MECHANICAL ENGINEERING
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DISCREPANCIES IN KINEMATICS AND DYNAMICS OF MILD AND SEVERE SLIPPING

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INTRODUCTION

Motivation

- Slips, trips, and falls were identified as the second leading cause of fatal occupational injuries [1] costing over $180 billion annually [2].
- Not all slips result in falls. Severe slips are more dangerous than mild slips and highly likely to result in falls [1].
- Appropriate classification of the mild and severe slippers will lead to identification of the persons with high risk of fall.
- Previous research has noted the potential of the kinematic variables in identification of mild and severe slippers. [3]

Objectives

- To use a set of kinematic and dynamic variables, namely sagittal whole-body angular momentum (*H*), COM height (COM_h), and double/single support phase duration (*DS/SS*), to classify mild and severe slippers during their normal gait and first 30% of their slips.

Hypotheses

- We hypothesize that *H*, COM_h, and *DS/SS* differ between mild and severe slippers.

METHODS

Subjects

- Eleven male and nine female young adults (age (mean±SD)=23.6 ± 2.52) participated in an IRB-approved study.

Procedures

- Subjects walked on a walkway with no information about floor being slippery.
- Starting position was adjusted to have left foot strike on the slippery surface (Fig. 1).
- The data used full gait cycle were isolated (right before the heel strike on slippery surface) plus 30% of the gait cycle time during slipping.

Data Collection

- Reflective markers were used to capture 3D position of different body segments.
- Subjects wore a harness to ensure their safety and PVC-soled shoes to avoid unwanted friction discrepancies between subjects.

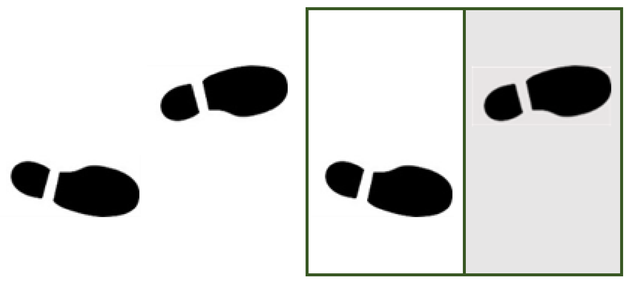

Fig. 1 Foot placement on the contaminated surface to induce a slip

Analysis

- The isolated normal gait for each individual was normalized to 100 points (i.e. percent). Upon slip initiation, the additional 30% of slip trial was concatenated.
- COM height (COM_h) and sagittal whole-body angular momentum (*H*) were determined with segmental analysis, i.e., using each limbs markers and associated anthropometric data. Double/single support phases were identified via heel and toe markers.
- *H*, COM_h, and *DS/SS* were all normalized and made dimensionless to facilitate comparison: *H* was normalized to height, COM velocity, and body mass [4], COM_h to height and *DS/SS* to gait cycle.
- Using heel markers, subjects were labeled as mild or severe slippers: individuals with a Peak Heel Velocity (PHV) higher than 1.44 m/s were considered severe slippers [1].
- The differences between time-courses of *H*, COM_h, and *DS/SS* were compared between mild and severe slippers using independent *t*-tests with significance level of 0.05.

RESULTS

- 12 individuals were labeled as mild slippers.
- Mild slippers showed no significant differences compared to severe slippers on all three variables (*H*, COM_h, and *DS/SS*) during the normal walking before the slip initiation. However, the two groups were significantly different in all three variables post slip initiation (Fig. 2).
- Severe slippers had a lower COM_h from 24%-30% post-slip (*p*-value<0.05), an excessive *H* during slipping (from 3% to 27%) (*p*-value<0.001), and shortened single support phase following a slip (*p*-value<0.001).

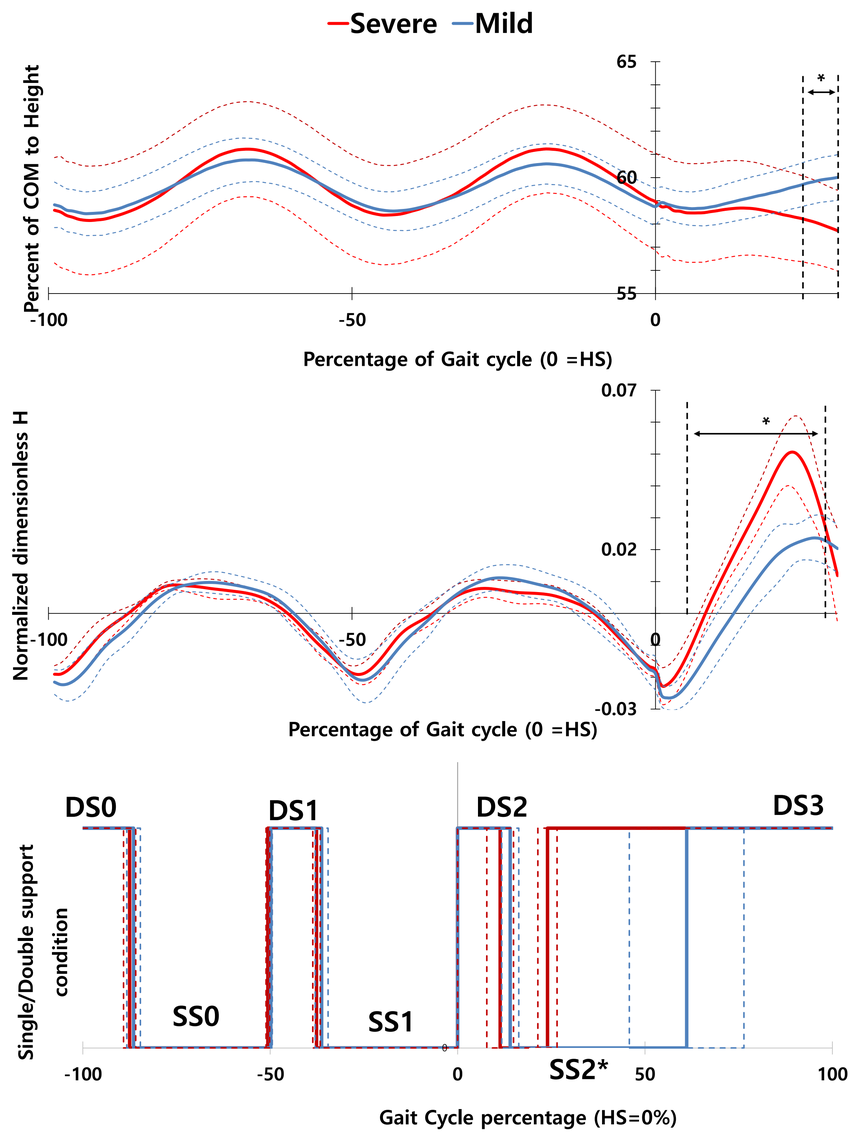

Fig. 2: Average values of variables and their SD. Asterisk shows significant differences.

DISCUSSION and CONCLUSION

- Higher COM_h in mild slippers suggests that subjects who could maintain their COM experienced less severe slips.
- Previous research claimed a significant height drop is associated with "falls" in presence of harness [5].
- The post-slip difference in *H* of the severe slippers can clearly be due to rapid lower extremity movement.
- The regulation of *H* around 27% post-slipping coincides with rapid counter-balance hand movements to lower the *H* [6].
- Elongated post-slipping single support in mild slippers may suggest that the "toe-touch" response is a crucial strategy to arrest the fall when the body lost complete control of the balance following perturbations [6].
- Future work will investigate if the observed associations are causal for severe slipping or not.

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