Ergonomics

ISSN: 0014-0139 (Print) 1366-5847 (Online) Journal homepage: https://www.tandfonline.com/loi/terg20

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To cite this article: Santosh K. Verma, Zhe Zhao, Theodore K. Courtney, Wen-Ruey Chang, David A. Lombardi, Yueng-Hsiang Huang, Melanye J. Brennan & Melissa J. Perry (2014) Duration of slip-resistant shoe usage and the rate of slipping in limited-service restaurants: results from a prospective and crossover study, Ergonomics, 57:12, 1919-1926, DOI: 10.1080/00140139.2014.952348

To link to this article: https://doi.org/10.1080/00140139.2014.952348

Published online: 10 Sep 2014.

Ergonomics, 2014
Vol. 57, No. 12, 1919–1926, http://dx.doi.org/10.1080/00140139.2014.952348

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Duration of slip-resistant shoe usage and the rate of slipping in limited-service restaurants: results from a prospective and crossover study

Santosh K. Verma[a,b]*, Zhe Zhao[c], Theodore K. Courtney[a,d], Wen-Ruey Chang[e], David A. Lombardi[a,d], Yueng-Hsiang Huang[f], Melanye J. Brennan[a] and Melissa J. Perry[g]

[a]*Center for Injury Epidemiology, Liberty Mutual Research Institute for Safety, Hopkinton, MA, USA;* [b]*Department of Family Medicine and Community Health, University of Massachusetts Medical School, Worcester, MA, USA;* [c]*Department of Public Health, School of Public Health and Health Sciences, University of Massachusetts, Amherst, MA, USA;* [d]*Environmental and Occupational Medicine and Epidemiology Program, Department of Environmental Health, Harvard School of Public Health, Boston, MA, USA;* [e]*Center for Physical Ergonomics, Liberty Mutual Research Institute for Safety, Hopkinton, MA, USA;* [f]*Center for Behavioral Sciences, Liberty Mutual Research Institute for Safety, Hopkinton, MA, USA;* [g]*Department of Environmental and Occupational Health, The George Washington University, Washington, DC, USA*

(*Received 23 October 2013; accepted 18 July 2014*)

Several studies have indicated that slip-resistant shoes may have a positive effect on reducing the risk of slips and falls, a leading cause of injury at work. Few studies, however, have examined how duration of shoe usage affects their slip-resistance properties. This study examined the association between the duration of slip-resistant shoes usage and the self-reported rate of slipping in limited-service restaurant workers. A total of 475 workers from 36 limited-service restaurants in the USA were recruited to participate in a 12-week prospective study of workplace slipping. Of the 475 participants, 83 reported changing to a new pair of shoes at least once during the 12-week follow-up. The results show that slip-resistant shoes worn for less than six months were moderately more effective than those worn for more than six months. Changing to a new pair of shoes among those wearing slip-resistant shoes at baseline was associated with a 55% reduction in the rate of slipping (RR = 0.45, 95% CI = 0.23–0.89). Further research is needed to develop criteria for the replacement of slip-resistant shoes.

Practitioner Summary: The duration of usage impacts the slip-resistance properties of slip-resistant shoes. Slip-resistant shoes worn for less than six months were moderately more effective in reducing slips than slip-resistant shoes worn for more than six months. Shoe use policies should not only encourage or require their use but also include guidance on replacing slip-resistant shoes at regular intervals.

Keywords: slips; falls; injury; restaurants; slip-resistant shoes; shoe wear; shoe usage; personal protective equipment; safety

1. Introduction

Falls lead to a significant injury burden both at work and in the general population (Finkelstein, Phaedra, and Miller 2006). The US National Center for Injury Prevention and Control reported that over 9.25 million visits to hospital emergency departments were due to falls in 2011 (Centers for Disease Control and Prevention 2012). In 2011, 25% of non-fatal occupational injuries and illnesses involving days away from work were due to slips, trips and falls (Bureau of Labor Statistics 2012). The proportion of same-level slip-, trip- and fall-related occupational injuries ranges from 20% to 40% of all disabling occupational injuries in developed countries (Courtney et al. 2001; Leamon 1992; Leclercq, Thouy, and Rossignol 2007; McNamee et al. 1997). In the USA, about 30% of disabling occupational same-level fall-related injuries result in 31 or more workdays lost (Yeoh, Lockhart, and Wu 2013). According to the Liberty Mutual Workplace Safety Index, the direct cost of same-level fall-related injuries in the USA in 2010 was estimated to be US$8.6 billion, and the inflation-adjusted cost of work-related injuries due to same-level falls increased by 42.3% from 1998 to 2010, the greatest increase among major leading workplace injury causes (Liberty Mutual Research Institute for Safety 2012). Yeoh, Lockhart, and Wu (2013) reported that US workers in the health care and social assistance industry, the transportation and warehousing industry, and the accommodation and food services industry had the highest risk for same-level fall-related injuries.

Based on studies in working populations, slipping is a primary initiating event for same-level falls and contributes to between 40% and 85% of fall-related occupational injuries (Courtney et al. 2001; Kemmlert and Lundholm 2001; Manning et al. 1988; Verma et al. 2008). In addition, slipping that does not result in a fall can still result in an injury from striking an object or from a muscular strain (Manning and Shannon 1981; Troup, Martin, and Lloyd 1981). Hayes-Lundy et al. (1991) reported that 11% of grease burns in fast-food restaurants could be attributed to slips.

*Corresponding author. Email: santosh.verma@libertymutual.com

Different shoe sole materials and tread patterns have different slip-resistant properties (Chang and Matz 2001; Li et al. 2004; Li and Chen 2005), and slip resistance can vary widely among common footwear materials (Chang and Matz 2001; Menz, Lord, and McIntosh 2001). The Health and Safety Laboratory published a report on the slip potential of common 'occupational footwear' based on ramp tests in the laboratory environment (Health and Safety Laboratory U.K. 2009). They reported that shoes marketed as 'slip-resistant' provide better slip-resistance than shoes that are not marketed as slip-resistant. Bell et al. (2008) reported on an effective slip, trip and fall prevention intervention programme for hospital employees where slip-resistant shoes were a part of a comprehensive intervention approach. For older adults, Menant et al. (2008) indicated that use of low heels and slip-resistant shoes both inside and outside the home can reduce risk of slips and falls. Gao et al. (2004) explored the risk of slips and falls in cold climates and found that use of slip-resistant footwear was one of the most efficient approaches for preventing slips and falls. Verma et al. (2011a) conducted a prospective cohort study in limited-service restaurant workers and found that slip-resistant shoes were associated with a 54% reduction in the self-reported rate of slipping. They further reported that slip-resistant shoes reduced the effects of rushing and walking on a contaminated floor on the risk of slipping and suggested that slip-resistant shoes may have a substantial potential for slip and fall prevention (Verma et al. 2011b).

Duration of shoe usage can affect the tread depth and the physical properties of the sole material (William 1999). Few studies have examined the effects of shoe wear on the coefficient of friction between the shoe sole and the floor or the perception of slipperiness (Chiou, Bhattacharya, and Succop 1996; Li, Wu, and Lin 2006; Ziaei et al. 2013). In addition, there are no published studies that have examined the effect of shoe wear on the risk of slipping in actual work environments.

Given the potential of slip-resistant shoes in preventing slips and falls, this study aims to examine the association between duration of slip-resistant shoe usage and the rate of slipping in limited-service restaurant workers. We examined whether slip-resistant shoes worn for six months or less were more effective than slip-resistant shoes worn for more than six months. We also explored whether change of shoes was associated with a reduced rate of slipping.

2. Methods

This study was conducted in 36 limited-service restaurants from three major chains in the states of Connecticut, Massachusetts, New York, Pennsylvania, Tennessee and Wisconsin in the USA. These restaurants had similar main menu items, including, for example, hamburgers and fried potatoes. Floors in all participating restaurants in this study were of the same type – quarry tiles. Several approaches were used to recruit the restaurants for the study that included approaching chains, stores or franchisees that had previously been receptive to research studies by the investigative team members, approaching restaurant trade associations, direct solicitation of stores or franchisees, and outreach via the loss control department of a large worker's compensation insurance company.

A total of 475 workers were recruited from these restaurants during 2007–2008. The study was approved by the Institutional Review Board of the Liberty Mutual Research Institute for Safety and the Office of Human Research Administration at the Harvard School of Public Health.

2.1 Enrolment procedure

Once permission to enrol a restaurant was received, members of the study team met onsite with the restaurant manager to explain the research study, administer a baseline survey to the manager and set up an appointment to enrol and survey the restaurant's employees. Restaurant managers were given fliers to post in their employee break area advertising the study with the date of the survey team's upcoming visit. On the scheduled date, informed consents were obtained, participants were enrolled and surveys were conducted in the restaurant. Restaurant workers not working on the day of enrolment were encouraged to come to the restaurant sometime during that day, with their work shoes, if they were interested in participating in the study. The survey materials were made available in three languages: English, Spanish and Portuguese. After completing the baseline survey, participants were asked to report their slip experience every week for the following 12 weeks. Enrolment procedures have been previously described in detail (Verma et al. 2010, 2011a).

2.2 Individual factors

Demographic information about each participant was collected, including age, gender, weight, height, race, highest education level and primary language. Questions about job and restaurant characteristics included job tenure in the current restaurant and restaurant chain.

2.3 Slip-resistant shoes

Since clear classification criteria for slip-resistant shoes could not be found in the peer-reviewed literature, shoes were classified as slip resistant if there was a manufacturer claim of the shoe as slip-resistant using a label on the shoe sole. Participants were asked to remove the right shoe for assessment of the presence or absence of this label.

2.4 Duration of shoe usage

In the baseline survey, participants were asked how many months they had been wearing their current work shoes. Participants were categorised into two groups based on the duration of the shoe usage: those with shoes worn no more than six months and those with shoes worn more than six months. A criterion for six months was chosen because some slip-resistant shoe companies and slip-resistant shoe programmes recommend changing slip-resistant shoes every six months (see references Shoes for Crews 2013; Skechers 2013). During the 12-week follow-up surveys, participants were asked to report whether they replaced old shoes with brand new shoes.

2.5 Slipping

A study team member carefully explained the definition of a slip to the study participants by stating that 'A slip is simply a loss of traction of your foot – you can slip without falling'. Each week, for 12 weeks, participants reported the number of slips and the number of hours they worked in the previous week. Rate of slipping was the primary outcome of interest (total number of slips reported/total number of hours worked during follow-up).

Participants were given a choice of reporting their weekly slip experience by telephone using the interactive voice response system, by an Internet-based survey, or by filling out and mailing printed survey forms.

3. Statistical analysis

Restaurants recruited in the survey were clustered within chains, and workers were clustered within restaurants. To account for the clustering of participants within restaurants, a generalised estimating equation model with a compound symmetry covariance structure (Liang and Zeger 1986; Zeger and Liang 1986) was used to assess the association between the shoe characteristic (slip-resistant or not) and the rate of slipping, stratified by the duration of shoe usage. As there were three chains, two indicator variables for chains were included in the regression model to account for the clustering of restaurants within chains.

Univariate/multivariable negative binomial generalised estimating equation models were used to estimate unadjusted and adjusted rate ratios (RRs) for slipping. All potential confounders (individual factors mentioned in the Methods section) were selected *a priori* and were included in the multivariable model regardless of the significance level. If the multivariable model failed to converge, then some non-significant variables were dropped from the multivariable model.

To examine the association between shoe change (from used shoes to brand new shoes) and the rate of slipping, a crossover analysis was conducted and clustering at the individual level was taken into consideration. The rate of slipping before the shoe change and after the shoe change was compared using RRs. The analysis was stratified by the use of slip-resistant and non-slip-resistant shoes at baseline. RRs for the change of shoes and their 95% confidence intervals (CIs), based on robust standard error estimates are presented. All statistical analyses were performed using the SAS system version 9.3.

4. Results

4.1 Slip-resistant shoes worn ≤ 6 months versus > 6 months

Of the 475 participants in the study, 462 (97%) from 36 limited-service restaurants reported the duration of their current shoe use in the baseline survey. A total of 279 (59%) participants reported having worn their work shoes for six months or less, while 183 (39%) had shoes that were worn for more than six months. Shoes were examined; 313 (68%) participants wore slip-resistant shoes and 149 (32%) wore non-slip-resistant shoes. Seventy of the 475 participants worked in restaurants that provided shoes.

Table 1 presents demographic information about participants whose work shoes were worn six months or less at baseline (Group 1) and more than six months (Group 2). The mean age of participants in the two groups was not significantly different (mean = 31 years). In both the groups, more than three-fifths of the participants were female (69% and 62%, respectively). The primary language of both groups was English (89% and 88%, respectively). Almost two-thirds of participants reported they had at least completed high school. The differences between age, gender, BMI, primary language, education level and job tenure between the two groups were also not significantly different from each other at $\alpha = 0.05$. A higher proportion of participants with shoes worn for six months or less wore slip-resistant shoes as compared to those with shoes worn for longer than six months (71.3% and 62.3%, respectively; $p = 0.04$).

Table 1. Demographic characteristics of participants by duration of shoe use at baseline ($N = 462$).

	Group 1: participants with shoes worn 6 months or less ($n = 279$)	Group 2: participants with shoes worn more than 6 months ($n = 183$)
Age (years)		
Mean (SD)	30.7 (12.7)	31.2 (14.4)
Median (range)	28.0 (15–71)	25.0 (15–78)
Female (*n*, %)	193 (69.2)	113 (61.8)
BMI (*n*, %)		
≤ 18.5	4 (1.4)	10 (5.5)
18.5–24.9	108 (38.7)	70 (38.7)
25.0–34.9	119 (42.7)	82 (44.8)
35.0–39.9	26 (9.3)	15 (8.2)
40 +	22 (7.9)	6 (3.3)
Primary language (*n*, %)		
English	248 (88.9)	161 (88.0)
Spanish	23 (8.2)	16 (8.7)
Portuguese	8 (2.9)	6 (3.3)
Education (*n*, %)		
Never attended school	2 (0.7)	3 (1.6)
Grades 1–11	92 (33.0)	60 (32.8)
Completed high school	113 (40.5)	70 (38.3)
Some college or above	72 (25.8)	50 (27.3)
Job tenure (months)		
Mean (SD)	33.9 (49.5)	38.5 (46.8)
Median (range)	18 (0–312)	19 (0–300)
Slip-resistant shoe (*n*, %)		
Yes	199 (71.3)	114 (62.3)
No	80 (28.7)	69 (37.7)

Table 2 presents RRs for rate of slipping, stratified by the duration of shoe usage (≤6 months and >6 months). For both the groups, use of slip-resistant shoes was significantly associated with a reduced rate of slipping in the unadjusted regression model (Table 2). In the multivariable model that was adjusted for age, gender, BMI, highest education level, primary language, job tenure and restaurant chain, slip-resistant shoes worn for six months or less were associated with a 58% reduction in the reported rate of slipping (RR = 0.42, 95% CI = 0.28–0.64). Slip-resistant shoes worn for more than six months were marginally associated with a reduction in the reported rate of slipping associated (RR = 0.55, 95% CI = 0.29–1.02). In both unadjusted and adjusted regression models, use of slip-resistant shoes that were worn six months or less at baseline were associated with a higher reduction in the reported rate of slipping during the 12-week follow-up than those that were worn for more than six months (69% vs. 57%, respectively, in the univariate and 58% vs. 45% in the multivariable model).

4.2 Crossover analysis

Of the 475 participants, 83 reported changing their used shoes to brand new shoes at least one time within the 12-week follow-up. Three of those 83 participants reported changing their shoes in the first week and were dropped from the crossover analysis. One participant with a very high reported rate of slipping (278 slips per 2000 hours) was also excluded

Table 2. RR* and their 95% CIs for the rate of slipping during 12-week follow-up by duration of shoe use at baseline.

	Univariate				Multivariable			
	≤6 months		>6 months		≤6 months[a]		>6 months[b]	
	RR	95% CI	RR	95% CI	RR	95% CI	RR	95% CI
Slip-resistant shoes	0.31	0.19–0.50	0.43	0.23–0.81	0.42	0.28–0.64	0.55	0.29–1.02
Non-slip-resistant shoes	1.00	–	1.00	–	1.00	–	1.00	–

Note: RR for slipping compares the rate of slipping among those wearing slip-resistant shoes to those who were not wearing slip-resistant shoes.
[a] Adjusted for age, gender, BMI, education, primary language, job tenure and chain of the restaurants.
[b] Adjusted for age, gender, BMI, education, job tenure and chain of the restaurants. Language was dropped as the model failed to converge.

Table 3. RR for the rate of slipping before and after shoe change, and their 95% CIs from univariate/multivariable regression models.

	Before shoe change vs. after shoe change			
	Univariate		Multivariable[a]	
	RR	95% CI	RR	95% CI
Slip-resistant shoes ($n = 44$)	0.44	0.27–0.73	0.45	0.23–0.89
Non-slip-resistant shoes ($n = 35$)	0.61	0.34–1.11	0.64	0.33–1.23

[a] Adjusted for age, gender, BMI, primary language, highest education level, restaurant and restaurant chain.

from the analysis. When participants changed their shoes, the shoes were 9.4 months old on average for slip-resistant shoes and 14.6 months old on average for non-slip-resistant shoes.

For the slip-resistant shoe users who changed their shoes to a new pair of shoes, the rate of slipping was 18 slips per full-time equivalent (FTE, 2000 work hours) before and 8 slips per FTE after the change. For non-slip-resistant shoe users, these rates were 19 slips per FTE before and 17 slips per FTE after shoe change. For the participants using slip-resistant shoes at baseline, changing their used shoes to brand new shoes was associated with a 56% reduction in the reported rate of slipping (RR = 0.44, 95% CI = 0.27–0.73; Table 3). For those wearing non-slip-resistant shoes at baseline, this association was not statistically significant (RR = 0.61, 95% CI = 0.34–1.11). After adjusting for age, gender, BMI, primary language, highest education level, restaurant and restaurant chain, the multivariable model indicated results similar to the unadjusted model.

5. Discussion

This study examined the association between the duration of shoe usage and the slipping rate in limited-service restaurant workers. Among those who had been wearing their shoes for less than six months at baseline, we found that slip-resistant shoes were associated with a reduced rate of slipping. Although not statistically significant at $\alpha = 0.05$, slip-resistant shoes were also associated with reduced rate of slipping among those wearing their shoes for more than six months. Changing to a new pair of shoes was associated with a more than 50% reduction in the reported rate of slipping for slip-resistant shoe users, but was not significantly associated with the rate of slipping for the non-slip-resistant shoe users.

Very few studies have examined the effects of shoe wear on the risk of slipping. Chiou, Bhattacharya, and Succop (1996) found that use of new shoes while walking on medium and highly oily floor conditions was associated with a lower perception of slipperiness than older shoes. For these two conditions, they did not find a significant difference in the dynamic coefficient of friction between new and old shoes. We found that in an active work environment, slip-resistant shoes worn for less than six months were moderately more effective than slip-resistant shoes that were used for more than six months. For ‘new shoes’, Chiou, Bhattacharya, and Succop (1996) tested shoes that were brand new and used for the first time. However, we classified shoes based on whether they were worn for six months or less or they were worn more than six months.

William (1999) noted that duration of shoe usage and the frequency of their use may affect the available tread and the physical properties of the sole material (such as roughness and hardness). Both these factors can affect the slip-resistance properties of the shoes. Ziaei et al. (2013) examined the effect of different shoe sole tread groove depths on the required coefficient of friction. Twenty-two healthy men walked on dry and slippery surfaces wearing shoes with shoe groove depths of 1, 2.5 and 5 mm. They found tread groove depth to be a significant factor associated with the required coefficient of friction at the shoe-surface interface on dry and slippery floors. Li, Wu, and Lin (2006) found that higher friction values were recorded for footwear pads with deeper tread grooves on wet and water-detergent-contaminated floors. The average coefficient of friction gain ranged from 0.018 to 0.108 for each millimetre increase in tread groove depth, depending on the tread groove width, floor and contaminant.

Tsai and Powers (2008) found that individuals wearing shoes with harder soles were at greater risk for slipping. Asymmetric sole wear may also affect gait and the fatigue in lower limbs and, thus, may increase the risk of slipping (Sole et al. 2010). Grönqvist (1995) suggested that footwear must be discarded before the tread pattern is worn out. However, workers may replace shoes primarily based on the appearance of the top.

Comparing the effectiveness of brand new shoes as compared to used shoes for slip-resistant shoe users, we found that the slipping rate after the shoe change was about half of the slipping rate before the shoe change. We did not find any significant effect on slipping rate among those who were wearing non-slip-resistant shoes. We also fitted a fixed effects model which considers only differences *within* each individual and found similar results

At present, slip-resistant shoe companies recommend changing shoes every six months. Several factors other than duration of use may affect shoe wear. Slip-resistant shoe companies may consider designing shoe soles with a marker to indicate the sole wear and the time to replace shoes. To maximise the effectiveness and efficiency of such markers, further research may be needed to develop criteria for the replacement of slip-resistant shoes.

5.1 Limitations and strengths

We classified shoes as slip-resistant or not based on manufacturer claims. However, not all ‘slip-resistant’ shoes provide equal slip resistance. The UK Health and Safety Laboratory reported that among shoes marketed as ‘slip-resistant’, 33% posed low, 33% posed moderate and 33% posed high slip potential on quarry tiles (a common type of floor surface found in the limited-service restaurants) with glycerol contamination. They also found that almost all shoes that are not marketed as slip-resistant posed high slip potential in this environment. (Health and Safety Laboratory U.K. 2009). Second, we used duration of shoe use as a proxy for shoe wear. Duration of use affects both the available tread depth and the ageing of the sole material. However, frequency of use (both on and off work), hardness of sole material, gait and other personal characteristics may also affect shoe wear.

At baseline, we classified shoes into slip-resistant or not based on visual inspection of manufacturer label. However, we did not have reliable information about shoe type after the change of shoes. It is likely that participants using slip-resistant shoes at baseline changed to another pair of slip-resistant shoes. It is also possible that a subset of participants using non-slip-resistant shoes at baseline changed to slip-resistant shoes and, thus, we observed a reduced rate of slipping (not significant) in this population.

A fixed effects model controls for variables that do not change within an individual. There is still a potential for confounding, however, by variables that change with time. In the previous study, we found that rushing, distraction and walking on contaminated floors were associated with a higher risk of slipping (Verma et al. 2011b). In this study, the prevalence of distraction, rushing and walking on a contaminated floor before and after the shoe change was similar (data not shown). Thus, it is unlikely that the effect of shoe change could be fully explained by these potential confounding factors.

As slipping was self-reported, it is possible that participants may have reported fewer slips after getting brand new shoes or a high number of slips may have motivated them to get a new pair. However, such bias will affect both slip-resistant shoe users and non-slip-resistant shoe users. As we did not find shoe change to be associated with a lower rate of slipping among non-slip-resistant shoe users, our results may not be fully explained by such biases.

One of the major strengths of the study is that the use of slip-resistant shoes was directly observed by investigators at baseline, which limits self-report bias. Another strength is that 36 restaurants belonging to three different major chains from six different states participated in the study, thus increasing the external validity (generalisability) of the findings. However, since 34 of the 36 restaurants were owned by larger employers, some of the findings may not be generalisable to smaller employers.

6. Conclusion

This is one of the first studies to examine the association between duration of shoe use and the rate of slipping in limited-service restaurants. Slip-resistant shoes have been shown to be effective in reducing rate of slipping and workers should be encouraged to wear slip-resistant shoes. Findings suggest that change to a new pair of slip-resistant shoes, and slip-resistant shoes less than six months old were more effective than older shoes in reducing the rate of slipping. Further research is needed to develop criteria for replacement of slip-resistant shoes.

Acknowledgements

The authors thank the following people who contributed to the collection of data or study administration: Jacob Banks, Christopher Brunette, Albert Chang, Helen Corns, Niall O’Brien, Greg Schultz, Joanna Willetts, Joe Ferreira, Sandra Goncalves, Gabriela Herscovici, Patricia Boelsen, and Monica Colon. The authors also thank Margaret Rothwell for editing and proofreading the manuscript. The authors are indebted to Tin-Chi Lin for his help with the fixed effects model, and Xu Xu and Ray McGorry for their constructive criticisms of earlier drafts of the manuscript.

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