Preventing Slips and Falls

According to published research by the Liberty Mutual Research Institute for Safety, same-level slips and falls represent nearly 11 percent of all workers compensation claims and over 13 percent of all claims costs. This is second only to manual material handling, which represents 37 percent and 40 percent, respectively.

In most industry groups, slips and falls represent the highest, or second highest, type of workers compensation claim.[1] In addition, 11 percent of low back pain-related claims and 12 percent of low back pain-related claims costs are attributed to slips and falls.[2]

The Liberty Mutual Workplace Safety Index ranking of the 10 leading causes of workplace accidents and the Liberty Mutual Executive Survey of Workplace Safety of 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 the same level represents $4.4 billion, or 11.46 percent of the total $38.7 billion—second behind overexertion. But, according to the executive survey, most executives perceive falls on the same level to be much less of a problem—the seventh most important cause overall.

Why the difference between reality and the perceived importance of slips and falls? Why do slips and 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 and falls occur and the development of managed safety processes, which target those complex causes.

Figure 1. Slip and Fall Prevention Continuum

Causes of Slips and Falls

Causes of slips and falls are complicated and involve several sciences and disciplines. These disciplines include ergonomics, biomechanics, psychology and tribology.

Ergonomics is involved in slips 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 may 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.[3] Second is muscular strength. Several 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.

Biomechanics involves the study of the mechanics of the body and how we walk and interface with surfaces as we walk. This information is helpful in understanding the dynamics of slipping and at what point a fall might occur. For example, 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 usually results in uncontrolled forward movement and most often results in a fall.[3] However, recent research has shown heel slip distance and perception of slipperiness are not in agreement.[4]

Psychology is how we perceive and respond to slippery conditions. 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.

Tribology is the study of the interaction of sliding surfaces and 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. More recently, tribology has been applied to slips and falls.

In slips and falls, tribology is commonly associated with friction between the shoe sole and the floor surface, lubrication at the interface or contaminate on the floor surface (such as water, grease or oil) and wear of floor surface and shoe sole material over time. All three are considered when assessing the potential for slips and falls and all three support why controls for slips and falls are so important.

Same-Level Falls

Causes of slips, trips and falls are not fully understood but before prevention strategies can be implemented, clarification of accident and injury mechanisms are important[5]. Many same-level falls can be 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 dressings or finishes, inappropriate floor surface materials for the environment, 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. 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.

Other factors that increase the likelihood of slips and falls on floor surfaces include insufficient lighting, uneven surfaces and unexpected changes in environment, including transitions from tile to carpet, concrete to tile, hot to cold, and dry to humid. Transitions in height can also be a problem. Slips and falls from stairs have similar causes in addition to poor tread design and lack of handrail protection.

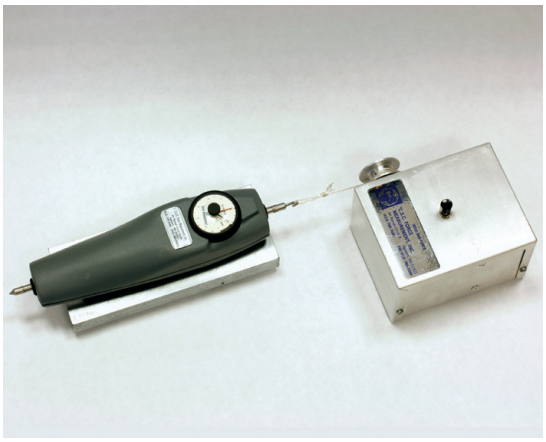

Figure 2. Horizontal Pull Slipmeter (HPS)[7]

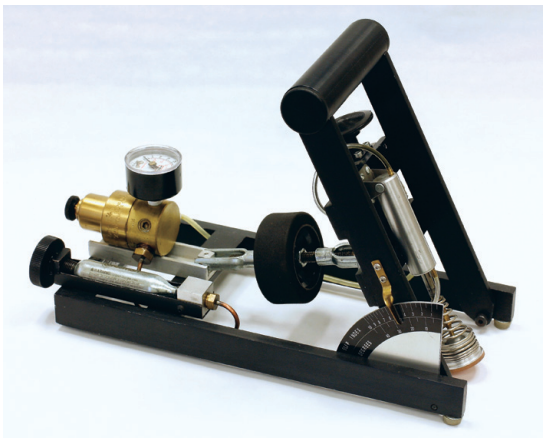

Figure 3. English XL (VIT)[8]

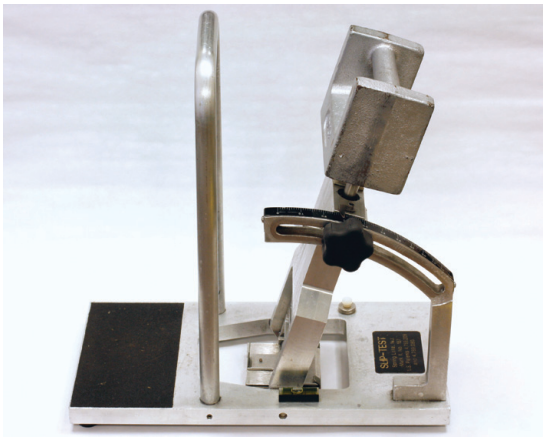

Figure 4. Brungraber Mark II[8]

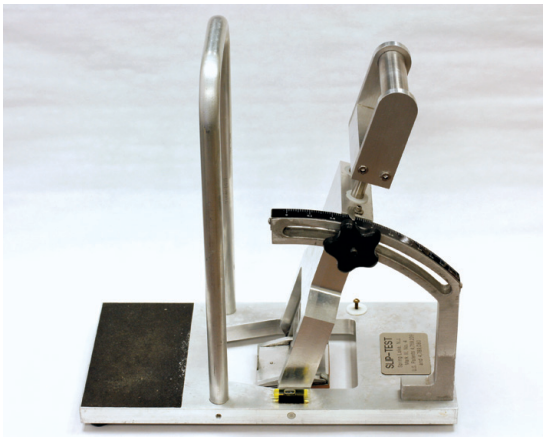

Figure 5. Brungraber Mark III[8]

What is Friction?

Friction is defined as the resistance to movement of one body over another, and is described here as the interface between shoe sole and floor surface. The coefficient of friction (μ) is defined as the ratio between friction force (F) to normal force (F_N), or mathematically expressed as:

$$\mu = \frac{F}{F_N}$$

Friction depends on contaminates on the floor, floor surface material, surface finish, shoe sole material, surface finish on the shoe, and shoe sole tread pattern, etc.

Friction or traction between the shoe and floor depends on all these factors. For example, we know that water tends to decrease the coefficient of friction, consequently increasing the chances of falling. How much? We don't know because it depends upon the floor surface, the shoe material and other factors. This is why it is difficult to predict when slips and falls will occur.

Measuring Slip Resistance

An important American National Standard Institute (ANSI) standard was released in 2001 that deals with slip resistance on working / walking surfaces. ANSI/ASSE A1264.2-2006, *Standard for the Provision of Slip Resistance on Walking/Working Surfaces*[6] addresses floor surface characteristics, footwear traction properties, environmental factors (water, oil, etc.) and management controls.

ANSI/ASSE 1264.2 describes slip-resistance testing of floors using four approved slip meters; including the Horizontal Pull Slipmeter (HPS) developed by the Liberty Mutual Research Institute, the Brungraber Mark II Portable Inclinable Articulated Slip Tester (PIAST), the Brungraber Mark I Portable Articulated Slip Tester (PAST) developed by Dr. Robert Brungraber, and the Variable Incidence Tribometer (VIT) or English XL developed by William English. The HPS slip meter can be used only on dry, clean floors, while the PIAST and VIT can be used

for both wet and dry floors. The ANSI standard includes a 0.5 coefficient of friction (COF) slip-resistance guideline for dry floor conditions only. ANSI/ASSE 1264.2 recognizes that the 0.5 COF guideline should not be used alone when evaluating slip resistance. Other factors to be evaluated must include footwear, environment and others described above. The correct use of a slip meter is to evaluate the slip resistance of the floor surface as part of an overall fall prevention program.

The slip meters above report results as either COF or Slip Index values. The Slip Index is expressed as the COF times ten, and for the HPS is interpreted as 5 or less (relatively slippery), 5–6 (generally acceptable), or 6 or higher (relatively not slippery).

Some floor dressing and polish manufacturers cite research that their products are UL listed[9] with a 0.5 COF. This number is for dry, clean floor conditions only. Adding water or other contaminates to the floor will invalidate this number.

The 1990 Americans with Disabilities Act; The Americans With Disabilities Act Accessibility Guidelines (ADAAG), cites a minimum COF of 0.6 for level surfaces and 0.8 for ramps, but specifies no method for determining compliance.

Slips and Falls Prevention

A managed slip and fall prevention process can be depicted as a work system continuum with elements indicated in Figure 1.[10] The circular arrangement (continuum) represents an extensive palette of the various elements influencing the falls management process. Use the following guidelines when developing a slip and fall prevention program.

Housekeeping and Maintenance

- Develop written floor cleaning protocols that address specific floor contaminants:
  - Identify the contaminant and select cleaners that will break it down.
  - Identify the concentration of cleaner desired to remove the contaminant and the tools you need to clean the contaminate. Does the tool remove the contaminant or spread it?
  - Determine an appropriate floor-cleaning schedule and stick to it. Identify those responsible and the time of day cleaning should take place to reduce the chance of slips and falls.
  - Perform occasional testing of floor surfaces to monitor slip resistance levels and determine effectiveness of floor cleaning protocol.
- Train housekeeping staff or persons responsible in inspection, maintenance and cleaning requirements, inspection maintenance and cleaning procedures, safe handling and disposal of chemicals and solutions, emergency conditions and operations, and record keeping or reporting related to housekeeping and maintenance.
- Ensure adequate lighting is available to see floor hazards and defects.

Housekeeping Behavioral Controls

- Identify and report potential hazards to appropriate supervision.
- Maintain "sweep logs" or perform routine inspections, including unannounced inspections, and record the results.
- Publicly congratulate and recognize employees in best-performing departments.
- Measure hazards or cleanliness as these are more reliable indicators than measuring slip and fall accidents.
- Hold first-line supervisors accountable for hazards in their departments.

Warnings and Signage

- Provide warnings or signage whenever a slip and fall hazard has been identified and leave in place until appropriate action can be taken. Warning signs should use symbols that follow ANSI Z535.3 2007, *Criteria for Safety Symbols*.
  - Provide barricades and warning signs to isolate processes in hazardous areas. Signs can be good reminders, especially when it comes to areas exposed to the public. Signs reminding employees to pick up and throw away all waste can also be effective.

- Provide enough trash containers located close to points of waste generation. If trash containers are not close, waste materials will probably end up on the floor to be swept up later.

Floor Mats

- Select mats whose edges will not curl by design. These mats often have a beveled edge or a flat edge to reduce tripping exposure.
- Select mats with non-slip backing that resists movement.
- Select mats that guard against damage to underlying floor surface caused by mold and mildew.
- Routinely inspect mats for damage and excess wear, and replace as necessary.
- Do not place mats or runners against objects that don't allow the mat to lie flat; e.g. machinery and process areas, doors or furniture.
- Establish procedures for the placement, maintenance, inspection and storage of mats.
- Store mats or runners to prevent edges from curling.

Floors and Floor Treatments

- Determine whether current floor surface materials offer sufficient slip-resistant qualities for the environment and, if not, consider replacement.
- When it is not practical to replace flooring, consider applications or treatments to improve slip resistance on floor surfaces. Examples include abrasive floor treatments, chemical etching and carpeting:
  - Abrasive floor applications provide a rough surface treatment to enhance surface traction and impart greater slip resistance. Cleaning, durability and cost must be considered. Some inexpensive floor applications can deteriorate or wear away with time and need to be reapplied. Broom-finished concrete floors, certain paints and epoxy compounds containing abrasive granules are be good examples of durable floors. Abrasive strips wear away quickly and must be replaced often.
  - Chemical etching professionally applied to natural stone or concrete floors produces microscopic ridges and valleys in the floor and increases surface roughness. Etching produces a higher coefficient of friction with most shoe sole materials. This type of floor can lose its effectiveness if not cleaned thoroughly and frequently.
  - Carpeting offers inherent slip-resistant qualities but can be difficult to keep clean and needs to replaced often in high traffic areas.

Footwear

- The Shoe and Allied Trade Research Association (SATRA) has produced guidelines for slip-resistant sole design as follows: (See Liberty Mutual Reference Note LC 5407, Preventing Slips and Falls: Slip Resistant Footwear[10])
  - Sole should have a raised tread pattern on heel and sole, with a leading edge in many directions. In other words, a crosshatch or similar design.
  - Tread pattern should extend over whole sole and heel area.
  - Sole should have a flat, flexible bottom construction. Consider a low-density midsole that conforms to the ground and maximizes contact area.
  - A square heel breast (acts as leading edge) is recommended as opposed to a rounded edge. Consider a wedge sole for indoor occupational footwear: catering, hospitals and sports footwear.
- Other researchers recommend a microcellular shoe-sole material so that a rough sole surface exists even when worn.[11]
- Selection of slip resistant footwear materials should include consideration of the floor material and surface conditions expected in the job.[12, 13]

Summary

In summary, slips and falls are very costly and caused by multiple factors. The science of tribology describes these factors nicely and includes friction between the shoe sole, the floor surface, the environment and wear over

time. Prevention must address all these factors. A prevention-based management program addressing slips and falls must include floor cleaning protocols and training maintenance personnel.

By applying these four rules of slip and fall hazard identification you will be well on your way to preventing indoor slips and falls.

- **Rule 1:** Investigate all slip and fall accidents, incidents and near incidents thoroughly, from a cause and prevention standpoint.
- **Rule 2:** Look for the root cause(s) of slip or fall accidents.
- **Rule 3:** Conduct periodic accident reviews to determine trends in the causes of slip, trip or fall accidents.
- **Rule 4:** Conduct periodic self-inspections to look for slip, trip or fall hazards and risk factors. Make a checklist of cause factors based on any slip, trip or fall accidents. Eliminate any exposures before they cause an accident.

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