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Assessing floor slipperiness in fast-food restaurants in Taiwan using objective and subjective measures

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Abstract

Slips and falls are major problems in occupational injuries in which floor slipperiness is a critical issue. Most of the studies on slipperiness assessments were conducted in laboratories. Field assessments are rarely reported in the literature. This study investigated floor slipperiness in seven kitchen areas of 10 western-style fast-food restaurants in Taiwan using both objective and subjective measurements which were conducted by friction measurements and by employees' ratings of floor slipperiness, respectively. The friction measurement results showed that the sink area had the lowest average friction in the kitchens. Employees, however, rated both the sink and back vat (chicken fry) areas as the most slippery areas. The Pearson's and Spearman's correlation coefficients between the averaged friction coefficients and subjective ratings for all 70 evaluated areas across all 10 restaurants were 0.49 and 0.45, respectively, with $p<0.0001$ for both. The results indicate that average friction coefficient and perception are in fair agreement, suggesting that both might be reasonably good indicators of slipperiness.

Keywords: Slip and fall incidents; Friction measurement; Subjective rating of floor slipperiness; Fast-food restaurants

1. Introduction

Slip and fall accidents are serious safety problems in work environments (Leamon, 1992; Swensen et al., 1992). In Taiwan, falls accounted for 14.5% of all occupational injuries in 2001, second only to traffic accidents (Council for Labor Affairs, 2002). Among these reported fall cases, 73.7% were falls on the same level. Statistics show that the majority of falls in the USA and European countries also occur on the same level with roughly 40–50% of same level falls attributable to slipping (Courtney et al., 2001). In addition to falls, slips likely contribute to many other occupational injuries. Hayes-Lundy et al. (1991), for example, reported that 11% of grease burns in fast-food restaurants were attributed to slips. Additionally, slips or trips while carrying a load were identified as a contributing factor for low back injuries in over 30% of all such cases (Leamon, 1992).

Contaminants such as grease and water are common on the floors of restaurant kitchens. Hence, slippery floors, which are a critical factor for falls on the same level, are common in restaurants (Chang et al., 2003). Leamon and Murphy (1995) reported that slips and falls resulted in the second most frequent claims and were the most costly claims in workers' compensation within the restaurant industry in the USA. They 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, resulting in an annual per capita cost of US $116 per employee.

Measurement of friction between the shoe and floor is the most common method to assess floor slipperiness (Chang et al., 2001b). It is generally assumed that slips are more likely to occur on floors with a low coefficient of friction (COF), and mean COF values are often used to assess the potential risk of slip and fall accidents. In addition to the mean COF value, friction variation can

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also play a role in determining slipperiness. Strandberg (1985) indicated that local friction variation could increase the potential of slip and fall accidents. The slipperiness of a floor is initially judged subjectively by several mechanisms, which may include visual perception and proprioceptive recognition to maintain body balance. Discontinuities in friction across floor surfaces may result in unexpectedly encountering a low friction area without body posture adjustments, leading to a fall. People do manipulate gait when aware of walking on slippery surfaces, casting doubt on the validity of the mean COF value as the sole indicator of slipperiness (Leamon, 1992; Grönqvist et al., 2001).

The Brungraber Mark II, an inclined-strut slipmeter driven by gravity, is a friction measurement device commonly used in the USA (Grönqvist et al., 1999; Powers et al., 1999; Chang and Matz, 2001; Chang et al., 2001a, 2003; Chang, 2002). This slipmeter simultaneously applies forces parallel and normal to a floor surface with an impact of a footwear pad on the floor at an inclined angle in order to eliminate the dwell time problem with the static friction measurement.

The COF values measured using the Brungraber Mark II were compared with the tangential to normal force ratio (F_H/F_V) obtained from a force plate through the operation of the slipmeter on the force plate (Grönqvist et al., 1999; Powers et al., 1999). The results indicated that the COF obtained directly from the slipmeter and from the force plate measurements showed good agreement over different floor surfaces with different contaminants for non-slip conditions. The COF values measured with the Brungraber Mark II were shown to have a strong correlation ($r > 0.95$) with those measured with a dynamic apparatus to simulate a slip, although the absolute COF values obtained from both devices were quite different (Grönqvist et al., 1999).

In addition to the friction measurements, perception of floor slipperiness is also essential to assessing slipperiness. Myung et al. (1993) compared the subjective ranking of slipperiness produced from paired comparisons after walking on surfaces, and the static COF of ceramic, steel, vinyl, plywood and sandpaper measured with a mechanical device to simulate a foot slip. They found that the higher the measured COF value, the less slippery the subjective ranking, with the exception of vinyl tile. Their results indicated that humans have a promising ability to subjectively differentiate floor slipperiness reliably, even though the measured static COF differences among these floor surfaces might not be prominent. They concluded that humans were reliable, but risky, discriminators of floor slipperiness.

The results from Cohen and Cohen (1994) were, however, somewhat different. In a laboratory experiment, their subjects visually compared 23 tested tiles to a standard tile with a COF of 0.5 and reported whether the tile was more slippery. They found a significant number of disagreements between subjective responses and the COF values of the tiles.

Swensen et al. (1992) conducted a study to collect both subjective rating and ranking of surface slipperiness of steel beams with different coatings from ironworkers and college students after walking on the surfaces. They found that the correlation between subjective rating and the measured COF of the beams were strong for both ironworkers ($r = 0.75$) and college students ($r = 0.90$). The subjective ranking of these surfaces, however, was consistent with the measured COF for ironworkers but not for college students ($r = -0.14$).

Grönqvist et al. (1993) compared the results of subjective ratings from walking experiments with objective measures of slipperiness using biomechanical and tribological approaches in the presence of a slippery contaminant. 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 COF ($r = 0.97$, $p < 0.05$).

Most studies comparing friction measurement and perception of floor slipperiness published in the literature were conducted in laboratories with new floor surfaces and artificial contaminants. These conditions may not represent what most employees encounter daily. Field studies can better reflect realistic conditions of floor surfaces. However, field studies of floor slipperiness using both friction measurements and employees' ratings of slipperiness are rare. The main objective of this study was to examine the relationship between point-in-time friction measurements and employee reports of floor slipperiness over major working areas in western-style fast-food restaurants in Taiwan.

2. Methods

Ten western-style fast-food restaurants participated in the study. The conditions in this type of restaurant during lunchtime represent one of the worst situations during their daily operation due to a large volume of customers over a short time period and contaminants on floor surfaces. Both friction measurements and subjective ratings were conducted concurrently in each restaurant during weekdays immediately after the lunch period, starting at approximately 1 p.m. and finishing before 5 p.m. The attempt was to capture lunchtime conditions as closely as possible for comparisons. There was no major floor cleaning in these restaurants between the lunch period and the time when friction was measured.

2.1. Major working areas

The general kitchen areas investigated in this study included the cooking, food preparation and front counters/service areas. Seven major working areas, including fryer, back vat, oven, sink, beverage stand, front counter and walk through, were identified in each restaurant. These were work areas for the majority of employees and included most of the highly contaminated areas along with some less contaminated areas for comparison. The fryer and back vat are the areas for frying french fries and chicken, respectively. The front counter is the area to take customers' orders and payments and to deliver food. The beverage stand is typically located next to the front counter inside the kitchen. The sink is used for tasks such as defrosting chicken pieces and washing cookware. The oven is used mainly to roast chicken. The walk through area is the entrance where employees enter and exit the kitchen.

Quarry tile was the typical floor in the kitchens of these restaurants. The tiles in seven out of 10 restaurants had grit particles imbedded on the surface originally, but most of the grit surface appeared to be worn. The ages of the tiles were unknown, but believed to be older than the ages of the restaurants since all these restaurant properties were rented and there was no replacement of the floor tiles prior to opening of the current businesses at these locations. The average age of these restaurants at the time of the visits was 32.4 months with a standard deviation of 26.7 months.

2.2. Friction measurement

2.2.1. Device

Two Brungraber Mark II slipmeters with Neolite test liners as footwear pads were used to measure friction. To reduce the variation in friction measurements due to different operators, devices and test pads, each slipmeter was operated by the same operator with the same Neolite pad throughout the study. To avoid cross contamination, one slipmeter was always used in the areas where greasy contaminants were anticipated such as the fryer, back vat and oven, while the other slipmeter was used in non-greasy areas such as the sink, beverage stand, walk through and front counter. Fig. 1 shows the on site measurement of friction using the Brungraber Mark II slipmeter. The guidelines for operating this slipmeter are published by the American Society for Testing and Materials (ASTM, 2002). During a measurement, the footwear pad of this slipmeter impacts the floor surface at an inclined angle with the vertical direction. If a non-slip occurs at the interface upon the impact, the inclined angle is increased. Conversely, the angle is decreased if a slip occurs. The COF value is determined by the angle at which a non-slip is changed to a slip. The measurement protocols recommended by Chang (2002) were adopted.

Fig. 1. Measurement of friction coefficient using the Brungraber Mark II slipmeter.

2.2.2. Pre-measurement training

One operator was experienced with the slipmeter while the other one was a novice. To minimize the variation of friction measurements due to operator, slipmeter and Neolite pad, a pre-measurement exercise was conducted. The two operators measured two different terrazzo tiles under both dry and wet conditions. Twenty-four measurements were made by each operator (2 tiles $\times$ 2 surface conditions $\times$ 6 repeats). A pair-wise t-test comparing the differences of the measurements generated with different operators, slipmeters and test pads indicated a significant difference ($p = 0.046$). The novice practiced using the slipmeter daily under the guidance of the experienced operator. A second pre-measurement exercise, under the same experimental conditions as the first one, was conducted 1 week later and resulted in a non-significant result for operator, slipmeter and test pad difference ($p = 0.77$).

2.2.3. Surface conditions

Any loose, gross contaminants on the floor surfaces, such as french fries, were removed before making friction measurements. In the sink areas where water was the contaminant, a wet measurement was conducted by applying water to the floor surface in order to simulate actual floor conditions during the lunch period when washing tasks were being performed. Water was replenished in the footwear striking area during repeated strikes under the wet conditions. The amount of water for each replenishment was 10 ml to build up the maximum thickness determined by surface tension.

Besides loose debris and wet testing, the surface condition was not altered before the measurements.

2.2.4. Areas and tiles of measurement

Friction of the floor is highly location dependent, as indicated by Chang et al. (2003). The more tiles measured, the better the floor slipperiness may be represented. In order to reflect what employees might encounter when walking through an area, a line of tiles across the area was measured in the selected areas. The line of measurement was in the direction of traffic representing the walk path through the area and was at least 30 cm from the wall or edge of the cooking equipment since employees usually do not walk very close to these landmarks. This selection method was adequate for the areas of fryer, back vat, oven and beverage stand since the employees working in these areas usually do not stand there for prolonged periods and would not interfere with the traffic going through the area. However, in the sink areas, the actual line of friction measurement was at least 45 cm from the sink since an employee might stand in front of the sink to wash cookware and other employees might not walk within 30 cm from the sink. The sink, oven, fryer and back vat were considered critical areas in the kitchen due to the likelihood of contamination by water and/or grease (Chang et al., 2003). In these areas, one tile was measured no more than every 30 cm. This distance was determined as approximately a half step length of a human stride. For the front counter, walk through, and beverage areas, one tile was measured no less than every 60 cm since these areas were considered less critical due to a less likelihood of contamination. The size and criticality of the selected areas determined the number of tiles measured per area.

After the line of tiles was selected, friction was measured with Neolite in both directions along the line. On each tile measured, there was one friction measurement for each direction. The Neolite pad was sanded prior to the friction measurement of each tile in order to maintain a consistent surface condition on the pad. The sanding protocol introduced by Chang et al. (2003) was used. The temperature and relative humidity during the measurements averaged 28°C (± 2.2) and 61% (± 6.4), respectively.

2.3. Survey of floor slipperiness

A floor slipperiness survey, developed by this research team, was used to assess floor slipperiness perceived by employees. Those employees that worked during the lunch period on the day of the visit were invited to participate and were compensated for their time completing the survey.

All the subjects who participated in the survey were individually interviewed. Each participant answered the survey questions anonymously. The subjects rated the slipperiness of the same floor areas measured with the slipmeters according to their recall of experience in the kitchen during that lunch period. A four-point rating scale was used, with 1 as "extremely slippery" to 4 as "not slippery at all."

2.4. Data analysis

In exploring the correlation between friction and perception, it is essential that there is sufficient variation in both friction values and perception ratings based on the selection of participating restaurants and evaluated areas. A two-way ANOVA was used to determine whether restaurant and area made a significant difference in the measured friction values and perception ratings. A Duncan's multiple range test was then performed to examine the differences among the selected areas in the measured COF values and perception ratings, in which the results from all restaurants were pooled. Since the ages of the floor tiles in these restaurants were unknown, the interaction between restaurant and area was not investigated in the ANOVA analysis and a Duncan test for the restaurants was not performed. The Pearson's and Spearman's correlation coefficients between the average friction coefficients and the employees' subjective ratings were computed.

3. Results

3.1. Friction measurement

The number of tiles measured per restaurant ranged from 35 to 47 with an average of 41.5. The numbers of tiles measured in each area had means and standard deviations of 4.1 ± 0.87 (front counter), 6.7 ± 0.82 (fryer), 6.5 ± 0.71 (oven), 8.1 ± 1.91 (back vat), 7.7 ± 1.57 (sink), 4.6 ± 0.84 (walkthrough), and 3.7 ± 0.67 (beverage stand).

Table 1 presents the means and standard deviations of the friction coefficients for the seven areas in all 10 restaurants. In addition to the mean friction coefficient, it is also essential to examine the variation of friction on the floors. Although it is not clear about the level of friction variation necessary to increase the potential of slipping and falling, the coefficients of variation (CV), obtained by dividing the standard deviation by its mean value, for friction coefficients of all the areas in the restaurants were calculated. On average, the sink and back vat areas had the highest CV values in COF, while the beverage and front counter areas had the lowest CV values.

For the measured friction, the results of the ANOVA indicated that both participating restaurant and evaluated area were significant factors ($p < 0.0001$). Table 2

Table 1
Means and standard deviations of friction coefficients for the seven areas in the 10 restaurants

Restaurant	Front counter	Fryer	Oven	Back vat	Sink	Walk through	Beverage
1	0.69 (0.05)	0.76 (0.08)	0.71 (0.24)	0.69 (0.17)	0.31 (0.11)	0.82 (0.15)	0.75 (0.07)
2	0.77 (0.06)	0.88 (0.10)	0.98 (0.07)	0.88 (0.10)	0.13 (0.07)	0.81 (0.07)	0.78 (0.09)
3	0.91 (0.11)	0.76 (0.19)	0.88 (0.16)	0.51 (0.21)	0.29 (0.08)	0.83 (0.22)	1.00 (0.06)
4	0.79 (0.07)	0.78 (0.29)	0.61 (0.12)	0.75 (0.14)	0.14 (0.09)	0.98 (0.08)	0.82 (0.04)
5	0.93 (0.03)	0.75 (0.06)	0.74 (0.05)	0.67 (0.05)	0.31 (0.07)	0.79 (0.10)	0.85 (0.06)
6	0.75 (0.07)	0.87 (0.08)	0.90 (0.14)	0.95 (0.11)	0.20 (0.04)	0.79 (0.05)	0.84 (0.09)
7	1.05 (0.05)	0.88 (0.13)	0.59 (0.08)	0.46 (0.25)	0.78 (0.15)	0.96 (0.12)	1.05 (0.06)
8	1.10 (0.00)	0.83 (0.03)	0.26 (0.03)	0.56 (0.32)	0.37 (0.03)	1.07 (0.04)	1.10 (0.00)
9	1.00 (0.09)	0.47 (0.48)	0.86 (0.06)	0.65 (0.26)	0.09 (0.03)	0.99 (0.08)	0.99 (0.08)
10	0.83 (0.07)	0.94 (0.06)	0.80 (0.35)	0.97 (0.13)	0.08 (0.02)	1.05 (0.06)	0.86 (0.06)

Table 2
Sample sizes (n), means, standard deviations and multiple comparison results for different areas for the measured COF

Area	n	Mean	Standard deviation	Duncan group*
Beverage	74	0.91	0.14	A
Walk through	92	0.90	0.16	A
Front counter	82	0.90	0.15	A
Fryer	134	0.79	0.24	B
Oven	130	0.72	0.24	C
Back vat	162	0.71	0.25	C
Sink	154	0.28	0.21	D

*Different letters in Duncan group mean they were significantly different at $\alpha = 0.05$.

shows the means, standard deviations, and Duncan's group of the seven areas in COF. As a whole, the beverage, walk through and front counter areas had the highest COF values with mean values of 0.91, 0.90, and 0.90, respectively. The friction coefficients in these areas were significantly ($p<0.05$) higher than those in the other four areas. The friction coefficient in the fryer area (0.79) came in the second group to the aforementioned three areas and was significantly ($p<0.05$) higher than those of the oven, back vat and sink areas. The COF values in the oven (0.72) and back vat (0.71) areas were in the third group and were significantly ($p<0.05$) higher than that in the sink area (0.28). The results showed that the sink areas had the lowest average COF values across all 10 restaurants.

3.2. Subjective rating of floor slipperiness

Forty (40) females (71.4%) and 16 males (28.6%), out of 58 employees from all 10 restaurants working during the lunch period on the day of measurement, participated in the survey, yielding a participation rate of 96%. The number of participants per restaurant ranged from 4 to 10 with an average of 5.6. The means ($\pm$ standard deviation) of subject age, length of tenure, and working hours per week of the participants were 22.5 ($\pm$5.9) years, 13.1 ($\pm$13.3) months, and 37.9 ($\pm$9.5) h, respectively.

Table 3 shows the means and standard deviations of the subjective scores of floor slipperiness for the seven areas in all 10 restaurants. Similar to the CV for friction, the sink and back vat areas had the highest CV values in perception rating, while the front counter and walk through areas had the lowest CV.

The results of the two-way ANOVA indicated that both restaurant and area were significant factors in perception rating ($p<0.0001$). Table 4 shows the means, standard deviations, and Duncan's group of the seven areas in perception rating. The mean ratings in the back vat (2.68) and sink (2.70) areas that were rated as the most and the second most slippery areas, respectively, were significantly ($p<0.05$) lower than those of the oven (3.15), beverage (3.72), walk through (3.74) and front counter (3.74) areas. The fryer area was rated as the third most slippery area with a mean rating of 2.96 which was significantly lower than those of beverage, walk through and front counter areas ($p<0.05$). The floor slipperiness of the oven area was rated as the fourth slippery area in the kitchen. It was also significantly lower than those of beverage, walk through and front counter areas ($p<0.05$). The differences among the beverage, walk through, and front counter areas were not statistically significant.

3.3. Correlation between friction and perception

The subjective rating was correlated with the measured friction coefficient across all the evaluated areas by calculating Spearman's rank correlation coefficients and Pearson's correlation coefficient. Each area in each restaurant was treated as an individual sample with its mean COF value and subjective score from Tables 1 and 3. The relationship between the average friction coefficient and the average subjective score is shown in Fig. 2. The Pearson's and Spearman's correlation coefficients were 0.49 and 0.45 ($p<0.0001$ for both), respectively, with a sample size of 70.

Table 3
Means and standard deviations for the subjective scores of floor slipperiness

Restaurant	Front counter	Fry vat	Oven	Back vat	Sink	Walk through	Beverage
1	3.80 (0.45)	3.25 (0.50)	3.25 (0.96)	2.60 (1.34)	3.20 (1.30)	3.80 (0.45)	4.00 (0.00)
2	3.89 (0.33)	2.80 (1.23)	3.50 (0.71)	2.50 (1.08)	2.30 (1.25)	4.00 (0.00)	3.78 (0.44)
3	3.75 (0.50)	2.50 (0.58)	2.00 (1.15)	1.75 (0.96)	2.75 (0.96)	3.00 (0.82)	3.50 (0.58)
4	4.00 (0.00)	3.80 (0.45)	3.40 (0.55)	2.80 (0.84)	2.60 (1.14)	3.40 (0.55)	4.00 (0.00)
5	4.00 (0.00)	3.20 (0.84)	3.20 (0.84)	2.75 (0.50)	3.00 (1.00)	4.00 (0.00)	4.00 (0.00)
6	4.00 (0.00)	3.75 (0.50)	3.50 (0.58)	4.00 (0.00)	3.25 (0.96)	4.00 (0.00)	3.25 (0.96)
7	3.20 (0.45)	2.00 (0.71)	2.50 (0.58)	1.75 (0.50)	2.25 (0.96)	4.00 (0.00)	3.60 (0.55)
8	3.67 (0.52)	3.00 (0.63)	2.33 (0.82)	2.33 (0.82)	2.50 (1.22)	4.00 (0.00)	4.00 (0.00)
9	3.72 (0.49)	2.86 (0.38)	4.00 (0.00)	3.43 (0.53)	3.14 (0.69)	3.86 (0.38)	3.43 (0.53)
10	3.25 (0.50)	2.75 (0.50)	2.80 (0.82)	2.75 (0.50)	2.25 (0.50)	3.50 (0.58)	3.50 (0.58)

Table 4
Sample sizes (n), means, standard deviations and multiple comparison results for different areas for the subjective ratings of floor slipperiness

Area	n	Mean	Standard deviation	Duncan group*
Front counter	54	3.74	0.44	A
Walk through	53	3.74	0.48	A
Beverage	53	3.72	0.49	A
Oven	53	3.15	0.88	B
Fryer	54	2.96	0.85	B, C
Sink	54	2.70	1.04	C
Back vat	53	2.68	0.97	C

*Different letters in Duncan group mean they were significantly different at $\alpha = 0.05$.

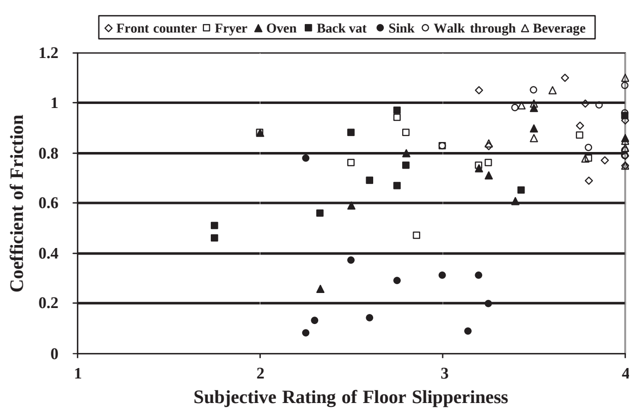

Fig. 2. Average coefficient of friction versus subjective score across 70 working areas.

A high subjective score variation may be associated with a high variation in COF. Comparing the results shown in Tables 1 and 3, there were six areas that had a large variation in both subjective score and COF: the oven area of restaurant 8, the back vat areas of restaurants 3 and 8, and the sink areas of restaurants 1, 2 and 4. Similar to the correlation between the mean values of COF and subjective rating, the correlation between friction CV and subjective rating CV is shown in Fig. 3, and the Pearson's and Spearman's correlation

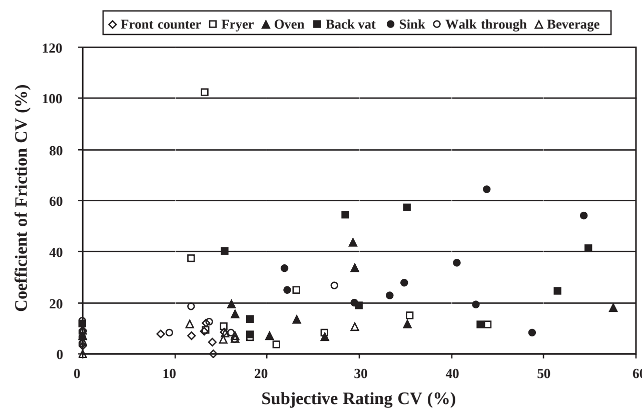

Fig. 3. Average coefficient of variation (CV) in coefficient of friction versus CV in subjective score across 70 working areas.

coefficients for CV were 0.41 and 0.52 ($p < 0.0001$ for both), respectively.

4. Discussion

Despite speculations that friction variation can play a significant role in the perception of slipperiness (Strandberg, 1985), the results from the current study indicate that the mean value of COF had fair agreement with the perception rating. However, the results from Chang et al. (2003) indicated a significant variation among the friction measured on four floor tiles in the same areas. Therefore, it is necessary to measure friction on several tiles in the area and use the average to represent the friction in that area.

The friction values of the tiles in the kitchens are not only time dependent but also location dependent. Contaminants such as water, oil, sauce, powder, or other debris are very likely present on the floors of the major food processing and cleanup areas such as the fryer, back vat, oven, and sink areas. The tiles in these areas are more likely to have a low COF. Due to water contamination, the sink area had the lowest COF value in the kitchen for eight of the restaurants. The mean friction coefficients in the sink area for restaurants 9 and

10 were as low as 0.09 and 0.08, respectively, which were the lowest COF values measured in this study. The beverage and front counter areas are less likely to experience floor contamination since there are fewer sources of contamination and any spillage is normally removed as soon as possible for a better business image. The results shown in Table 1 indicated that the tiles in the beverage, front counter and walk through areas had high COF values. The friction coefficients in the fryer and back vat areas were, in general, higher than 0.5, the widely applied standard in the USA (American National Standard Institute, 2001). However, 50% and 80% of restaurants had subjective ratings less than 3.0 in the fryer and back vat areas, respectively. This implies that the employees perceived the floors in those areas as ‘‘somewhat slippery.’’ Generally, grease and oil were observed on tiles in the fryer, oven and back vat areas of the restaurants. However, the effects of the contaminants on friction was not as pronounced as expected, given the presence of these contaminants. Low friction coefficients were obtained in these areas only on those tiles with visible spillage of oil and/or mixtures of oil and water. Accumulation of grease on the Neolite pad during repeated strikes, as reported by Chang et al. (2003), could potentially affect the results of friction measurements in these greasy areas.

The correlation between the subjective and objective measurements of floor slipperiness was statistically significant; however, some disagreements were noted as some employees rated low friction coefficient areas as not slippery while others rated high friction coefficient areas as slippery. An example of the former situation was found in the sink area of restaurant 9 where the friction coefficient was very low (0.09) but the subjective rating was high (3.14). Examples of the later situation were found in the fryer area of restaurant 7 and the oven area of restaurant 3. The employees rated these areas as slippery (2.0), but the friction coefficients in the two areas were comparably high (0.88 for both areas). Low subjective ratings, referring to more slippery conditions, were also found in the back vat areas of restaurants 3 and 7 (1.75 for both) where the friction coefficients were not as low (0.51 and 0.46, respectively). Situations in these two areas may be explained by the high friction variation of the two areas where the subjects experienced certain low friction tiles and tended to rate the whole area as more slippery. The back vat area was rated as the most slippery area among the seven areas, but the mean friction coefficients were much higher than those of the sink areas. Fig. 2 shows that the data points with a high perception rating where the floors were rated as not-slippery are more condensed, but the data points with a low perception rating where floors were rated as more slippery are more dispersed. The data points with a high perception rating were mainly obtained from the front counter, beverage, and walk through areas. The results shown in Fig. 2 indicate that, in these areas, the COF was high and the employees were more certain about floor slipperiness. The data points with a low perception rating represent the results primarily from the other four areas. The wider spread of the data points here indicates that the variations of both the friction values and subjective ratings in these areas were high. In these areas, the employees seemed to be less consistent, possibly less certain, about the level of floor slipperiness as compared to that of the front counter, beverage, and walk through areas. These variations in friction and subjective rating could also result from variations in employees' exposure to the floor conditions.

Spillage of water, oil, and/or mixtures of both are very likely, especially in the fryer, back vat, oven and sink areas. Spillage on the floor is normally transferred to other areas under the shoes of the employees walking from one area to another. Repeatedly walking on spillage also reduces the amount of the contaminants in an area. In addition, spillage of water may be further reduced due to evaporation. The thickness of the film of oil on the floor may also become very thin and eventually invisible to the naked eye. It is for this reason that friction measurement results may be quite different if conducted at different times. The friction measurement results of the current study may reveal only the friction status at the time of measurement, but the results of the perception survey reflected the floor conditions throughout the whole lunch period.

There were several other limitations in this study. The sample sizes for the ANOVA of the measured friction and perception ratings were small due to the limited numbers of employees at these restaurants and fewer tiles measured at less critical areas. Friction in different restaurants was measured with identical Neolite pads on different days. The results from Chang (2002) indicated that friction variations with identical pads measured at different times could be statistically significant. Also, employees wore different kinds of shoes with different degrees of wear, but friction measurements were conducted with smooth Neolite pads. Since the shoe material and tread pattern on the shoe bottoms would affect the perception rating, not being able to control what employees wore certainly induced variations in perception and affected its correlation with friction. Employees' rating standards could also differ. In contrast to a laboratory study in which a calibration procedure could be used to control the base of the rating scale, employees used their break time to participate in the survey in this study, and space and time were limited due to the nature of this study. In addition, cross contaminations such as water in the sink area trapped under shoes contaminating the fryer area could alter employees' perception of the fryer area, but wet testing was not performed in the fryer areas to account for this possibility. Loose, gross contaminants could affect the perception ratings, but they were removed before the friction measurements. However, the removal of loose, gross contaminants was executed only three times during the whole study and usually one piece of french fry or chicken fry was removed each time. Therefore, its impact on the correlation should be very limited. It is known that the Brungraber Mark II has more squeeze-film effect, leading to lower COF values on liquid contaminated surfaces, than other slipmeters with similar measurement characteristics (Chang et al., 2001a). In this experiment, the COF values measured in the sink areas were lower than those in other areas which could help reduce the correlation coefficients between friction and perception.

5. Conclusions

This study provided a unique opportunity to explore the relationship between the average friction coefficient and perception over seven major working areas in a restaurant field environment. The results of the current study showed that the levels of friction in different areas in the kitchens of fast-food restaurants were significantly different. This coincides with the general perception that certain areas in a kitchen are more slippery than others. The friction coefficients in the sink areas were significantly lower than those of the other areas and hence were the most slippery areas in the restaurants. The average friction coefficients of the fryer and back vat areas were higher than the commonly used reference of 0.5, even though they were perceived as slippery areas by the employees. The subjective ratings of floor slipperiness showed that the employees perceived the back vat, sink and fryer as the most slippery areas in the kitchens. The correlation coefficients between the friction coefficients and the subjective ratings were statistically significant ($p<0.0001$). The results indicate that the average friction coefficient and perception are in fair agreement, suggesting both might be reasonably good indicators of slipperiness. Discrepancy between the measured friction value and the perception of floor slipperiness may increase the difficulties in effectively identifying slippery areas for interventions.

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