly reduce the likelihood of falls through improved design of exterior sidewalks, curbs, parking areas, improved lighting, and improved maintenance to increase awareness and eliminate hazards.

Sidewalks, Curbs, and Parking Lots

A business owner may not be responsible for injuries resulting from a fall on a public sidewalk located outside his or her property. However, some courts may impose liability for injuries on a sidewalk used exclusively by customers coming to and from the business. Consult with legal counsel if you have questions on liability.

A parking lot owner however can be responsible for maintaining the parking lot in a manner such that it is reasonably safe for people using it. This includes:

- Fill and patch cracks and holes.
- Repair and eliminate raised areas due to tree roots, settling, cold weather (frost heaves), and ordinary wear and tear.
- Reduce surface water by directing roof drainage away from sidewalks and parking areas.
- Clear sidewalks/parking areas of snow/ice before employees and guests arrive.
- Center and secure parking stoppers.
- Paint or stain parking stoppers near entrances Safety Yellow to improve visibility.

Curb Ramps and Handicap Ramps

State, local and national codes specify guidelines/requirements for curb ramps and handicap ramp design. For example, ramp slopes 1:15 minimum to 1:12 maximum with "slip-resistant" surfaces is often cited. As mentioned above, there are no specific guidelines on what "slip-resistant" means but some codes specify grooving or other alterations of the curb ramp to improve slip-resistance. Check with your state and local codes for requirements on ramp slip-resistance guidelines. Handicap ramps and curbs are colored Safety Yellow (see below). In some state or local codes, curbs or fire lanes in front of buildings are required to be painted red so be familiar with code requirements before giving recommendations.

Color, Contrast, and Visible Warnings

As mentioned above, recent U.S. Access Board Research recommends Safety Yellow as the preferred color for persons having very low vision. Yellow or yellow-orange warning surfaces are preferred over black warning surfaces. Safety Yellow therefore is a color most often used for visible warning in the pedestrian/highway environment.

Outdoor Lighting

Inadequate lighting may also lead to accidents involving falls in parking lots, trips over curbing, falls on a step or stairs from a parking lot to a store, and trips and falls due to holes, cracks, and uneven surfaces.

Summary

In summary, fall prevention programs need to be proactively managed. Prevention strategies include selecting the right floor surface, maintaining the floor through good housekeeping programs, and conducting periodic inspections for defects. A slip and fall prevention strategy with design focus includes entrance design and proper installation and design of matting systems. Like other safety and health systems, preventing slips and falls requires an integrated approach with everyone in the organization especially those associated with facility design such as

architects, design and construction, facility and property managers. Education and training for these key stakeholders in causes of falls and prevention as well as communication among all stakeholders is essential to the success of prevention efforts.

Endnotes

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