RECOVERY RESPONSES TO SURROGATE SLIPS ARE DIFFERENT THAN ACTUAL SLIPS

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INTRODUCTION Slipping and slip-related falls are a common and potentially dangerous problem, especially for older adults. We believe that it is possible to train corrective responses of older adults to reduce the incidence of slip-related falls. However, such an approach requires further understanding of the causal biomechanical distinctions between a successful and an unsuccessful recovery effort. Surrogate tasks are often used to study complex biomechanical events associated with large postural perturbations [1,2]. Although surrogate tasks enhance experimental control over one or more elements of a generally more complex event, such control may change the task of interest by imposing biomechanical constraints that reduce the validity of the surrogate. The purpose of the present study was to quantify the differences in lower extremity and trunk kinematics following a simulated slip versus an actual slip. We hypothesized that the simulated slips would result in significantly different (and less realistic) recovery kinematics, and that individuals who fell on either surface would have larger and faster trunk extensions, and more rapid slipping foot acceleration.

METHODS Twenty-two healthy young adults were each subjected to two types of unexpected slips during a single laboratory visit. Slips were induced in random order using a custom slipping platform and also using artificial ice [3]. The slipping platform consisted of three raised plywood platforms laid end-to-end to create a 7.2 m long walkway. The middle platform had two surfaces (31 x 122 cm), one for each foot, which could be locked in place or move along linear bearings. Each surface could slide a maximum distance of 62 cm in the direction of walking. During trials in which a slip was to be induced the middle platforms were unlocked remotely. The artificial ice consisted of a 1.2 x 1.2 m Plexiglas sheet, the surface of which was coated with a film of mineral oil prior to a slipping trial. Subjects were slipped on the artificial ice after 10 control trials (with no threat of a slip) were collected; they were unaware of the oil. Data from the first slip on the platform were compared to data from the slip on the oil.

From motion capture data (Motion Analysis, Santa Rosa, CA) the onset of the slip and the instant of recovery (the instant the non-slipping foot contacted the surface) were identified. The following variables were quantified for each subject: slip displacement (forward and mediolateral directions), peak slipping foot forward and mediolateral velocities and accelerations, slipping foot internal/external rotation, time to rear foot ground contact, distance the foot was placed behind the body center of gravity, peak trunk extension, and peak trunk extension velocity during the slip. Paired t-tests were used to compare responses during platform slipping and artificial ice slipping.

RESULTS AND DISCUSSION Four subjects (three female) either fell or grabbed the safety harness rope to avoid falling on the artificial ice. Fallers had significantly larger peak lateral flexion angles (30° vs. 13°, p=0.01) and more trunk rotation about the spine (24° vs. 14°, p=0.003). There were no significant differences in trunk extension between fallers and non-fallers. However, the peak slipping heel velocities were larger (214 cm/s vs. 148 cm/s, p=0.04), the slipping displacements were larger (55 cm vs. 30 cm, p=0.02), and the internal/external ankle rotation during the slip was larger (14° vs. 7°, p=0.02) in slips that resulted in a fall.

Four subjects (two male, two female) fell or grabbed the safety harness rope to avoid falling on the slipping platform. Subjects who fell or required rope assistance had significantly larger peak trunk extension angles (38° vs. 17°, p=0.002) but there were no differences in lateral flexion or rotation. Peak heel accelerations were larger (1000 cm/s^2 vs. 602 cm/s^2, p=0.04) and internal/external leg rotation was larger (14° vs. 7°, p=0.008) in those who fell compared to those who recovered.

Recovery from slips on the artificial ice appears to be biomechanically different than recovery from slips on the slipping platform (Table 1). Specifically, on the artificial ice the slipping foot's forward displacement and acceleration were 32% smaller and 85% larger than on the platform, respectively, despite nearly identical pre-perturbation walking velocities (127 cm/s on the platform, 126.7 cm/s on the ice) Slips induced on the slipping platform resulted in smaller slipping foot accelerations than those on the artificial ice. Furthermore, slips on the platform elicited a less conservative recovery response, despite nearly identical pre-perturbation walking speeds in both trials. A conservative response would include rapid placement of the rear foot far behind the center of mass to help prevent excessive trunk extension and reestablish the base of support.

Since several of the variables of interest are influenced by the methodology, providing a realistic perturbation is of great importance. Four of the ten measures that were significantly different between slipping surfaces were the same that distinguished fallers from non-fallers on those surfaces. Simulated slips may be an appropriate vehicle to investigate specific variables associated with sudden postural perturbations, however constraining the direction and displacement of the slip and the additional friction between the slipping foot and the surface, appear to influence the elicited recovery response.

REFERENCES [1] Marigold et al *J Neurophys* **89**(4), [2] Tang et al. *Exp Brain Res* **119**(2), [3] Brady et al. *J Biomech* **33**(7)

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Table 1. Mean (sd) values and paired t-tests results for variables that were significantly different in artificial ice versus slipping platform trials.

	Slipping Foot Variables						*Rear Foot Variables*		*Torso Variables*	
	Forward		M-L						Extension	
	displ. (cm)	accel. (cm/s2)	displ. (cm)	veloc. (cm/s)	accel. (cm/s2)	int/ext rot (deg)	Time to foot placement (ms)	Distance behind CG (cm)	angle (deg)	ang. Veloc (deg/s)
Artificial Ice	33.9 ± 20.1	1279 ± 760	6.7±4.2	56.0 ± 42.7	1040 ± 728	14.7 ± 8.8	303 ± 110	13.2 ± 22.0	12.9 ± 7.6	72.8 ± 46.0
Slipping Platform	50.3 ± 13.3	691 ± 356	**	**	**	8.5 ± 4.8	501 ± 190	-10.4 ± 17.7	21.5 ± 12.8	112.8 ± 52.2
p	0.015	<0.001	<0.001	<0.001	<0.001	0.006	0.003	0.004	0.004	0.002