FALLS RESULTING FROM A LABORATORY-INDUCED SLIP OCCUR AT A HIGHER RATE AMONG YOUNG AND OLDER ADULTS WHO ARE OBESE

[1]Leigh J. Allin, [2]Xuefang Wu, [2]Maury A. Nussbaum, and [3]Michael L. Madigan

[1]University of Virginia, Charlottesville, VA, USA
[2]Virginia Polytechnic Institute and State University, Blacksburg, VA, USA
[3]Texas A&M University, College Station, TX, USA
Email: leigh.allin@virginia.edu

INTRODUCTION

Falls due to slipping are a serious occupational concern. Slipping is estimated to cause 40-50% of all fall-related injuries [1]. Epidemiological data suggest that individuals who are older or obese fall more frequently than younger, non-obese adults [2]. The problem of slip-related falls may be exacerbated by a high prevalence of obesity and an aging workforce in the United States. The purpose of this study was to investigate the effects of obesity and age on slip severity and fall frequency following a laboratory-induced slip. Results from this study can help to identify obesity and/or age as risk factors for falling from slipping, and may aid in the development of fall-prevention strategies

METHODS

Seventy-two adults completed the study including: 26 young (18-29 years) non-obese (BMI 17.7-24.9 kg/m^2); 25 young obese (BMI 29.1–40.4 kg/m^2); 10 older (50-66 years) non-obese (BMI 19.5-26.3 kg/m^2); and 11 older obese (BMI 30.1–45.1 kg/m^2) individuals. During each experimental session, participants wore a harness and walked at a comfortable, but purposeful, pace along a 10m walkway. After 10-20 walking trials, a thin layer of vegetable oil was applied to the surface of a force platform to induce a slip of the dominant foot.

Positions of selected anatomical landmarks were sampled at 100 Hz using a six-camera motion analysis system (Vicon Motion Systems, Centennial, CO) and low-pass filtered at 7 Hz (second-order, zero-phase-lag Butterworth filter). Ground reaction forces under the slipping foot and force applied to the harness were sampled at 1000 Hz using a force platform (Bertec Corporation, Columbus, OH) and a uniaxial load cell (Cooper Instruments and Systems, Warrenton, VA), respectively. Both were low-pass filtered at 20 Hz.

Slip outcomes were classified as falls, recoveries, or harness-assisted based on methods similar to Brady et al. [3] and Yang and Pai [5]. Gait speed, step length, and four measures of slip severity (slip duration, slip distance, peak slip velocity, and mean slip velocity) were calculated for each slip classified as either a fall or recovery. Slip severity thresholds, separating most falls from most recoveries, were iteratively determined. The effects of obesity and age group on gait speed and step length were analyzed using two-way analyses of variance. Slip severity measures were analyzed using three-way analyses of covariance, with independent variables of obesity group, age group, and gender, and with gait speed as a covariate. Slip outcome was analyzed using a logistic regression model with independent variables of obesity group, age group, gender, and gait speed. Statistical analyses were performed using JMP 10 (SAS Institute Inc., Cary, NC) with a significance level of $p \leq 0.05$.

RESULTS AND DISCUSSION

Slip outcome differed between obesity groups (p=0.005; Table 1) in that 33.3% of obese participants fell after slipping, while only 8.3% of non-obese participants fell. The odds ratio for obesity group indicated that obese participants were 8.24 [95% C.I.: 1.81, 57.10] times more likely to fall than non-obese participants when adjusting for age group, gender, and gait speed. Slip outcome did not differ between age groups (p=0.937) or genders (p=0.399; Table 1).

Table 1: Slip outcomes among groups

	Fall	Recovery	Harness-Assisted	Total
Total	15	48	9	72
Obese	12	21	3	36
Non-obese	3	27	6	36
Older	5	12	4	21
Young	10	36	5	51
Male	5	24	4	33
Female	10	24	5	39

Mean slip velocity was 8.3% higher (p=0.022) among obese participants, but slip duration (p=0.974), slip distance (p=0.121), and peak slip velocity (p=0.065) did not differ between obesity groups (Table 2). Age group did not affect any slip severity measures. Slip distance (p=0.005), peak slip velocity (p<0.001), and mean slip velocity (p<0.001) increased with gait speed, but gait speed did not affect slip duration (p=0.148). Gait speed and step length did not differ between obesity (speed p=0.486, step length p=0.886) or age groups (speed p=0.245, step length p=0.593; Table 2).

In general, participants who fell experienced more severe slips. The majority of falls occurred at slip distances beyond 50 cm, slip durations longer than 0.3 s, peak slip velocities above 2.5 m/s, and mean slip velocities above 1.0 m/s. More specifically, a slip distance of 56.5 cm separated 85.4% of recoveries from 86.7% of falls, a slip duration of 0.35 s separated 54.2% of recoveries from 86.7% of falls, a peak slip velocity of 2.57 m/s separated 91.7% of recoveries from 80.0% of falls, and a mean slip velocity of 1.19 m/s separated 79.2% of recoveries from 86.7% of falls.

CONCLUSIONS

Laboratory-induced slips resulted in more severe slips and a higher fall rate among individuals who are obese. However, no obesity × age interaction effects were found for slip outcome or slip severity. These results suggest that the higher fall rates reported among obese individuals may be due, at least in part, to a greater rate of falling after slipping while walking. Slip severity thresholds that separated the majority of falls from recoveries were also reported, and may have practical value in the design of fall-resistant flooring.

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REFERENCES

1. Courtney et al. *Ergonomics* **44**, 1118-1137, 2001.
2. Fjeldstad et al. *Dynamic Medicine* 7:4, 2008.
3. Brady et al. *J Biomech* **33**, 803-808, 2000.
4. Cham and Redfern, *J Biomech* **34**, 1439-1445, 2001.
5. Yang and Pai, *J Biomech* **44**, 2243-2249, 2011

Table 2: Gait and slip severity measures (mean ± standard deviation)

	Gait Measures		Slip Severity Measures			
	Gait Speed (m/s)	Step Length (m)	Slip Duration (s)	Slip Distance (cm)	Peak Slip Velocity (m/s)	Mean Slip Velocity (m/s)
Obese	1.25 ± 0.14	0.70 ± 0.07	0.42 ± 0.27	42.1 ± 27.2	1.89 ± 0.98	1.05 ± 0.59*
Non-obese	1.31 ± 0.17	0.69 ± 0.13	0.38 ± 0.24	38.4 ± 23.9	1.70 ± 0.89	0.97 ± 0.61*
Older	1.32 ± 0.19	0.70 ± 0.08	0.32 ± 0.10	42.2 ± 25.5	1.84 ± 0.90	1.16 ± 0.66
Young	1.27 ± 0.14	0.71 ± 0.06	0.36 ± 0.12	40.2 ± 25.3	1.81 ± 0.93	0.97 ± 0.56
Male	1.29 ± 0.16	0.73 ± 0.06	0.31 ± 0.09	34.2 ± 23.4	1.67 ± 0.90	0.96 ± 0.60
Female	1.27 ± 0.16	0.69 ± 0.07	0.38 ± 0.12	46.5 ± 25.6	1.95 ± 0.91	1.08 ± 0.58

* Significantly different between BMI groups