MECHANICAL ENGINEERING
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Does Inadequate Angular Momentum Regulation Cause Falls?

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INTRODUCTION

Motivation

- Falls impact the economy negatively, costing over $150 billion each year [1].
- Falls also negatively impact the society, by continually being amongst the top causes of the fatal injuries in the US work places [2].
- Sagittal angular momentum (*H*) is a quantity representing the movement of rotation of an object.
- Previous studies [3] indicated that severe slippers, who are more prone to fall [4], had significantly higher *H* following a slip, compared to mild slippers. The two severity groups also deviated in their COM height (COM_h) and Single/Double Stance duration (SS/DS) (Fig. 2)[3, 5].

Objectives

- To compare the time lead/lag between the deviations observed in COM_h, *H*, and single support duration to rule out or substantiate causal relationships.

Hypotheses

- We hypothesize that a time-lead over COM_h would substantiate a causal relationship between deviations in *H* and severe slipping, and hence, falling.

METHODS

Subjects

- Twenty healthy young adults (age (mean±SD)=23.6 ± 2.52) participated in this study upon signing a written consent. There were 11 males and 9 females and excluded in case of history of gait disorders.

Procedures

- Participants were asked to walk at their comfortable speed in a long walkway. Subjects wore a harness system throughout the experiment.
- Subjects performed four "practice walking trials" getting familiar with the setup. Then, a slippery contaminant was applied to the walkway without informing the subjects.

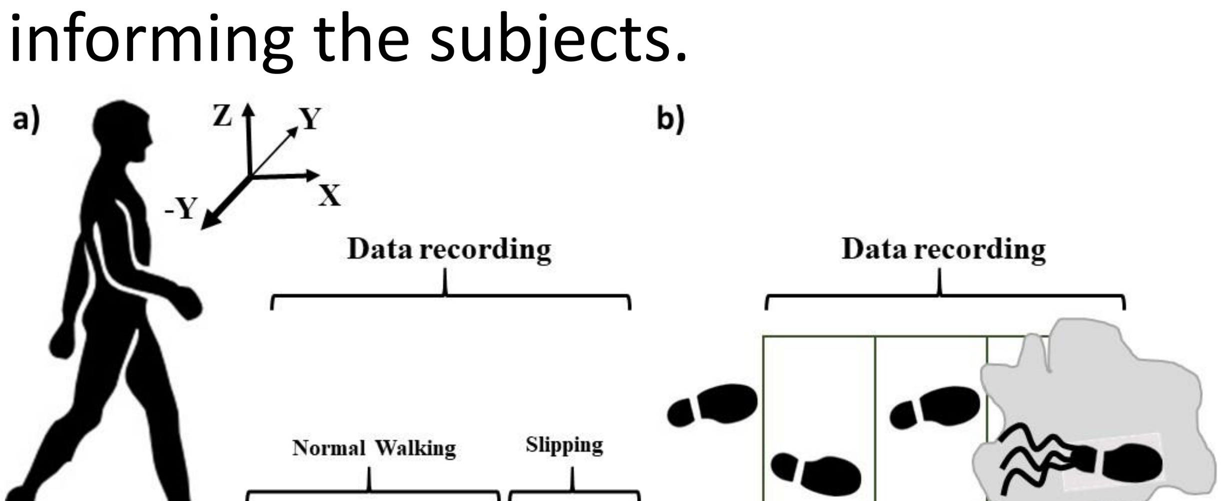

Fig. 1 Experimental setup from side (a) and top (b) view

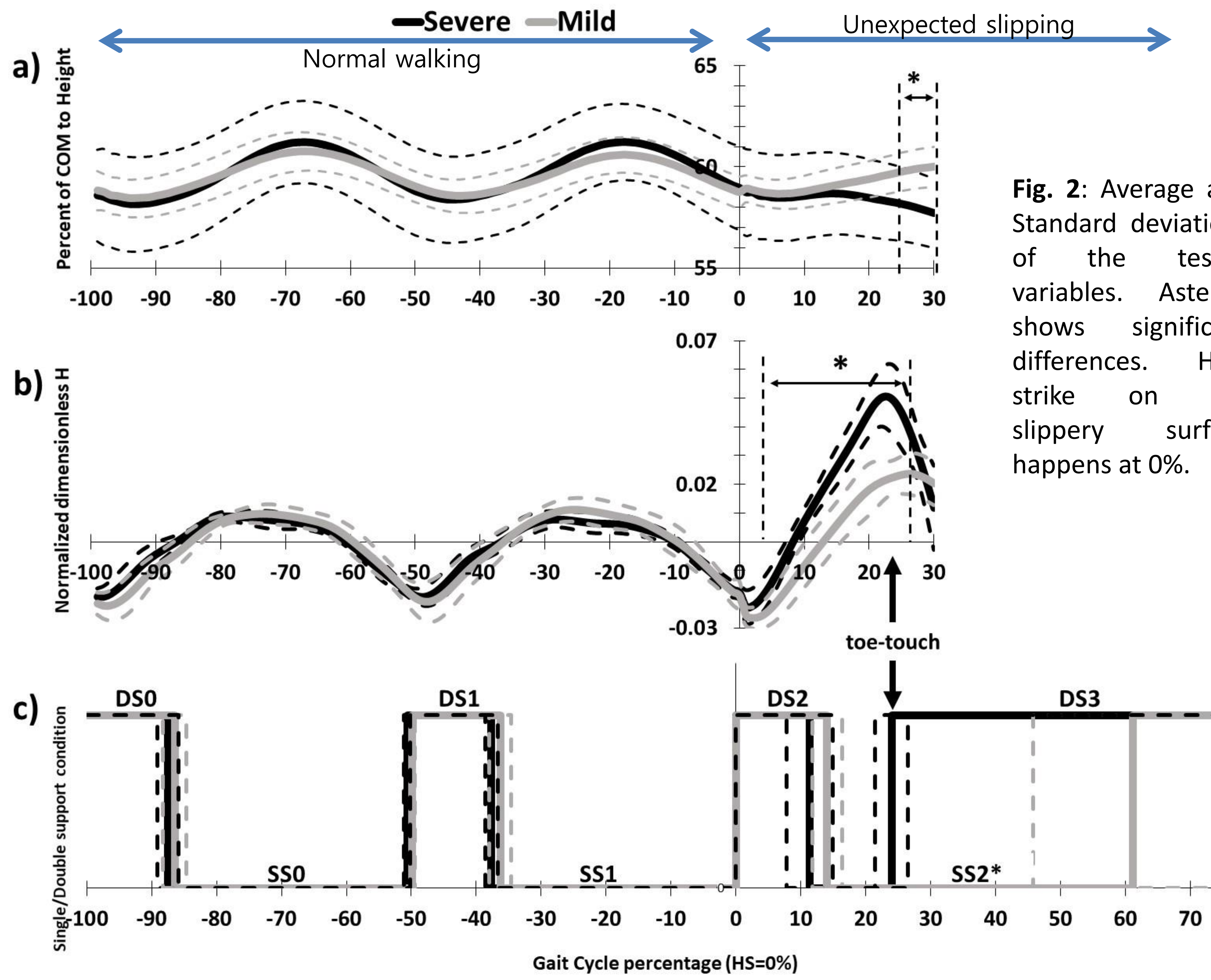

Fig. 2: Average and Standard deviations of the tested variables. Asterisk shows significant differences. Heel strike on the slippery surface happens at 0%.

Data Collection

- Markers' data during normal walking and slipping were collected for analysis.

Analysis

- COM_h was calculated by weighted-averaging limbs' distances and masses.
- *H* was measured via multiplying each limb's mass, velocity, and angular velocity to its distance and moment of inertia, respectively, as it follows: $\boldsymbol{H} = \sum_{i=1}^{n} \boldsymbol{m_i}(\boldsymbol{r_{com/i}} \times \boldsymbol{v_{com/i}}) + \boldsymbol{I_i \omega_i}$
- The gait cycle duration was normalized to 100 points for all subjects, and the slipping behavior was converted to 30 points (i.e. % gait cycle). The support duration analysis was done for 75% instead of 30% post-slipping (Fig. 2c).
- COM_h and *H* were normalized to subject's weight, height, and speed.
- Subjects were classified as severe slippers if their Peak Heel Speed (PHS) during slipping exceeded 1.44 m/s [4].
- Independent *t*-test was used to find inter-group differences and time sequence of deviations examined.

RESULTS

- Mild slippers (12 persons) and severe slippers (8 persons) were no different during the walking but were different in all tested variables upon slipping.
- Severity groups differed in COM_h from 24% to 30% after slip initiation (*p*-value<0.05, Fig. 2a).
- Severe slippers showed higher *H* post-slipping (from 3% to 27%) (*p*-value<0.001, Fig. 2b).
- Mild slippers had normal SS phase while all severe slippers had a shortened SS (*p*-value<0.001) and placed their swing limb on the floor after slipping ("toe-touch" behavior).

DISCUSSION and CONCLUSION

- The time lead of the deviations in *H* over COM_h suggests that the excessive rotation of the body, (i.e. higher *H*), causes the drop in COM_h rather than a direct vertical collapse on the legs.
- Toe-touch could be a measure to constrain and lower *H*, since *H* can only be changed via a torque around the body's COM by the swing limb.
- *H* may be a key variable in controlling slips: The CNS may choose to change its control method and incorporate the toe-touch response as a measure to re-establish the balance, or even take a safer fall depending on how high *H* value is. Future studies should further investigate the causality of *H* to falls.

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References

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