

Tribology: Preventing Slips and Falls in the Workplace

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Slips and falls in the workplace represent more than a trivial problem. According to published research by the Liberty Mutual Research Center for Safety & Health (see related article in this issue and sidebar “Perception ≠ Reality”), 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 claim¹. 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 falls².

The Liberty Mutual Workplace Safety Index ranking of the 10 leading causes of workplace accidents and the Liberty Mutual Executive Survey of Workplace Safety, both released in 2001, reveal 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 in the workplace 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.

This article explains the causes of workplace slips and falls using the science of tribology, and explains how an effective slip and fall prevention program can reduce or eliminate those causes.

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 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. 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.
- **Psychology** is how we perceive and respond to slippery conditions. For example, when a person perceives a slippery condition (e.g., walking on ice), that person will adjust his or her gait to prevent a slip. A problem often occurs when a person does not perceive a slippery condition, does not adjust his or her gait, slips unexpectedly, fails to recover and falls. A good example is when there is water or grease on the floor, which hasn't been cleaned up, or the age-old example of a banana peel on the 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.

Causes of Same-Level Falls

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, and 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. However, grease, dirt or other contaminates can reduce that benefit by filling in the voids (thus the importance of floor cleaning protocols discussed in "Slips and Falls Prevention"), and the peaks can wear over time, thus reducing the slip-resistance benefit.

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

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 (F_N) force or mathematically expressed as:

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

Coefficient of friction values can be interpreted as .5 or less (relatively slippery), .5-.6 (generally acceptable), or .6 or higher (relatively not slippery).

Friction depends on contaminants 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, therefore increasing the chances of falling. How much? We don't know, because it depends on floor surface, shoe material and other factors. This is why it's difficult to predict when slips and falls will occur.

Measuring Slip Resistance

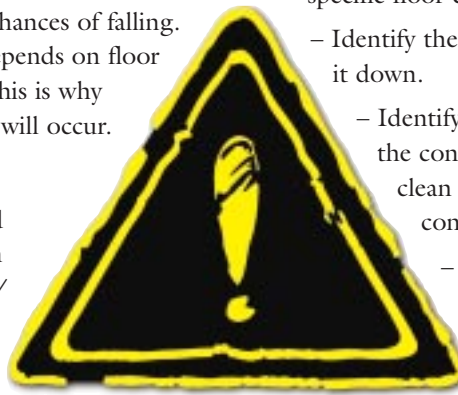
An important American National Standard Institute (ANSI) standard was approved in 2001 dealing with slip resistance on working/walking surfaces. ANSI/ASSE A1264.2-2001 *Standard for the Provision of Slip Resistance on*

Walking/Working Surfaces addresses floor surface characteristics, footwear traction properties, environmental factors (water, oil, etc.) and management controls.³

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 Center, the Brungraber Mark II Portable Inclinable Articulated Slip Tester (PIAST) and Brungraber Mark I Portable Articulated Slip Tester (PAST), developed by Dr. Robert Brungraber, and the Variable Incidence Tribometer (VIT), 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. The standard includes a .5 coefficient of friction (COF) slip-resistance guideline for dry floor conditions only. ANSI/ASSE 1264.2 recognizes that the .5 COF guideline should not be used alone when evaluating slip resistance. Other factors 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.

Some floor dressing and polish manufacturers cite research that their products are UL listed with a .5 COF. This number is for dry, clean floor conditions only. Add water or other contaminants and this number is no longer valid.

The 1990 Americans with Disabilities Act-The Americans with Disabilities Act Accessibility Guidelines (ADAAG) cites a minimum COF of .6 for level surfaces and .8 for ramps, but specifies no method for determining compliance.



Slips and Falls Prevention

Preventing slips and fall requires a comprehensive approach, which considers all three scientific disciplines of tribology. Use the following guidelines when developing a slip and fall prevention program:

Housekeeping

- Develop written floor cleaning protocols, which 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, including what 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 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 as to 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 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 whenever a slip and fall hazard has been identified until appropriate correction can be effected. Warning signs should use symbols that follow ANSI Z535.3 1991 *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 generation of waste. If trash containers are not close, waste materials will probably end up on the floor to be swept up later.

Floor Mats

- Mats should be secured against movement.
- Install mats so they do not create a tripping hazard. Surface mats and runners should have a beveled edge, flat edge or other treatment to help reduce the possibility of tripping on the edge.
- Routinely inspect and adequately maintain mats. Replace damaged mats promptly.
- Establish procedures for the placement, maintenance, inspection and storage of mats. Store mats or runners to prevent curling of edges.

Floors and Floor Treatments

- Determine whether current floor surface materials offer sufficient slip-resistant qualities for the environment and, if not, consider replacement.
- When not practical to replace flooring, consider applications or treatments to floor surfaces to improve slip resistance. 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 examples.
- Chemical etching or hydrochloric acid professionally applied to mineral 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 be 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:
 - 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 worn⁴.
- Selection of slip resistant footwear materials should consider the floor material and surface conditions expected in the job⁵.

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 and floor surface, the environment and wear over time. Prevention must address these factors. A prevention-based management program addressing slips and falls must include floor cleaning protocols and training of maintenance personnel. Apply these four rules of slip/fall hazard identification and you'll be well on your way to preventing indoor falls:

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A Success Story

Slippery floor conditions are inherent to this large casual dining company's operations. In the organization, 56 percent of the workers compensation accidents and 74 percent of workers compensation costs are attributed to slips, falls, lifting and carrying. Slip and fall incidents are commonly caused by grease condensing on the floors, water splashes and leaks, food and ice spills, and ice forming on freezer floors.

A new division-level safety committee sought to reduce the number of slip and fall incidents, and their associated costs, and to educate their workforce in fall-prevention measures. Liberty Mutual Loss Prevention worked closely with the committee to heighten management's awareness of slip and fall incidents, and prevention measures needed at the local restaurant level. Loss Prevention consultants visited approximately 20 percent of the restaurants in the division, emphasizing floor maintenance and cleaning procedures. Loss Prevention also addressed other critical work activities associated with slips, falls, lifting and carrying.

Preventive measures at all restaurants focused on performance issues (slip-resistant footwear, cleaning procedures, clean-as-you-go policy) and correction of physical defects affecting the slip resistance of floor tile (worn or broken tile, worn or missing grout, poor drainage, etc.). A "back-to-basics" floor cleaning campaign was a catalyst to improvement in this loss area.

Fiscal year loss comparisons reveal a 14 percent frequency rate reduction in workers compensation falls and handling claims, and the prevention of 73 accidents, or a savings of \$76,772 for the division.

Rule #1:

Investigate all slip/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: Do periodic accident reviews to determine trends in the causes of slip, trip or fall accidents.

Rule #4: Do periodic self-inspections to look for slip/trip/fall hazards or risk factors. Make a checklist listing your cause factors based on your accidents. Eliminate exposures before they cause an accident.

References

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