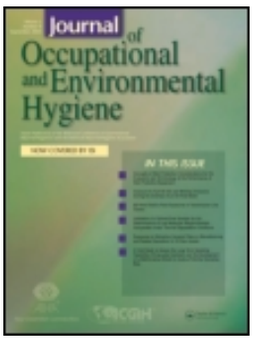

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Factors Influencing Restaurant Worker Perception of Floor Slipperiness

Theodore K. Courtney, Yueng-Hsiang Huang, Santosh K. Verma, Wen-Ruey Chang, Kai Way Li, and Alfred J. Filiaggi

Liberty Mutual Research Institute for Safety, Hopkinton, Massachusetts

Falls are responsible for a substantial injury burden in the global workplace. Restaurant environments are particularly challenged by slips, trips, and falls. This study explored those factors that could influence workers' self-reports of slipperiness in U.S. fast-food restaurants. One hundred and twenty-six workers employed in 10 fast-food restaurants in the northeastern United States participated in the study representing a study-wide response rate of 87.5%. Participants' ratings of floor slipperiness and occupational slip history within the past 4 weeks were collected through written questionnaire. Additional factors collected by questionnaire included age, gender, shift length, and shoe type. Shoe condition (wear) and shoe contamination were visually assessed by the investigators. Floor friction was also measured. Lower restaurant mean coefficient of friction and the presence of contamination on workers' shoe soles were environmental factors significantly associated with workers reporting more slippery conditions. A recent workplace history of slipping with or without a subsequent fall was also significantly associated with workers reporting more slippery conditions. Workers over the age of 45 reported conditions to be significantly less slippery than younger workers. The results suggest that worker ratings of slipperiness are influenced not only by the actual level of friction but also by the other individual and environmental factors noted above. Recommendations for future studies would include a longitudinal design to better capture the temporal sequence between these variables. More field research is needed to better understand the association between workplace conditions, worker perception of slipperiness, and slipping at work.

Keywords falls, perception, restaurants, slipperiness

Address correspondence to: Theodore Courtney, Liberty Mutual Research Institute for Safety, Quantitative Analysis Unit, 71 Frankland Road, Hopkinton, MA 01748; e-mail: theodore.courtney@libertymutual.com.

INTRODUCTION

Slips, trips, and falls (STF) are responsible for a substantial injury burden in the global workplace.[1–2] Slipperiness contributes to between 40% and 50% of fall-related injuries in the United States and in Europe.[2]

Restaurant environments are particularly challenged by STF. In the United States, one out of every three disabling restaurant injuries is the result of STF, with the largest percentage of injuries (26%) attributed to falls on the same level.[3] Falls to the floor account for 6 of the 10 most disabling restaurant injuries in terms of the median number of days away from work (range = 12–82 median days lost). Leamon and Murphy[4] reported that the incidence rate of falls on the same level over a 2-year period was 4.1 per 100 full-time equivalent restaurant employees. They further calculated that total workers' compensation losses due to same level falls in restaurants resulted in an industry-wide cost of $116 per restaurant worker.

Slips and falls can occur on wet or contaminated surfaces and where there are transitions in floor types (e.g., from the carpet in a dining area to the ceramic tile in a kitchen area). Common sources of slippery floors include dishwashing overspray or runoff, leaking equipment or pipes, food debris, and spillage from transport of open containers (such as those holding fryer grease and food wastes).[3]

In human locomotion, the slipperiness of a floor is initially judged by several mechanisms, which may include visual perception and proprioception to maintain body balance. People can and do manipulate gait when aware of walking on slippery surfaces.[1,5–6] Discontinuities in friction across floor surfaces may result in unexpectedly encountering a low friction area without body posture adjustments, leading to a fall. Recent reports in the literature have suggested that worker self-reports may be a reasonably good indicator of floor slipperiness.[5]

Several studies have compared friction measures with subjective slipperiness ratings. Myung et al.[7] reported that higher measured static coefficient of friction (COF) values were associated with less slippery subjective rankings from subjects walking on the surfaces in question, with the exception of vinyl tile.

In contrast, Cohen and Cohen[8] had subjects visually assess tile samples and contrast them with a standard tile (COF = 0.5). They reported a significant number of disagreements between subjects' responses and the static COF values of the tiles.

Swensen et al.[9] collected subjective ratings and rankings of steel beams of varying coatings from ironworkers and college

students after walking on the surfaces. They reported that the correlation between subjective ratings and the measured static COF was strong for both ironworkers ($r = 0.75$) and college students ($r = 0.90$).

Grönqvist et al.[10] compared walking-based subjective ratings with objective biomechanical and tribological slipperiness measures in scenarios involving slippery contaminants. They reported a significant correlation between the subjective evaluation scores and the objective measurements, such as slip distance ($r > 0.99$, $p < 0.01$), and the measured dynamic COF ($r = 0.97$, $p < 0.05$).

Li et al.[11] compared COF measured by the Brungraber Mark II slipmeter with participants' subjective ratings of different floor types, states of contamination, and types of footwear. They reported correlations ranging from $r = 0.8$ to $r = 0.975$ under all surface conditions.

The results of these studies vary but generally show a positive relationship between objective (typically friction) and subjective measures. However, most of the published studies comparing friction and worker perception of floor slipperiness were conducted in laboratory settings with new floor surfaces and artificial contaminants. Controlled, artificial conditions may not be representative of real conditions. The potential for extension of the conclusions of laboratory studies could be limited in less controlled, real-world working environments. In particular, the influence of more variable environmental conditions (e.g., degree and nonuniform distribution of contaminants), differences between lab subjects and actual working populations, and reductions in procedural control afforded by laboratory designs could all be influential. Compared with laboratory studies, field studies of objective and subjective measures of slipperiness are rare.

The first of a series of studies targeting such relationships between objective and subjective measures of slipperiness in active restaurant environments was recently published by the authors.[12] In that study, among 56 restaurant workers in Taiwan, a significant correlation ($r = 0.49$, $p < 0.0001$) between COF values measured with the Brungraber Mark II slipmeter and worker self-reports of slipperiness was observed.[12] This was a more modest degree of association than those reported in the laboratory environment. The potential influence of other factors in the field environment could account for the reduced association.

Relatively little is known about the factors that may influence workers' self-reported perception of floor slipperiness in the active working environment. The present study explored personal, situational, and physical factors that could potentially influence workers' self-reports of floor slipperiness in U.S. fast-food restaurants.

METHODS

Workers in 10 fast-food restaurants in the northeastern United States were recruited to participate in this study. Subjects were compensated for their participation, and the study was conducted under the supervision and approval of the Liberty Mutual Research Institute for Safety Institutional Review Committee for the Protection of Human Subjects.

A survey instrument modeled after Chang et al.[12] was developed to assess workers' floor slipperiness perception. Each participant completed the survey anonymously. Surveys were routinely collected during and immediately following the lunch period on a weekday, as this provided the greatest concentration of active employees during the day. Participants completed the survey questionnaire during their break outside the kitchen (in a dining room location set aside for the study team).

Measures

Workers were asked to rate floor slipperiness based on a typical workday. A 4-point rating scale was used, from 1 (not slippery) to 4 (very slippery). Workers were also asked whether they had experienced a slip, with or without a subsequent fall, while working at the restaurant within the previous 4 weeks (positive slip history). The survey also collected data on each worker's age, gender, ethnic group, tenure, work hours per week, shift length, and shoe type, among other factors.

Workers had the option of completing the survey in English, Spanish, or Portuguese; study personnel fluent in both Spanish and Portuguese were present at each site during data collection. The fast-food kitchen areas investigated in this study included cooking, food preparation, and front counter/service areas. An individual worker's ratings across all areas in which they normally worked were combined to develop an overall individual perceived slipperiness rating. Shoe type (antislip or not), shoe condition (visible tread wear observed or not), and visible shoe contamination (present or not) were assessed by visual inspection by an investigative team member. These on-site assessments were later confirmed by a panel of the investigators (T.C., W.C., K.L., A.F.) who examined digital photographs taken to document the type and condition of each worker's footwear.

Floor friction was also measured. Coefficient of friction values for a minimum of 39 tiles in the main working and traffic areas of each restaurant kitchen were obtained using a Brungraber Mark II slipmeter with Neolite test liners (pads). The F-1677-96 standard method published by the American Society for Testing and Materials[13] was used, along with protocol refinements recommended by Chang.[14] Global mean COF scores for each restaurant were calculated from the measurement results.

Data Analysis

Spearman's correlation coefficient for continuous variables and t-tests or analysis of variance (ANOVA) for categorical variables were used to assess univariate associations between worker slipperiness perception and personal factors (including workplace slip history) and floor and shoe conditions. Linear regression was used to assess multivariate associations. All data analyses were conducted using the SAS system version 9.1 (SAS Institute, Inc., Cary, N.C.).

TABLE I. Participant Demographics, Slip History, and Footwear Conditions

Variable	Frequency	Percentage
Age[A]		
14–24 years	59	48.0
25–34 years	26	21.1
35–44 years	17	13.8
45–54 years	10	8.1
55–64 years	8	6.5
65+ years	3	2.4
Gender[B]		
Female	75	60
Male	50	40
Ethnicity		
Asian	5	3.97
Black	5	3.97
Hispanic	56	44.44
White	60	47.62
Shift start time		
Before 7 a.m.	46	36.51
Between 7–10 a.m.	39	30.95
After 10 a.m.	41	32.54
History of slip (prior 4 weeks)		
No	83	65.87
Yes	43	34.13
Shoe contamination		
Absent	73	57.94
Present	53	42.06
Shoe sole wear		
Not worn	51	40.48
Worn	75	59.52
Slip resistant shoe		
No	81	64.29
Yes	45	35.71

[A]Three values missing for age.
[B]One value missing for gender.

RESULTS

One hundred and twenty-six employees participated in the study for a response rate across all 10 restaurants of 87.5%. Table I summarizes participant demographics, slip history, and footwear conditions. Workers averaged 34.5 (standard deviation [SD] = 8.6) work hours per week, had a mean age of 30 (range = 14–71) years, and had worked in their specific location for an average of 34.5 (median = 17) months. Sixty percent of the workers were women. Forty-eight percent of workers identified themselves as White, 44% as Hispanic, 4% as Black, and 4% as Asian.

Global mean COF across the 10 restaurants varied from a high of 0.81 to a low of 0.42, with a mean of 0.64, a median of 0.64, and a standard deviation of 0.11. Overall worker perception of slipperiness scores on the 4-point Likert scale ranged from 1 to 3.33 with a study-wide mean of 1.91, a median of 1.83, and a standard deviation of 0.60.

TABLE II. Spearman's Correlation Coefficients for Restaurant Mean COF, Length of Service, and Hours Worked on Perception of Slipperiness

Variable	Spearman Correlation Coefficient	*p* Value
Restaurant friction mean COF	−0.33	<0.001[A]
Length of service (months)	−0.14	0.14
Hours worked (per week)	−0.017	0.86

[A]Significant, $p < 0.001$.

Table II presents Spearman's correlation coefficients exploring the association between worker perception of slipperiness and mean restaurant COF, length of service, and hours worked per week. Restaurant COF was negatively correlated (as COF decreased, workers reported increased slipperiness) with worker perception of slipperiness ($r = -0.33$ $p < 0.001$).

Table III presents means and *p* values associated with t-tests and ANOVA for categorical variables. Visible contamination on the shoe ($p = 0.05$) and a history of a workplace slip and/or fall in the past 4 weeks ($p < 0.001$) were significantly associated with workers reporting more slippery conditions (greater perception of slipperiness). Age was marginally significant overall: $F(2, 123) = 2.79$, $p = 0.06$. The 46+ year age group reported significantly less slippery conditions compared with the 14–24 year age group ($p = 0.02$). Differences between the 25–45 year age group and either the younger or older age groups were not significant ($p = 0.25$ and $p = 0.18$, respectively).

Similar to univariate analysis, results from multivariate linear regression modeling presented in Table IV indicate that lower restaurant mean COF ($p < 0.001$), worker age less than 46 years ($p = .011$), visible contamination on shoe ($p = .008$), and a history of an occupational slip and/or fall in the past 4 weeks ($p = .013$) were significantly associated with greater perception of slipperiness.

For each 0.1 increase in restaurant mean COF (higher measured friction score), the mean worker slipperiness perception score *decreased* (indicating a perceived less slippery environment) by 0.19 ($p < 0.001$). To put this in perspective, mean COF values had a range of 0.39. Therefore, the difference between highest and lowest mean COF restaurants was approximately 0.74 points (i.e., 32% of the 1–3.3 range in slipperiness perception scores). A participant age of greater than 45 years was associated with a 0.42 point *reduction* in slipperiness perception score (perceived as less slippery, $p = .008$). The presence of visible shoe gross contamination was associated with 0.25 point *increase* in the slipperiness perception score (more slippery). A workplace slip history in the past 4 weeks was associated with a 0.28 point *increase* in slipperiness perception score ($p = .013$). Comparing those who did not report

TABLE III. One-Way ANOVA of Categorical Personal and Environmental Factors with Perception of Slipperiness

Variable	Mean Perception Score	*p* Value
Age[A]		
14−24 years	2.03	—
25−45 years	1.89	0.25
46+ years	1.66	0.02*
Gender		
Female	1.85	0.15
Male	2.01	—
Shoe contamination		
Absent	1.82	0.05*
Present	2.04	—
Shoe sole wear		
Not worn	1.93	0.77
Worn	1.90	—
Slip resistant shoe		
No	1.87	0.25
Yes	2.00	—
History of slip		
No	1.78	<0.001***
Yes	2.16	—
Shift start time[B]		
Before 7 a.m.	1.87	0.83
7–10 a.m.	1.98	0.56
After 10 a.m.	1.90	—

[A]Overall F(2, 122) = 2.7, p = 0.06.
[B]Overall F(2, 125) = 0.34, p = 0.72.
*Significant, $p < 0.05$.
***Significant, $p < 0.001$.

a slip (n = 83) with those who did (n = 42), nonslipper's ratings were significantly negatively correlated with restaurant mean COF ($r = -0.43$, $p < 0.001$) while slipper's ratings were not correlated with restaurant mean COF ($r = 0.02$, $p = 0.91$).

DISCUSSION

Worker self-reports of current or prior exposure are commonplace in the ergonomics literature on musculoskeletal disorders. Whereas their accuracy and precision are typically limited for epidemiologic investigations when compared with more quantitative observational or equipment-based measures,[15] they can provide an important worker-centered compliment to such measures.[16] It can be argued that there is warrant for their use in practice where their availability, practicality, and efficiency could prove useful in identifying exposures, prioritizing interventions, and even improving accommodative conditions.[17]

The slip, trip, and fall literature documents that humans are relatively capable discriminators of floor friction when presented with classic psychophysical test paradigms, such as paired comparison scenarios under controlled conditions in dry, wet, and contaminated conditions.[7,9,18] As noted previously, there are also several studies that have addressed the issue of relationship between subjective approaches and objective engineering measures.[7–10] However, these have been conducted under highly controlled and often completely artificial conditions limiting their generalizability to real work environments.

Friction

In the present study conducted in the field environment in active U.S. fast-food restaurants, a higher restaurant overall

TABLE IV. Multivariate Linear Regression Model of Association Between Worker Perception of Slipperiness, Personal Factors, and Floor and Shoe Conditions

Variable	Parameter Estimate	Standard Error	*t* Value	Pr > |*t*|
Restaurant friction Mean	−0.188	0.505	−3.72	<0.001***
Age (over 45 years)	−0.424	0.156	−2.72	0.008**
Tenure (months)	0.001	0.001	0.62	0.534
Gender	0.056	0.106	0.53	0.596
Shoe contamination	0.250	0.094	2.66	0.009**
Shoe sole wear	−0.066	0.120	−0.55	0.586
Slip resistant shoes	−0.071	0.154	−0.46	0.648
Shift start time	0.037	0.068	0.54	0.590
Hours worked (weekly)	0.006	0.007	0.85	0.399
History of slip	0.280	0.109	2.54	0.013*

Note: Overall $R^2 = 0.28$.
*Significant, $p < 0.05$.
**Significant, $p < 0.01$
***Significant, $p < 0.001$.

mean COF was significantly associated with decreased worker perception of slipperiness. The highest and the lowest mean COF restaurants represented a change of 32% in the perception rating. The finding that worker perception of slipperiness was correlated with floor friction was consistent with results from an earlier fast-food restaurant study conducted by the investigators in Taiwan.[12] Based on the findings from the two studies conducted in different countries, languages, and work environments, a significant association, though weaker than that found in laboratory studies, exists between these measures in the field environment.[5,7–11]

The present study identified several other factors (in addition to friction) that were significantly associated with workers' ratings of slipperiness and that may contribute to the observed difference in the degree of association between these objective and subjective measures in the laboratory and the field. These included gross contamination of the footwear, the age of the worker, and a prior history of slipping and/or falling in the prior 4 weeks at work. The implications of each of these are discussed below.

Contamination

Visible evidence of contamination was associated with increased worker perception of slipperiness. The presence of gross contamination (visibly evident contaminants such as foodstuffs, sauces, or other debris on workers' shoe soles) accounted for an 11% shift in the mean perception rating. This indicates that the presence of gross floor contamination can influence workers' slipperiness perception.

From a practical standpoint, the observation that 42% of participants in this study had such contamination suggests the need for better approaches to controlling gross contamination in fast-food restaurants. This may take the form of more frequent floor inspections during peak hours. Saari and Nasanen[19] reported substantial improvements in accident rates following implementation of positive feedback aimed at improving industrial housekeeping conditions. Management can play an important role by introducing workers to best practices and instilling good safety behaviors, including housekeeping.[3]

Age

Workers over 45 reported less slipperiness than their younger colleagues. The difference accounted for only an 18% shift across utilized perception score range. However, decreasing sensitivity (less slippery reports) in the ratings from older workers may reflect an influence of decreased sensory and motor perception.[20–21] With reduced sensitivity, older workers may be less likely to detect slipperiness changes. Combined with decreases in gait and postural control, including capabilities to recover balance with age, workers over 45 may potentially be more vulnerable to slippery conditions than their younger colleagues.

Epidemiologic evidence from the literature provides some support for this. Laflamme and Menckel[22] reported that the working surface accounted for more injuries among middle-aged and older workers. Falling (especially on the same level) was also more frequent among older workers. The former result was consistent with Bureau of Labor Statistics data indicating that the *floor, ground surface* was the leading source of disabling workplace injuries for workers 55 years and over.[23] Kemmlert and Lundholm[24] reported an increase in STF in workers aged 45 years and older. Courtney et al.[2] also reported that the incidence rate of fall-induced fatality increased sharply from age 55 and peaked in workers aged 65 and older.

Two alternative explanations could be that age was confounded with either job tenure or hours worked per week. However, neither tenure nor hours worked per week were significantly associated with changes in the perception score. Additionally, age remained significant when these same factors were controlled for in the multivariate linear regression analysis. A third alternative explanation could be that workers with more lifetime experience in restaurants (a factor not assessed in this study) reported conditions as less slippery. However, job tenure and experience could be expected to be correlated. The finding on the noninfluence of tenure in combination with the findings on the influence of age and the evidence from the literature suggest age as the most plausible explanation for the effect.[2,21–24]

Recent Slip or Fall

A recent workplace history of slipping with or without a subsequent fall was associated with increased worker perception of slipperiness (a shift of approximately 12% on the utilized perception scale). The investigators' prior experience with laboratory studies and the report of Cham and Redfern[6] suggested that a recent slip or fall experience might substantially alter participants' perceptions. Cham and Redfern observed that compensatory adaptations in stride length, acceleration, and other gait-related factors persisted in participants who had experienced a slippery surface even when they were returned to a known nonslippery surface. This concern led us to examine the potential influence of recent slip history on perception ratings. Comparing those who slipped in the past 4 weeks with those who did not, nonslipper's ratings were significantly correlated with friction score (Spearman's $r = -0.43$, $p < 0.001$). Slipper's ratings were not correlated (Spearman's $r = 0.02$, $p = 0.91$).

The Role of Perception

The present study sought to observe the potential influence of a variety of workplace factors (including friction) on worker perception of slipperiness. There remains substantial discussion as to whether measured friction can be considered the gold standard of slipperiness.[1,5] There are human aspects of slipping and falling that cannot be accounted for by the COF, including visual cues, proprioception, motor control, adaptive balance, memory, etc. In fact, Grönqvist et al.[5] argue that human-centered methods are complementary to, rather than redundant with, mechanical friction-based test methods, adding the human factor to the assessment of slipperiness. They further point out that human-centered methods have also been

used, in some cases, as the gold standard for experimental evaluation of mechanical test methods.

The findings of the present study document that worker's perception reports are associated with measured friction but are also associated with a number of other factors, potentially related to risk, for which measured friction cannot exclusively account. In this sense, a worker's self-report of slipperiness could provide additional information on what makes a work surface slippery and, as Grönqvist et al.[5] suggest, could potentially complement friction measurements.

There is already some support in the literature for use of a subjective, retrospective rating scale in a related capacity. Hirvonen et al.[25] asked workers to subjectively rate the risk of accidents (as opposed to degree of slipperiness) in their work tasks associated with slippery or uneven surfaces and stairs using a 4-point scale. Worker scores were added to achieve a grand risk score. Worker risk scores were significantly associated with a higher frequency of sudden acceleration events (a potential indicator of perturbation in stability indicating a slip).

Limitations

Floor friction is point-in-time dependent. The friction measurement results of the current study could reveal only the friction status at the time of measurement, but the results of perception survey likely reflected the floor conditions of both the most recent lunch period and other workdays. Chang[14] indicated that friction variations across different times of measurements using identical pads could be statistically significant, though surface contamination levels had a greater impact than variations over time.

Given the variety of worker footwear and sole materials encountered, as well as time and site access constraints, it was not possible to assess each type of sole material using a sample pad of that particular material throughout each sampled facility. Floor friction was measured using a single type of sample pad made of a man-made material, Neolite, a standard test material. In addition, whereas the presence or absence of gross contamination was assessed, it was beyond the scope of the study to assess the specific composition of each contaminant encountered. In addition to the study factors assessed, these measurement limitations may account, in part, for the lower association between friction and perception.

Additional factors that may have impacted the results included different kinds of shoe soles with different degrees of wear. Because the shoe material and tread pattern could affect the perception rating, not being able to control what workers wore could induce variations in perception. The potential influence of nonslip sole footwear vs. other footwear was assessed, but the difference in worker ratings was not significant. Workers' rating standards also likely varied by individual. However, these aspects would tend to bias results toward the null.

Participants used a 4-point scale in this rating design, which may have artificially constrained their ratings. Future applications of this approach should consider a greater number of response options (e.g., 8 to 10).

Another limitation is that several variables in the study were derived from self-reports of the participants. For example, participants may not have been able to accurately recall their slip and fall experience, which could result in the underreporting of these events in our study due to the length of time between the injury experience and the survey administration, the type of experience (e.g., falls may be better recalled than slips), and other recall biases. Given these limitations, care should be exercised when generalizing the results to other settings, particularly work settings other than fast-food restaurants.

CONCLUSIONS

The present study combined standardized friction measures, investigator observation, and a multilingual worker questionnaire to identify factors that could influence worker perception of slipperiness in the fast-food restaurant environment. As reported in prior studies, a lower device-measured restaurant mean COF was associated with an increased perception of slipperiness (workers reporting more slippery conditions). The results also suggest that a worker-centered approach to identifying slippery work conditions may reflect several other factors. The presence of visible contamination on workers' shoe soles was an environmental factor associated with workers reporting more slippery conditions. A recent workplace history of slipping with or without a subsequent fall was also associated with workers reporting more slippery conditions. In addition, workers over the age of 45 did not perceive slipperiness as well as younger workers. Due to the cross-sectional nature of the study, the temporal sequence between these variables could not be determined. Recommendations for future studies would include a longitudinal design to better capture the temporal sequence. More field research is needed to better understand the association between friction, shoe type, perception of slipperiness, and risk of slipping at work.

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REFERENCES

1. **Leamon, T.B.:** The reduction of slip and fall injuries: Part II—The scientific basis (knowledge base) for the guide. *Int. J. Ind. Ergon. 10*:29–34 (1992).
2. **Courtney, T. K., G.S. Sorock, D.P. Manning, J.W. Collins, and M.A. Holbein-Jenny:** Occupational slip, trip, and fall-related injuries—Can

the contribution of slipperiness be isolated? *Ergonomics 44*:1118–1137 (2001).
3. **Filiaggi, A.J., and T.K. Courtney:** Responding to disabling occupational injuries in restaurants: Practice-based approaches. *Prof. Saf. 48*(5):18–23 (2003).
4. **Leamon, T. B., and P. L. Murphy:** Occupational slips and falls: More than a trivial problem. *Ergonomics 38*:487–498 (1995).
5. **Grönqvist, R., J. Abeysekera, G. Gard, et al.:** Human-centerd approaches in slipperiness measurement. *Ergonomics 44*:1167–1199 (2001).
6. **Cham R., and M.S. Redfern:** Changes in gait when anticipating slippery floors. *Gait Posture 15*:159–171 (2002).
7. **Myung, R., J.L. Smith, and T.B. Leamon:** Subjective assessment of floor slipperiness. *Int. J. Ind. Ergon. 11*:313–319 (1993).
8. **Cohen, H.H., and D.M. Cohen:** Psychophysical assessment of the perceived slipperiness of floor tile surfaces in a laboratory setting. *J. Saf. Res. 25*:19–26 (1994).
9. **Swensen, E.E., J.L. Purswell, R.E. Schlegel, and R.L. Stanevich:** Coefficient of friction and subjective assessment of slippery work surface. *Hum. Factors 34*:67–77 (1992).
10. **Grönqvist, R., M. Hirvonen, and A. Tuusa:** Slipperiness of the shoe-floor interface: Comparison of objective and subjective assessments. *Appl. Ergon. 24*:258–262 (1993).
11. **Li, K.W., W.R. Chang, T.B. Leamon, and C.J. Chen:** Floor slipperiness measurement: Friction coefficient, roughness of floors, and subjective perception under spillage conditions. *Saf. Sci. 42*:547–565 (2004).
12. **Chang, W. R., K.W. Li, Y. H. Huang, A. Filiaggi, and T.K. Courtney:** Assessing floor slipperiness in fast-food restaurants in Taiwan using objective and subjective measures. *Appl. Ergon. 35*:401–408 (2004).
13. **American Society for Testing and Materials (ASTM):** *Standard Test Method for Using a Portable Inclinable Articulated Strut Slip Tester (PIAST)* (F-1677-96). [Standard] West Conshohochen, Pa.: ASTM, 2004.
14. **Chang, W.R.:** The effects of slip criteria and time on friction measurements. *Saf. Sci. 40*:593–611 (2002).
15. **Homan, M.M., and T.J. Armstrong:** Evaluation of three methodologies for assessing work activity during computer use. *AIHA J. 64*:48–55 (2003).
16. **Punnett, L, and D.H. Wegman:** Work-related musculoskeletal disorders: The epidemiologic evidence and the debate. *J. Electromyo. Kinesiol. 14*:13–23 (2004).
17. **Shaw, W.S., M. Feuerstein, V.I. Miller, and A.E. Lincoln:** Clinical tools to facilitate workplace accommodation after treatment for upper extremity disorder. *Assist. Technol. 13*:94–105 (2001).
18. **Chiou, S., A. Bhattacharya, and P.A. Succop:** Effect of workers' shoe wear on objective and subjective assessment of slipperiness. *Am. Ind. Hyg. Assoc. J.* 57:825–831 (1996).
19. **Saari, J., and M. Nasanen:** The effect of positive feedback on industrial housekeeping and accidents: A long-term study at a shipyard. *Int. J. Ind. Ergon. 4*:201–211 (1989).
20. **Mital, A.:** Issues and concerns in accommodating the elderly in the workplace. *J. Occup. Rehab. 4*:253–267 (1994).
21. **Lockhart, T.H., J.C. Woldstad, J.L. Smith, and J.D. Ramsey:** Effects of age-related sensory degradation on perception of floor slipperiness and associated slip parameters. *Saf. Sci. 40*:689–703 (2002).
22. **Laflamme, L., and E. Menckel:** Aging and occupational accidents: A review of the literature of the last three decades. *Saf. Sci. 21*:145–161 (1995).
23. **U.S. Department of Labor, Bureau of Labor Statistics:** Characteristics of Older Workers' Injuries by M. Personick and J.A. Windau. In *Fatal Workplace Injuries in 1993: A Collection of Data and Analysis* (Report 891). Washington, D.C.: U.S. Department of Labor, Bureau of Labor Statistics, 1995. pp. 23–27.
24. **Kemmlert, K., and L. Lundholm:** Slips, trips and falls in different work groups with reference to age. *Saf. Sci. 28*:59–75 (1998).
25. **Hirvonen, M., T. Leskinen, R. Grönqvist, E.Viikari-Juntura, and H. Riihamäki:** Occurrence of sudden movements at work. *Saf. Sci. 24*:77–82 (1996).