



## MOTIVATION

- Delayed responses to slipping accidents is associated with higher fall rates [1].
- Sensory deficits may delay recovery response [2].
- The sensory systems that trigger recovery responses are not well understood.
- Knowing the most critical sensory modalities



# **INVESTIGATING THE LINK BETWEEN KINEMATIC DEVIATIONS** AND RECOVERY RESPONSE TO UNEXPECTED SLIPS **Pilwon Hur and Kurt Beschorner**

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250

200

150

100

50

0

50

ngl

Join

TimeD



 Table 1 Correlation coefficients between all variables

Ankle	Knee	Hip	GRFap	GRFv	TA	MH	RF	MG
Ankle	.79	.82	34	26	.54	.73	45	.24
Knee	1	.73	48	46	.14	.38	67	.26
Hip		1	37	29	.70	.68	09	.55
GRFap			1	.85	.15	04	.63	.25
GRFv				1	.35	.33	.73	.32
TA					1	.85	.73	.50
MH						1	.71	.64
RF							1	.34
MG								1

may help target interventions for enhancing sensory information

## **OBJECTIVES**

- To determine correlation between preresponse deviations and motor response to an unexpected slip.
- To determine the order of deviations of the lower-body joint angles (proprioception) and 3D foot forces (somatosensation) to identify the systems responsible for slip detection.

## **METHODS**

### Subjects

- 9 healthy young adults
- 4 male and 5 female, age=22-33years

Time (ms) Fig.2 Representative vertical GRF for the mean baseline (solid blue) +/- standard deviations (dashed blue) and the slip (red). The vertical 300

line represents the time of deviation.

#### Variables

- Proprioceptive TimeDev
  - Sagittal joint angles of the ankle, knee and hip for slipping leg
- Somatosensation TimeDev
  - Vertical and shear GRFs of the slipping leg
- Motor Response TimeDev
  - Rectus femoris (RF),
  - Tibialis anterior (TA)
  - Medial gastrocnemius (MG)
  - Medial hamstring (MH).

*TimeDev* is defined as the first time that the

 $\Rightarrow$  Ankle-MH y = 0.5077x + 47.349 ■ Hip-MH y = 0.9756x + 1.4719 y = 2.2601x - 254.54A Hip-TA 100 150 250 300 200

## TimeDev of Motor Response (ms)

**Fig.3** Scatter plot showing correlation between *TimeDev's* for ankle, hip joint angles and TA and MH.

#### *TimeDev's* for each variable (Fig.4)

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#### Procedures

- Subjects were instructed to walk normally on a walkway with 4 force plates embedded (Fig.1).
- Subjects were informed that the floor would be dry.
- Five known dry conditions were followed by an unexpected slip trial.
- The unexpected slip was induced by applying a thin layer of a diluted glycerol contamination (90% glycerol and 10% water) to the floor surface above the 3<sup>rd</sup> force plate (Fig.1) [3].



Fig.1 Foot placement on the forceplates during the known dry condition, During unexpected slip condition, the 3<sup>rd</sup> forceplate (with red arrow) was contaminated with diluted glycerol to make subject slip.

slipping profiles deviate outside the 95% CI for baseline dry walking

$$TimeDev = \min\{time \mid Dev \ge 1.96\}$$

where Dev is defined as follows:

$$Dev = \frac{Var_{slip} - mean(Var_{base})}{stdev(Var_{base})}$$

Var. joint angles, GRFs, EMG profiles slip: unexpected slip condition base: baseline (known dry condition)

#### Statistical analysis

- Pearson's correlation analysis was performed between all variables
- Repeated measures ANOVA to investigate *TimeDev's* differences between variables

- *TimeDev's* were significanly different (p<0.01)
- The order of TimeDev's were similar to [3] with following order: GRF, knee angle, ankle angle, and hip angle.



Fig.4 Average TimeDev's for each variable. Error bar is ± SE. Thick lines represent groups of variables that have no statistical significance.

#### Data collection

- 56 reflective markers were used to measure kinematic data.
- 4 surface electromyography (EMG) electrodes were attached on the leg muscles ipsilateral to slip (right).
- Ground reaction forces (GRF) for each step were measured with 4 embedded force plates.





## **RESULTS AND DISCUSSION**

- Correlation between sensory and motor responses (Table 1, Fig.4)
- *TimeDev*'s for ankle (r=0.73, p=0.027) and • hip (r=0.68, p=0.043) joint angles were significanly correlated with *TimeDev* for MH.
- *TimeDev* for hip (r=0.70, p=0.037) joint angle lacksquarewas significantly correlated with *TimeDev* for TA.
- None of the kinematic deviations were correlated with MG or RF.

#### REFERENCES

[1] Mackey et al., Gait Posture, 23(1) 59-68, 2006 [2] Lockhart et al., Safety Sci, 40(7-8) 689-703, 2002

## CONCLUSION

- GRF and knee joint angle deviated first but were not correlated with the motor responses.
- Motor responses were correlated with ankle and hip joint angle deviations
- Deviations from hip joint angle may not contribute to motor response.
- Deviations from multiple systems may be required to initiate a motor response.
- Sensory deficits to ankle or hip joints may inhibit the body's ability to respond to a slip.

[3] Beschorner et al., IIE Occ Ergo and Hum Fact DOI:10.1080/21577323.2012.660904, 2012