Lateral foot placement does not sufficiently compensate for increased trunk excursions during very slow walking

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Introduction

Purpose: To investigate gait stability in the mediolateral (ML) plane at very slow speeds, including the contributions of the upper and lower body to maintaining stability.

Background:

As gait speed decreases:

- ML excursions of the centre of mass (CoM) increase [1]
- Step-width remains constant in the open-source dataset used in the current study [2]
- The relationship between CoM state and step-width weakens suggesting that the stepping strategy is less dominant at slower speeds [3]
- Peroneus longus, which causes ankle eversion, activity increases [4]

Hypothesis:

(1) As gait speed slows, the ML margin of stability (MoS) will decrease as the CoM excursions increase and step-width remains constant.

(2) The stepping strategy will be less dominant, and the lateral ankle strategy will compensate.

Methods

- Healthy adults (N=8, 6 female, 2 male) walking at 0.1-0.6 m/s and a self-selected speed from a public dataset [2]
- Stability measure: Calculated average minimum ML MoS during single support [5]
- Upper and lower body contributions: Evaluated the position of the centre of pressure (CoP) and trunk CoM at the minimum MoS. Analyzed ML hip and ankle torques at the minimum MoS event

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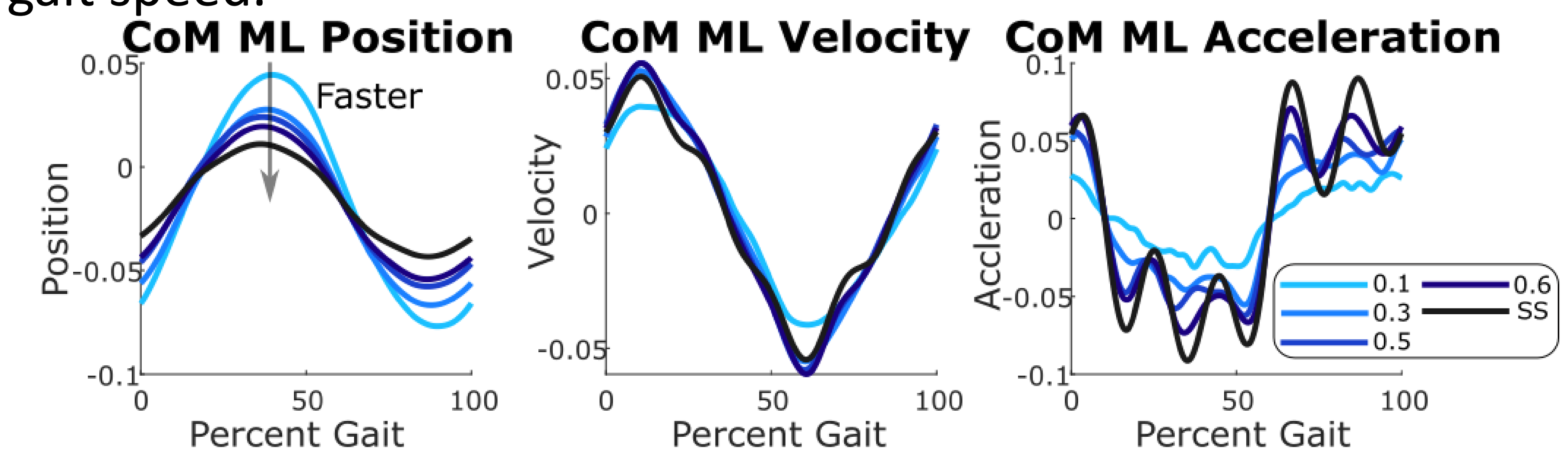
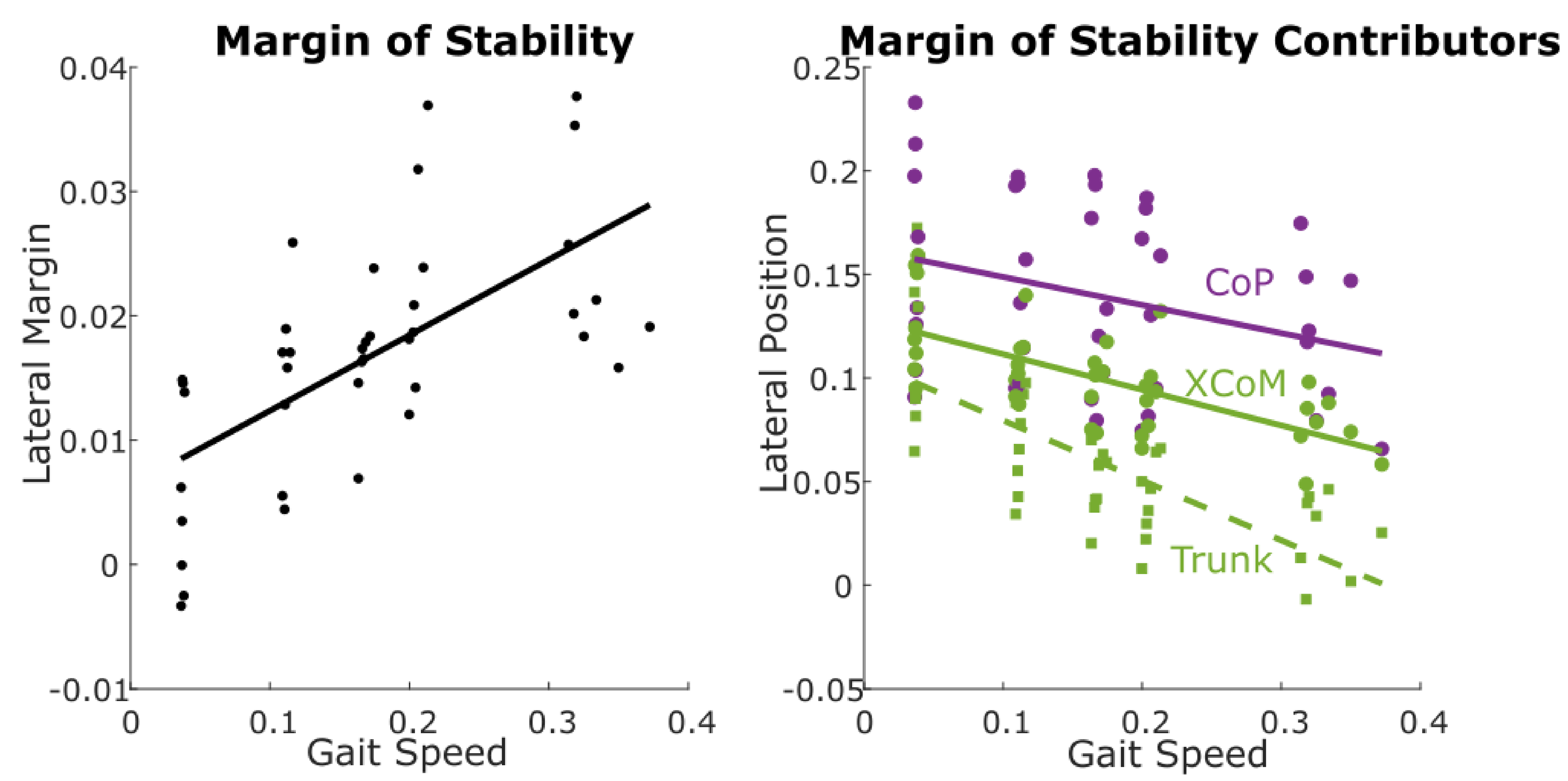
Results

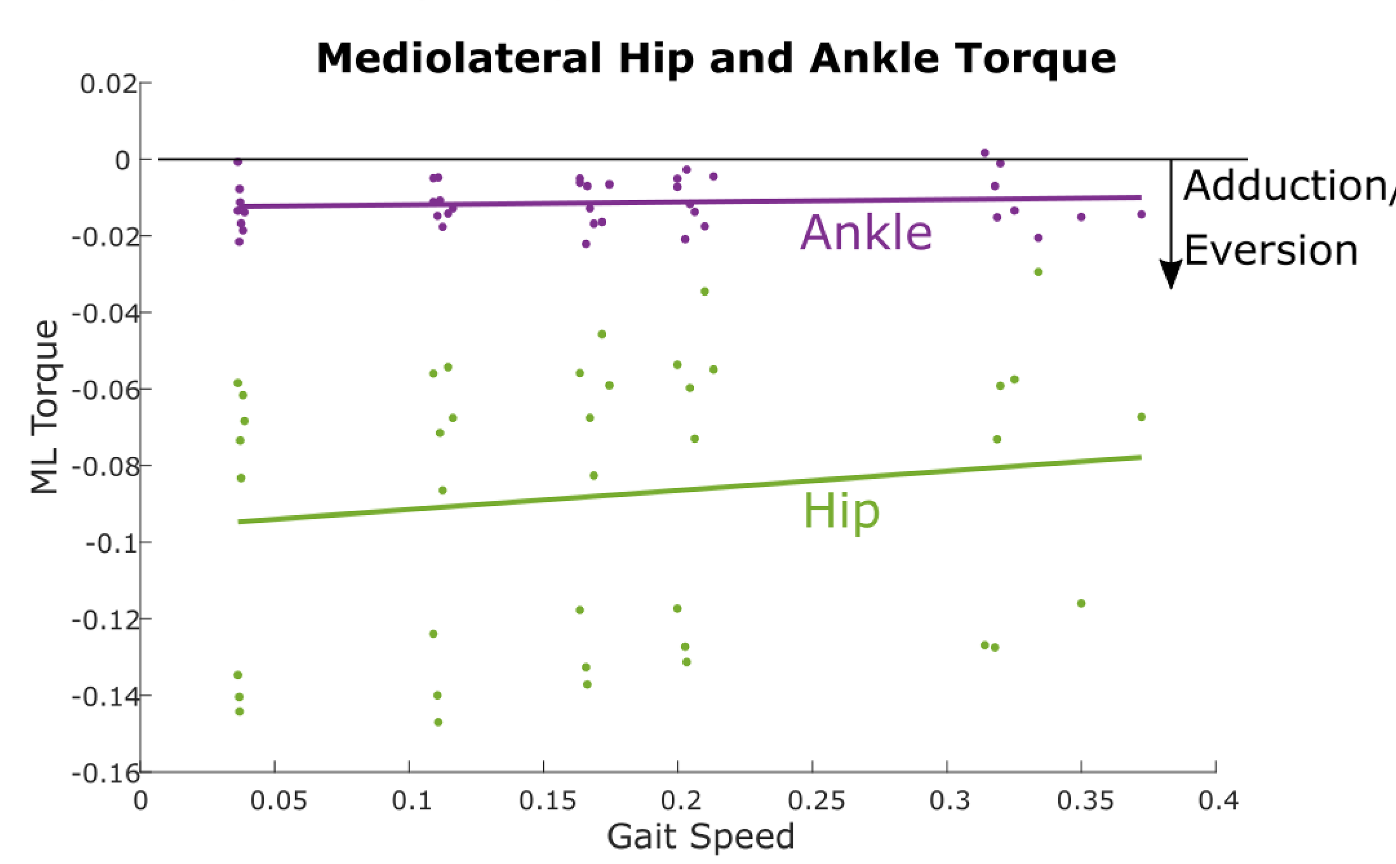
As gait speed slowed, the ML excursion of the CoM increased, and the ML CoM acceleration decreased. Surprisingly, though the ML CoM velocity remained relatively constant despite the change in gait speed.



The MoS decreased as gait speed decreased, with the lateral position of the XCoM increasing at a rate that was approximately 1.2 times greater than the lateral position of the CoP. The lateral position of the trunk CoM at the minimum MoS event also increased as gait speed slowed



At the minimum MoS event, the adduction hip torque decreased with gait speed. However, the eversion ankle torque did not significantly vary with gait speed.



Summary of Regression Results and Statistics

Measure	Slope	Intercept	R^2
MoS	0.06±0.02*	0.007±0.005	0.79
XCoM	-0.17±0.03*	0.13±0.01	0.88
CoP	-0.14±0.03*	0.16±0.01	0.96
Trunk	-0.29±0.06*	0.11±0.02	0.84
Ankle	0.007±0.01	-0.013±0.004	0.78
Hip	0.05±0.02*	-0.096±0.007	0.98

Mean±s.d., *$p < 0.05$

Discussion

- The increase in the lateral position of the XCoM is caused by the trunk moving the body CoM further laterally.
- XCoM excursions were not compensated by the CoP, leading to decreased MoS.
- The hip, not the ankle, appeared to provide joint-level compensation.
- Role of hip adduction torque still unclear. Possibilities include moving the CoP laterally or supporting the trunk.
- Surprisingly, ML CoM velocity remained relatively constant, requiring increases in CoM excursions to decrease acceleration.
- If the velocity was to decrease with gait speed, then this would allow for the ML excursions to remain constant while still decreasing acceleration.
- This seemingly disadvantageous behavior for gait stability suggests a trade-off between gait stability and the mechanical cost of walking.
- Further investigation is required to understand these trade-offs

References

[1] Orendurff et al., *J. of Rehab. Res. & Dev.*, 41, 829-834, 2004

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[3] Stimpson et al., *J. of Biomech.*, 68, 78-83, 2018

[4] den Otter et al., *Gait & Posture*, 19, 270-278, 2004

[5] Hof et al., *J. of Biomech.*, 38, 1-8, 2004