Safety in Fast-Food Restaurants

Factors That Influence Employee Perceptions of Floor Slipperiness

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

IN BRIEF
- Slip, trip and fall incidents are the leading sources of occupational injuries in restaurants.
- A multidisciplinary scientific field study explored underlying factors that may influence employees' self-reports of slipperiness in 10 fast-food restaurants.
- Results showed that a lower restaurant mean coefficient of friction, shoe sole contamination, a recent slip history and being younger than age 46 were factors associated with employees reporting higher slipperiness ratings.

Slip, trip and fall (STF) injuries are a serious problem and impose a significant burden on society. According to the Liberty Mutual Safety Index [Liberty Mutual Research Institute for Safety (LMRIS), 2009], costs for disabling workplace injuries in 2007 due to falls on the same level were approximately $7.7 billion or 14.6% of costs, and falls to a lower level were $6.2 billion or 11.7% of costs. Bodily reaction, which includes slips or trips without a fall, accounted for $5.4 billion or 10.2% of costs for the same period.

Data published by LMRIS (2009) show that falls on the same level and falls to a lower level increased 36.7% and 33.5%, respectively, between 1998 and 2007 after adjusting for inflation, while the overall costs of disabling workplace injuries increased only 5.8% during the same period. Statistics also show that most falls in the U.S. and European countries occur on the same level, with roughly 40% to 50% attributable to slipping (Courtney, Sorock, Manning, et al., 2001).

Slips and falls can occur on contaminated surfaces and at transitions in floor types, such as from the carpet in the dining area to the ceramic tile in the kitchen area. Slippery floors are common in restaurant kitchens (Chang, Cotnam & Matz, 2003) and are a critical factor in falls on the same level (Chang, Grönqvist, Leclercq, et al., 2001). Common causes of slippery floors include dishwashing overspray or run-off, leaking equipment or pipes, food debris, and spillage from transport of open containers such as those holding fryer grease and food wastes (Filiaggi & Courtney, 2003).

One of every three disabling restaurant injuries in the U.S. is the result of STF, with the largest percentage of injuries (26%) attributed to falls on the

Wen-Ruey Chang, Ph.D., is a principal research scientist at Liberty Mutual Research Institute for Safety (LMRIS) in Hopkinton, MA, and a NORA Partnering Award for Worker Health and Safety from NIOSH. Chang is a fellow of the Institute of Ergonomics and Human Factors and American Society of Mechanical Engineers. He also serves as an editor of *Ergonomics* and chair of the International Ergonomics Association Technical Committee on Slips, Trips and Falls. He holds a Ph.D. in Mechanical Engineering from University of California at Berkeley.

Theodore K. Courtney, M.S., CSP, is director of the Center for Injury Epidemiology at LMRIS. He is also an instructor on injury, safety and ergonomics at the Harvard School of Public Health. He holds a B.S. in Human Factors from Georgia Tech and an M.S. in Industrial and Operations Engineering from the University of Michigan. Courtney is a member of the editorial boards of *Professional Safety* and the *Journal of Occupational and Environmental Hygiene*. He is a member of ASSE's Greater Boston Chapter

Yueng-Hsiang Huang, Ph.D., is a senior research scientist at LMRIS. She earmed a Ph.D. in Industrial/Organizational Psychology from Portland State University. She is a member of the Society for Industrial and Organizational Psychology, American Psychological Association and Society for Occupational Health Psychology, and is associate editor for *Accident Analysis and Prevention*.

Kai Way Li, Ph.D., is a professor in the Department of Industrial Management at Chung-Hua University in Taiwan. Li holds a B.S. in Civil Engineering from the National Chiao Tung University, an M.S. in Industrial Engineering from University of Texas and a Ph.D. in Industrial Engineering from Texas Tech University.

Alfred J. Filiaggi, CSP, ARM, is a senior service director at Liberty Mutual Group's Loss Control Advisory Services. For 3 years before returning to the field operation in 2004, he was a research scientist at LMRIS. He previously served as a safety manager for three East Coast divisions of a large restaurant chain, providing safety program consulting for more than 250 restaurant operations. Filiaggi holds a B.S. in Commerce and Engineering Sciences from Drexel University. He is a member of ASSE's Three Rivers Chapter.

Santosh K. Verma, M.D., Sc.D., M.P.H., is a research scientist with LMRIS's Center for Injury Epidemiology. He is also an instructor at the University of Massachusetts Medical School. A member of the American Public Health Association, Verma also serves on the NORA Wholesale and Retail Trade Sector Council. He holds a doctorate in Occupational Health from Harvard School of Public Health and an M.B.B.S. degree from Gandhi Medical College, Bhopal, India.

©ISTOCKPHOTO.COM/NAZDRAVIE

Slippery floors are common in restaurant kitchens. Common causes include dishwashing overspray or run-off, leaking equipment or pipes, food debris, and spillage from transport of open containers.

same level (Filiaggi & Courtney, 2003). Moreover, Leamon and Murphy (1995) estimate that the incidence rate of falls on the same level was approximately 4.1 per 100 full-time restaurant employees over a 2-year period.

Friction measurements between the shoe sole materials and floor surfaces are the most common method of assessing slipperiness (Chang, et al., 2001). Levels of coefficient of friction (COF) are typically used to assess the potential risk of slip and fall incidents that are generally assumed more likely to occur on floors with a low COF value. Since people manipulate gait when aware they are walking on slippery surfaces, this casts doubt on the validity of the level of COF as a lone indicator of slipperiness (Strandberg, 1985; Leamon, 1992; Grönqvist, Hirvonen & Tuusa, 1993).

In addition to the level of COF, friction variation can play a role in determining slipperiness. Leclercq, Tisserand and Saulnier (1997) and Chang, et al. (2003), indicate that friction of the floor is highly location (tile) dependent. The potential for slip and fall incidents could be increased by local variations in friction (Strandberg, 1985; Pater, 1985; Andres, O'Connor & Eng, 1992; Grönqvist, Abeysekera, Gard, et al., 2001). Unexpectedly encountering an abrupt reduction in friction across floor surfaces without an opportunity for body posture adjustments could result in a slip and a possible fall.

Previous reports in the literature from laboratory studies suggest that employee self-reports could be a reasonably good indicator of floor slipperiness (Grönqvist, et al., 2001) and a potential complement to engineering measurements. Results reported in the literature indicate a strong correlation between the subjective rating or ranking of slipperiness with the objective measures, such as the level of COF and slip distance (Myung, Smith & Leamon, 1993; Swensen, Purswell, Schlegel, et al., 1992; Grönqvist, et al., 1993; Li, Chang, Leamon, et al., 2004).

Despite strong correlations reported, Cohen and Cohen (1994) indicate a significant number of disagreements between the tiles' COF level and subjective responses obtained by visual comparison of 23 tested tiles to a standard tile with a COF of 0.5.

Most studies comparing friction and perception of slipperiness published in the literature were conducted in laboratories using new floor surfaces and artificial contaminants that may not represent what most employees encounter daily. Therefore, the issue of fidelity could potentially limit the validity of the conclusions that could be applied to real work environments. Field studies using objective and subjective measurements of slipperiness are rarely reported in the literature even though realistic conditions of floor surfaces could be better reflected.

Besides the COF level, relatively little is published about factors that may influence employees' self-reported perceptions of floor slipperiness. A major field study was undertaken to explore personal, situational and physical factors that could influence such perceptions among employees in U.S. fast-food restaurants. A follow-up investigation involved a detailed assessment of the relationship between COF and employee perception ratings. This article summarizes major findings of this field study (Chang, Li, Huang, et al., 2006; Chang, Huang, Li, et al., 2008; Chang, Li, Filiaggi, et al., 2008; Courtney, Huang, Verma, et al., 2006).

Study Methods

Ten corporately owned restaurants of a U.S. fast-food chain participated in the study. Floor conditions during lunchtime in the kitchens of such restaurants represent one of the most heavily contaminated situations in their daily operation due to the large volume of customers served over a short time. Immediately after the lunch service, friction measurements and surveys of perception ratings were conducted concurrently in each restaurant on weekdays in an attempt to capture lunchtime conditions as accurately as possible.

Six major working areas, encompassing the back vat, front counter, fryer, grill, sink and walk-through, were identified in each restaurant. These represent the main work areas for most employees and include most of the highly contaminated areas along with some less-contaminated areas for comparison.

Survey of Perceived Floor Slipperiness

The research team developed a survey used in this experiment to assess floor slipperiness perceived by employees (Courtney, et al., 2006). Employees who worked during the lunch period on the day of the visit were invited to participate. Participants completed surveys during their break in a dining room location set aside for the study team. The protocol was approved by an institutional review board for the protection of human participants.

All participants completed the survey anonymously. They had the option of completing the survey in English, Spanish or Portuguese, and study personnel fluent in each language were present at each data collection site.

According to participants' recall of experience during the lunch period on the day of the visit, they rated the slipperiness of the major working areas identified using a four-point rating scale, with 4 meaning "extremely slippery" to 1 meaning "not slippery at all." In addition, they were asked whether they were in these areas during that lunch service.

Only the results of their ratings for those areas where they had been during lunch on that day were included in the perception rating analyses for the day of the visit. In a subsequent section of the survey, participants were asked to provide the same ratings of the same areas based on a typical workday and whether they typically worked in these areas.

In addition to the perception rating, participants were asked whether they had experienced a slip, with or without a subsequent fall, while working at the restaurant within the previous 4 weeks. The survey also collected data on each participant's age, gender, ethnic group, tenure, work hours per week, shift length and slip-resistant shoe use among other factors.

Friction Measurements

Quarry tile was the typical flooring in these restaurant kitchens. To reflect what employees might encounter when walking through the select areas, COF values of a line of tiles through each area were measured. Due to the likelihood of water and/or grease contamination in the back vat, fryer, grill and sink area, and the limited number of tiles available for friction measurements in the walk-through areas, one tile was measured approximately every 30 cm along the line selected in these five areas, representing approximately a half step length of a human stride (Sun, Walters, Svensson, et al., 1996). In the front counter areas, one tile was measured approximately every 60 cm due to a lesser likelihood

Table 1

Perception of Slipperiness

Variable	Mean perception score	*p* value
Age		
14 to 24 years	2.03	-
25 to 45 years	1.89	0.25
46+ years	1.66	0.02*
Shoe contamination		
Absent	1.82	0.05*
Present	2.04	-
Slip history (4 weeks)		
No	1.78	< 0.001**
Yes	2.16	-

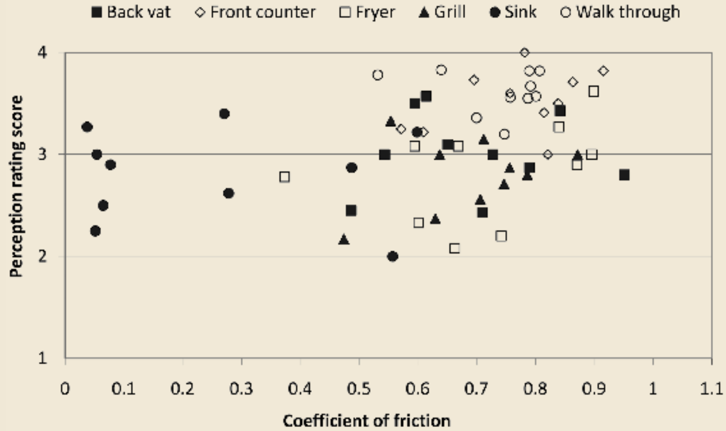
Note. *Categorical personal and environmental factors significant for association with employee perception of slipperiness. *Significant,* $p < 0.05$. ***Significant,* $p < 0.001$. *Not significant: Gender, shoe sole wear, slip-resistant shoes, shift start time. Adapted from "Factors Influencing Restaurant Worker Perception of Floor Slipperiness," by T.K. Courtney, Y.H. Huang, S.K. Verma, et al., 2006,* Journal of Occupational and Environmental Hygiene, *3(11), pp. 593-599.*

of contamination. COF was measured with two Brungraber Mark II slipmeters using Neolite test liners as footwear pads in contaminated and less-contaminated zones in each restaurant's work area. Friction was measured in both directions along the line of tiles selected with one measurement for each direction on each tile chosen. Wet measurements were conducted on the tiles in front of the sinks by saturating them with water to simulate actual floor conditions when washing tasks are performed.

The surface condition was not altered in all other areas and on tiles outside the contaminated zones of the sinks. Details of the protocols used to measure COF and select tiles in the contaminated and less-contaminated zones for friction measurements can be found in Chang, et al. (2006).

Figure 1

COF vs. Perception



Note. *The average COF versus average perception rating score over each working area across all the restaurants. Rating 1: extremely slippery, rating 4: not slippery at all. Adapted from "Objective and Subjective Measurements of Slipperiness in Fast-Food Restaurants in the USA and Their Comparison With the Previous Results Obtained in Taiwan," by W.R. Chang, K.W. Li, Y.H. Huang, et al., 2006,* Safety Science, 44, *pp. 891-903.*

Data Analysis

Spearman's correlation coefficient, *t*-tests and analysis of variance (ANOVA) were used to assess univariate associations between employee slipperiness perception and personal factors (including workplace slip history) and floor and shoe conditions. Linear regression was used to assess multivariate associations.

Since most survey questions were not specific to the day the survey was conducted, the slipperiness perception ratings for a typical day were used when analyzing survey results. Global COF values at the restaurant level were obtained by averaging all the measurements within a single restaurant. Individual participant's ratings of the areas in which they normally worked were averaged as an overall individual perceived slipperiness rating.

Slip-resistant shoe use (yes or no), shoe wear (visible tread wear observed or not) and visible shoe sole contamination were assessed by visual inspection of participating employees' footwear by on-site investigators. These field ratings were later confirmed by a post-hoc review of digital photographs of the footwear by a panel of the investigators to ensure consistent criteria.

In the follow-up investigation, detailed comparisons between COF and perception ratings alone were investigated at the level of major working areas. The Pearson correlation was used to investigate the relationship between different friction variables and the mean perception rating of each working area across all the restaurants.

In addition to the single linear regression, a multiple linear regression model was used to determine the contributions from the friction level and friction reduction in a step length to the outcomes of the perception rating scores. For this analysis, the research team used the perception ratings for the day of the visit because that was the day the friction measurements were taken.

To express all the measures in the same direction, the perception ratings were reversed by subtracting the original rating from 5 so that a higher subjective rating was associated with a higher COF (Gao & Abeysekera, 2002), both of which indicated less slippery conditions. The average perception rating for each working area in each restaurant was calculated by averaging the ratings from individuals who worked in that area during the lunch period on the day of the visit. The average COF for each working area in each restaurant was calculated by averaging all COF values measured from the contaminated zone in that area.

With various combinations, a total of 12 friction reduction variables that might reflect the change in COF that workers might encounter when walking through the area were generated from the friction measurements (Chang, Huang, et al., 2008). Since reductions in friction variations could contribute to slip and fall incidents, only friction reductions at a step length were included in the analyses.

Friction level and individual friction reduction variables were used to develop the multiple regression model one at a time to determine the contributions from individual variables. Friction reductions that had a level of contribution the same as or more significant than the friction level were identified.

Study Results

Field Study

A total of 126 employees participated in the study for a response rate of 87.5% across all 10 restaurants. Participants were a mean age of 30 years (range = 14 to 71), averaged 34.5 weekly work hours (SD = 8.6) and had worked in their specific location an average of 34.5 months (median = 17). Sixty percent of the participants were women. Forty-eight percent of participants identified themselves as white, 44% as Hispanic, 4% as Asian and 4% as black (Chang, et al., 2006; Chang, Huang, et al., 2008; Courtney, et al., 2006).

Global mean COF at the restaurant level 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 participant perception of slipperiness scores on the 4-point Likert scale, (4 = extremely slippery; 1 = not slippery at all) 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.

Thirty-four percent of participants reported slipping at work in the prior 4 weeks. Forty-two percent were observed to have shoe sole contamination, and 36% wore some kind of slip-resistant shoes.

The results of the Spearman's correlation indicated that participant perception of slipperiness was inversely correlated with mean restaurant COF; that is, participants reported higher ratings of slipperiness as COF decreased, (Spearman's $\rho = -0.33$, $p < 0.001$), but was not significantly correlated with length of service or hours worked per week.

Means and p values of t-tests and ANOVA for categorical variables found to have significant association with slipperiness perception are presented in Table 1 (p. 64). A workplace slip history in the past 4 weeks ($p < 0.001$), younger age (< 46 years, $p = 0.02$) and visible contamination on the shoe ($p = 0.05$) were significantly associated with employees reporting higher slipperiness ratings.

Similar to the univariate analysis, the results from multivariate linear regression indicated that lower restaurant mean COF ($p < 0.001$), worker age less than 46 years ($p = 0.008$), visible contamination on the shoe sole ($p = 0.009$), and a history of an occupational slip and/or fall in the past 4 weeks ($p = 0.013$) were significantly associated with higher slipperiness perceptions. As expected, participants without a slip in the past 4 weeks would give a higher mean slipperiness rating for restaurants with a lower mean restaurant COF value (Spearman's $\rho = -0.43$, $p < 0.001$), and vice versa. Ratings from those participants with a slip history were not correlated with the mean restaurant COF values (Spearman's $\rho = 0.02$, $p = 0.91$) (Courtney, et al., 2006).

Follow-Up Investigation

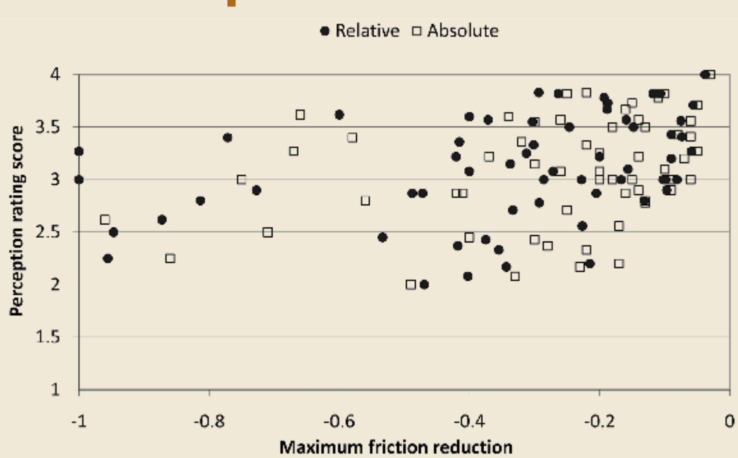
Friction was measured on a total of 353 tiles. Average COF values from high to low were the front counter (0.77), walk through (0.73), fryer (0.73), back vat (0.69), grill (0.69) and sink (0.28). To make for easier interpretation in subsequent analyses and figures, participants' perception ratings were reversed by subtracting the participants' rating from 5 in order to make it consistent with the COF value, such that 1 = extremely slippery and 4 = not slippery at all. The average perception ratings from high (not slippery) to low (slippery) were the walk through (3.64), front counter (3.60), back vat (3.02), sink (2.85), fryer (2.84) and grill (2.84). More details of the COF and perception rating for each major working area can be found in Chang, et al. (2006).

The Pearson correlation coefficient between the average COF and the average perception rating score for each working area across all the restaurants was 0.33 ($p = 0.01$) (Chang, et al., 2006). Figure 1 (p. 65) illustrates the relationship between the average COF and average perception rating score over each working area. This correlation coefficient was used as a benchmark for comparisons with the correlation coefficients for different combinations of friction reductions.

Among the 12 friction reduction variables calculated, the perception rating scores had higher correlation coefficients, with the maximum absolute and relative reductions in friction in a step length over the whole working area only ($r = 0.34$, $p = 0.008$; $r = 0.37$, $p = 0.004$, respectively) than with the average COF ($r = 0.33$) (Chang, Huang, et

Figure 2

Friction Reduction vs. Perception



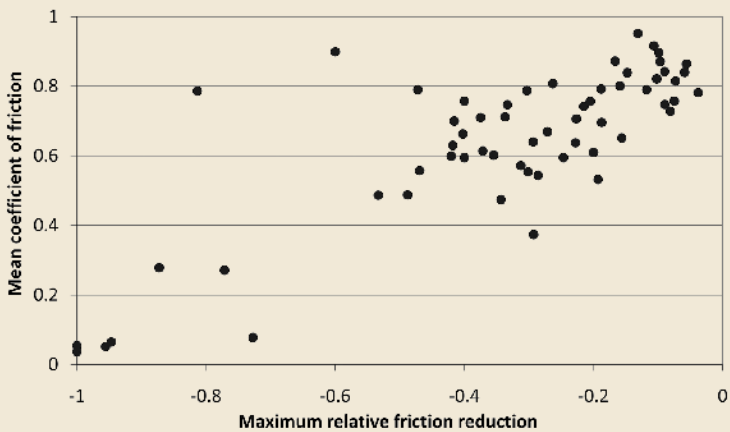
Note. *The maximum absolute and relative friction reductions versus average perception rating score over each working area across all the restaurants. Rating 1: extremely slippery, rating 4: not slippery at all. Adapted from "Assessing Slipperiness in Fast-Food Restaurants in the USA Using Friction Variation, Friction Level and Perception Rating," by W.R. Chang, Y.H. Huang, K.W. Li, et al., 2008,* Applied Ergonomics, *39(3), pp. 359-367.*

al., 2008). The values of the maximum absolute and relative reductions in friction in a step length for each working area are reported in detail in Chang, Huang, et al. (2008).

Figure 2 illustrates the relationships between the maximum absolute and relative reductions in friction in a step length and average perception rating score over each working area. It was also reported that some friction reduction parameters had a high Pearson correlation coefficient with the mean COF for each working area. The maximum absolute and relative reductions in friction in a step length over the whole working area, which had a higher correlation coefficient with the mean perception rating, had Pearson correlation coefficients with the mean COF of 0.64 and 0.80 ($p < 0.001$), respectively. Figure 3 illustrates the relationship between the maximum relative friction reduction in a step length over the whole working area and the mean COF for each working area.

Figure 3

Friction Reduction vs. Friction Coefficient



Note. *The maximum relative friction reductions versus mean friction coefficient over each working area across all the restaurants, which indicated that these two variables were not completely independent. Adapted from "Assessing Slipperiness in Fast-Food Restaurants in the USA Using Friction Variation, Friction Level and Perception Rating," by W.R. Chang, Y.H. Huang, K.W. Li, et al., 2008,* Applied Ergonomics, *39(3), pp. 359-367.*

Results of the multiple regression model indicated that the mean COF dominated the relationship between friction and perception when the mean COF and one friction reduction variable were used as independent variables in most of the friction reduction variables evaluated. The exceptions were the maximum absolute and relative reductions in friction in a step length over the whole working areas. The multiple regression models for the maximum absolute and relative friction reduction in a step length over the whole area along with the mean COF accounted for 13.8% and 13.7%, respectively, in predicting the perception rating with $p = 0.015$.

As a comparison, the results of single variable regression models with the perception rating score indicated that the mean COF, and the maximum absolute and relative reductions in friction in a step length over the whole area accounted for 11% ($p = 0.010$), 11.6% ($p = 0.008$) and 13.3% ($p = 0.004$), respectively, in predicting the perception rating.

Discussion

In the present field study, a higher mean COF was significantly associated with a lower employee perception rating of slipperiness at the restaurant level as well as the work area level. This finding was consistent with results from an earlier restaurant study conducted in Taiwan (Chang, Li, Huang, et al., 2004; Li, Courtney, Huang, et al., 2006).

Based on results from both studies, employee ratings may have some promise as a complement to workplace investigations of slipperiness involving more traditional engineering approaches such as friction measurement. In particular, such an approach might be helpful in preliminary assessments or in cases where engineering quantitative methods are not available.

Some support exists in the literature for use of a subjective, retrospective rating scale. Hirvonen, Leskinen, Grönqvist, et al. (1996), asked employees to subjectively rate the risk of accidents in their work tasks associated with slippery or uneven surfaces and stairs. Employee risk scores were found to be significantly associated with a higher frequency of sudden acceleration events that were potential indicators of a slip.

However, factors other than the COF level were associated with employees' ratings of slipperiness. These include gross contamination of footwear, employee age, and a history of slipping and/or falling at work in the prior 4 weeks.

Gross contamination of the footwear, such as foodstuffs, sauces or other debris on shoe soles, could lead to higher slipperiness perception ratings. Contaminants trapped under the footwear could potentially reduce the effectiveness of tread patterns, which is a critical aspect of slip-resistant footwear. Periodic footwear inspections and cleaning, if necessary, might improve conditions.

The findings also suggest a need to control for or to stratify perception ratings by the presence of such contamination on footwear. The finding that the shoes of 42% of participants had such contamination indicates the need for a better control of gross contamination of floors in fast-food restaurants. This may be accomplished by more frequent floor inspections during peak hours. Management plays an important role by introducing employees to best practices and instilling good safety behaviors including housekeeping (Filiaggi & Courtney, 2003).

Employees over age 45 reported lower slipperiness ratings than younger employees. Lower slipperiness ratings from older employees may reflect a better assessment of conditions due to experience or an effect of decreased sensory and motor perception (Mital, 1994; Lockhart, Woldstad, Smith, et al., 2002). With reduced sensitivity, older employees may be less able to detect slipperiness changes. With decreases in gait and postural control, including capabilities to regain balance with age, employees over age 45 may potentially be more vulnerable to slippery conditions than younger employees.

A recent workplace history of slipping was associated with increased worker perception of slipperiness that was not correlated with the mean restaurant COF values. However, these COF values were moderately correlated with the ratings from participants with no history of slips. This finding suggests that, in future uses of perception surveys, participants should be screened for a recent history of slipping and stratified in the analysis to ensure a better interpretation of the aggregate results (Courtney, et al., 2006).

Results also indicate that the average perception rating of slipperiness could have higher correlation coefficients with the maximum absolute and relative reductions in friction in a step length over the whole working area than with the average COF. This suggests that some friction reduction variables might be better indicators of slipperiness than the level of COF as has been speculated in the literature (Strandberg, 1985; Leamon, 1992; Grönqvist, et al., 2001).

However, to properly reflect friction reductions in a working area, more extensive and systematic measurements of COF for the calculations of friction reductions are needed. In particular, friction reductions that were better correlated with the perception rating scores were the maximum absolute and relative reductions in friction in a step length from the whole working area which involved measuring tiles more extensively in both the contaminated and less contaminated zones.

Capturing these special characteristics in a working area requires an extensive measurement strategy to cover the entire working area. More time and energy are required for friction measurements in order to obtain meaningful data for the friction reduction in a step length compared with those needed to obtain the mean COF. The perception rating has only a slightly higher correlation coefficient with some friction reduction variables evaluated than with the mean COF (Figures 1, p. 65 and 2, p. 66).

Furthermore, the friction variation variables were not completely independent of the mean COF. The correlation coefficients between the mean COF and several friction reduction variables were high (Figure 3, p. 67), indicating that an area with a low COF also most likely had a large maximum absolute or relative friction reduction in a step length. The results of multiple regression models further indicated that adding the friction reduction variables to the mean COF did not significantly increase the predictive power for the perception ratings.

This suggests that in practical applications, where time and effort are always critical and limiting factors, the use of the COF level instead of friction reduction measures could be warranted. However, since the results from Chang, et al. (2003; 2004; 2006; 2008) indicate significant variations among the COF measured on different tiles in the same areas, if one chooses to measure only COF level, it is important to measure several tiles in the area of interest and use the average to represent the area's COF level.

More information on slipping and falling hazards in restaurants can be found in Li, et al. (2006), while information on local management best practices in preventing slipping and falling hazards in restaurants was addressed by Filiaggi and Courtney (2003).

In summary, the results suggest that:

- Employee ratings of perceived slipperiness may be helpful in situations where slip meter measurement is not readily available.
- There is a need to control for perception ratings of employees who have recently experienced a slip or fall at work.
- Visible, gross contamination under footwear will influence worker ratings of slipperiness and also indicates a need for improved housekeeping practices.
- Employees over age 45 may potentially be more vulnerable to slippery conditions than younger employees, underscoring the importance of slip and fall interventions with an aging workforce.
- If measuring for slipperiness using mean COF, multiple tiles should be sampled and the average used to ensure inclusion of friction variation in the tested environment.

Conclusion

The present study combined standardized friction measurements, investigators' observations and a multilingual employee questionnaire to identify factors that could influence worker perception of slipperiness in the restaurant environment. Results were consistent with most prior studies that a lower restaurant mean COF was associated with an increased perception of slipperiness (more slippery conditions).

While an employee-centered approach may prove useful in identifying slippery work conditions, these results also suggest several key factors that could inadvertently affect the outcomes. The presence of visible contamination on workers' shoe soles was an environmental factor associated with higher slipperiness ratings. A workplace slip in the past 4 weeks also was associated with higher slipperiness ratings. In addition, employees over age 45 gave a lower rating of slipperiness than younger counterparts. These factors should be considered in stratifying data with subjective rating of slipperiness.

A detailed comparison was conducted to investigate the relationships among friction levels, friction variations and perception ratings of slipperiness. Among the 12 friction variations quantified, the perception rating scores have a slightly better Pearson correlation with the absolute and relative reductions in friction in a step length over the whole working area (r = 0.34 and 0.37, respectively) than with the mean COF of each working area (0.33). However, the additional effort and time needed to quantify friction variations rather than to obtain the mean COF may not be warranted, despite slightly higher correlation coefficients for the friction variations.

The results of the multiple regression model on the perception ratings indicated that adding friction reduction variables into the regression model in addition to the mean COF did not have a significant impact on the outcomes. Despite a slightly lower correlation with the perception rating than with some friction reduction variables, in practice, the mean COF of an area still is a reasonably good indicator of slipperiness.

If the observed relationships between physical and worker-centered measures of slipperiness proves robust across future studies, it suggests that employee self-reports could be used, alongside existing approaches, to identify and assess slippery workplace conditions for subsequent intervention. **PS**

Acknowledgments

The authors thank the participating restaurants for their support in this study. The authors also thank Jerilyn Dempsey, Mary Dionne, Debra Larnis, Camelina Lopes, Niall O'Brien, Margaret Rothwell and Danyel Tarinelli for their assistance.

References

Andres, R.O., O'Connor, D. & Eng, T. (1992). A practical synthesis of biomechanical results to prevent slips and falls in the workplace. *Advances in Industrial Ergonomics and Safety IV: Proceedings of the Annual International Industrial Ergonomics and Safety Conference*, 1001-1006.

Chang, W.R., Grönqvist, G., Leclercq, S., et al. (2001). The role of friction in the measurement of slipperiness, Part 1: Friction mechanisms and definition of test condition, *Ergonomics*, *44*, 1217-1232.

Chang, W.R., Cotnam, J.P. & Matz, S. (2003). Field evaluation of two commonly used slipmeters. *Applied Ergonomics*, *34*, 51-60.

Chang, W.R., Li, K.W., Huang, Y.H., et al. (2004). Assessing floor slipperiness in fast-food restaurants in Taiwan using objective and subjective measures. *Applied Ergonomics*, *35*(4), 401-408.

Chang, W.R., Li, K.W., Huang, Y.H., et al. (2006). Objective and subjective measurements of slipperiness in fast-food restaurants in the USA and their comparison with the previous results obtained in Taiwan. *Safety Science*, *44*, 891-903.

Chang, W.R., Huang, Y.H., Li, K.W., et al. (2008). Assessing slipperiness in fast-food restaurants in the USA using friction variation, friction level and perception rating. *Applied Ergonomics*, *39*(3), 359-367.

Chang, W.R., Li, K.W., Filiaggi, A., et al. (2008). Friction variation in common working areas of fast-food restaurants in the USA. *Ergonomics*, *51*(12), 1998-2012.

Cohen, H.H. & Cohen, D.M. (1994). Psychophysical assessment of the perceived slipperiness of floor tile surfaces in a laboratory setting. *Journal of Safety Research*, *25*(1), 19-26.

Courtney, T.K., Sorock, G.S., Manning, D.P., et al. (2001). Occupational slip, trip and fall-related injuries: Can the contribution of slipperiness be isolated? *Ergonomics*, *44*(13), 1118-1137.

Courtney, T.K., Huang, Y.H., Verma, S.K., et al. (2006). Factors influencing restaurant worker perception of floor slipperiness. *Journal of Occupational and Environmental Hygiene*, *3*(11), 593-599.

Filiaggi, A.J. & Courtney, T.K. (2003, May). Responding to disabling occupational injuries in restaurants: Practice-based approaches. *Professional Safety*, *48*(5), 18-23.

Gao, C. & Abeysekera, J. (2002). The assessment of the integration of slip resistance, thermal insulation and wearability of footwear on icy surfaces. *Safety Science*, *40*(7-8), 613-624.

Grönqvist, R., Hirvonen, M. & Tuusa, A. (1993). Slipperiness of the shoe-floor interface: comparison of objective and subjective assessments. *Applied Ergonomics*, *24*(4), 258-262.

Grönqvist, R., Abeysekera, J., Gard, G., et al. (2001). Human-centered approaches in slipperiness measurement. *Ergonomics*, *44*(13), 1167-1199.

Hirvonen, M., Leskinen, T., Grönqvist, R., et al. (1996). Occurrence of sudden movements at work. *Safety Science*, *24*, 77-82.

Leamon, T.B. (1992). The reduction of slip and fall injuries, Part II: The scientific basis (knowledge base) for the guide. *International Journal of Industrial Ergonomics*, *10*, 29-34.

Leamon, T.B. & Murphy, P.L. (1995). Occupational slips and falls: More than a trivial problem. *Ergonomics* *38*(3), 487-498.

Leclercq, S., Tisserand, M. & Saulnier, H. (1997). Analysis of measurements of slip resistance of soiled surfaces on site. *Applied Ergonomics*, *28*, 283-294.

Li, K.W., Chang, W.R., Leamon, T.B., et al. (2004). Floor slipperiness measurement: Friction coefficient, roughness of floors and subjective perception under spillage conditions. *Safety Science*, *42*(6), 547-565.

Li, K.W., Courtney, T.K., Huang, Y.H., et al. (2006, Sept.). Slipping and falling experience and perception of floor slipperiness: A field survey in 10 fast-food restaurants in Taiwan. *Professional Safety*, *51*(9), 34-38.

Liberty Mutual Research Institute for Safety. (2009). 2009 Workplace Safety Index. Hopkinton, MA: Author.

Lockhart, T.H., Woldstad, J.C., Smith, J.L., et al. (2002). Effects of age-related sensory degradation on perception of floor slipperiness and associated slip parameters. *Safety Science*, *40*, 689-703.

Mital, A. (1994). Issues and concerns in accommodating the elderly in the workplace. *Journal of Occupational Rehabilitation*, *4*, 253-267.

Myung, R., Smith, J.L. & Leamon, T.B. (1993). Subjective assessment of floor slipperiness. *International Journal of Industrial Ergonomics*, 11, 313-319.

Pater, R. (1985, Oct.). How to reduce falling injuries. *National Safety and Health News*, 87-91.

Strandberg, L. (1985). The effect of conditions underfoot on falling and overexertion accidents. *Ergonomics*, *28*, 131-147.

Sun, J., Walters, M., Svensson, N., et al. (1996). The influence of surface slope on human gait characteristics: A study of urban pedestrians walking on an inclined surface. *Ergonomics*, *39*, 677-692.

Swensen, E.E., Purswell, J.L., Schlegel, R.E., et al. (1992). Coefficient of friction and subjective assessment of slippery work surface. *Human Factors*, *34*(1), 67-77.