A Tale of Two Legs: Maintaining Dynamic Stability in A-P and M-L Directions in Persons with Unilateral Transtibial Limb Loss

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Introduction

- **Falling** remains a significant concern among individuals with lower limb loss, with **over 50%** of those surveyed having fallen in the past year [1].
- Although lateral instability has been shown to predict fall risk in the elderly [2], little is known about medial-lateral (M-L) dynamic balance in persons with transtibial limb loss (TTLL).
- Previous work has focused on static balance and dynamic balance in anterior-posterior (A-P) directions.
- Platform perturbations are useful to understand postural strategies under dynamic conditions [3] and may be used to predict balance capabilities [4].
- The **objective** of this study was to characterize dynamic balance control of individuals with TTLL across multiple directions.
- We **hypothesized** that individuals with TTLL would have a **smaller stability margin** as compared to unimpaired participants.

Methods

We examined responses to multi-directional perturbations at a standardized stance width.

- Four males with unilateral TTLL (AMP) and four age and gender matched unimpaired adults (CONT) participated.
- Ramp and hold perturbations in twelve evenly-distributed (0-330º) directions were randomly applied.
- Stance width was equal to subject inter-ASIS distance [5].

We calculated peak COM and COP displacements during a defined period.

Center of Mass (COM):

- COM calculated using subject anthropometrics and Vicon markers.

Center of Pressure (COP):

- Individual foot and cumulative COP calculated from ground reaction forces and moments recorded by force plates under each foot.

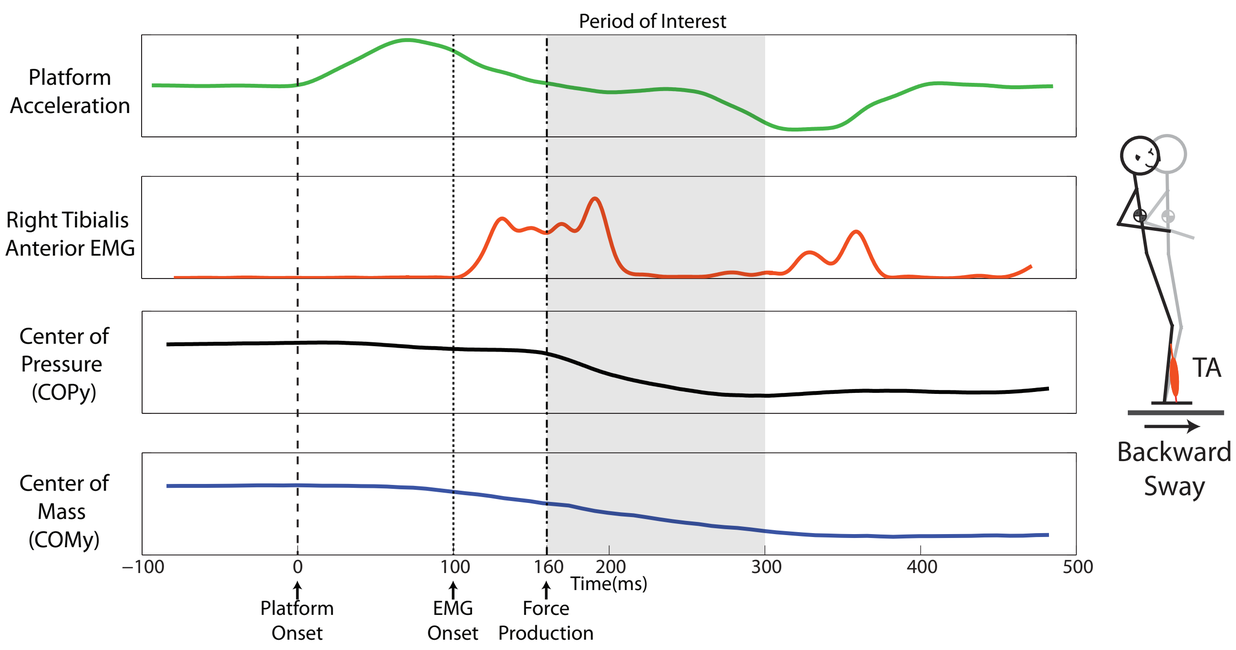
Stability Margin:

- Stability margin = peak COP - peak COM
- **Smaller stability margin represents increased likelihood of losing balance [6].**

Data Analysis:

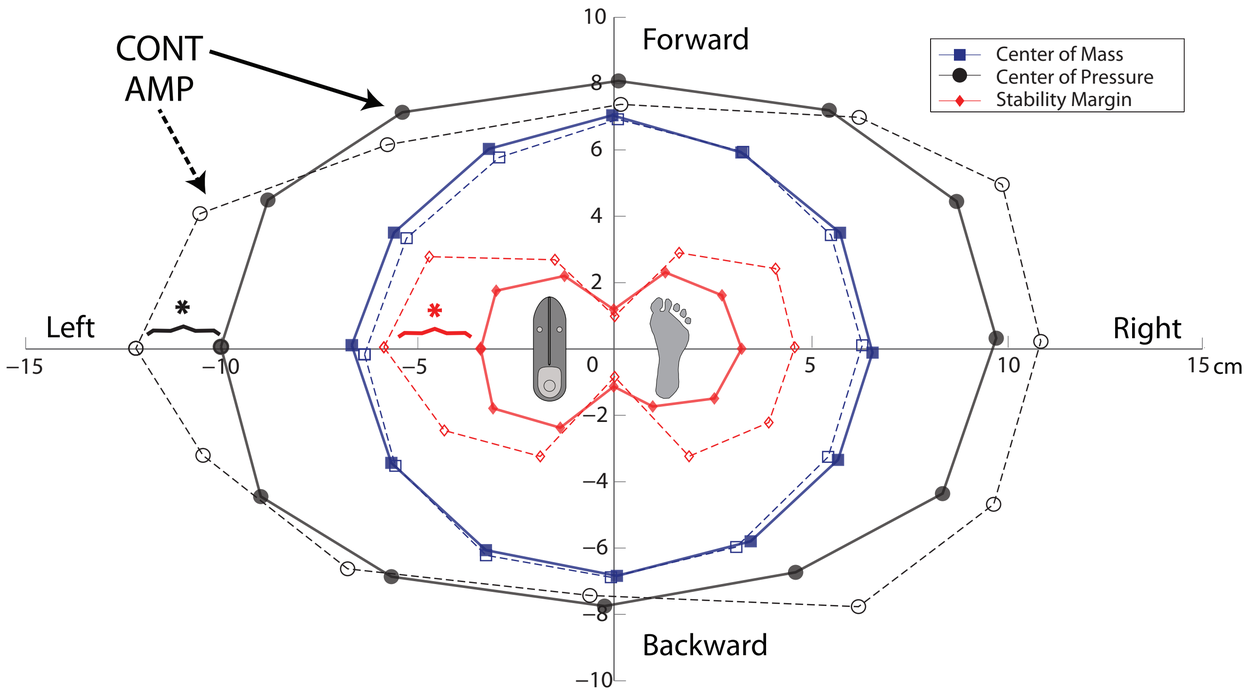
- Peak COM and COP determined from time period of 160-300 ms after platform onset (see figure below).
  - Begins after force production onset (160 ms) and ends prior to peak platform deceleration (300 ms) to limit effect of platform kinematics.
- Two-way mixed-design ANOVAs were performed for each dependent variable (α = 0.05).

Representative Control Subject - 90° Perturbation (Backward Sway)



Results

Stability margin increased with sway toward the prosthetic limb.



- **Stability margin** was significantly greater (**p=0.012*) in AMP group during lateral sway toward the prosthetic limb.
- This increase was due to a larger **COP displacement** (**p=0.012*) rather than a reduction in **COM displacement**.
- Stability margin did not differ between groups for any of the other cardinal directions analyzed.

COP responses under each foot differed based on sway direction.

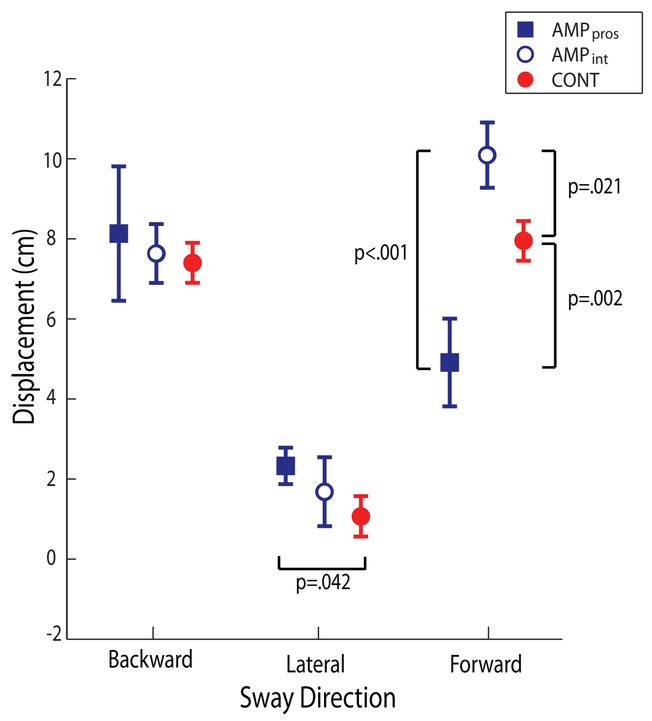
Forward Sway:

- Stability margin and cumulative COP peak displacement (above) did not differ between groups.
- **AMP subjects** had larger COP displacement in the intact leg as compared to both the prosthetic leg (*p<0.001*) and **CONT subjects** (*p=0.021*).

Lateral Sway:

- **AMP subjects** had larger COP displacement in the prosthetic limb when loaded as compared to **CONT subjects** (*p=0.042*).

Individual Foot COP Displacement



Discussion and Conclusions

Intact leg compensates for prosthetic leg deficits in forward sway.

- Ability for COP response in prosthetic foot is limited in forward sway.
- AMP subjects show increased reliance on the intact ankle for balance control in this direction, which is consistent with previous work [7].

Clinical Significance:

- Evaluation of intact leg should not be forgotten.
- Training to improve strength and range of motion of the intact ankle may be needed to enhance balance capabilities.

AMP group maximizes stability margin on prosthetic side.

- Results suggest that AMP subjects are unable to modulate COP displacement when perturbed toward the prosthetic side.
- As a result, maximum COP response leads to a larger stability margin.
- Unclear whether AMP subjects are able to increase balance response to maintain stability margin with more challenging perturbations.

Clinical Significance:

- Understanding dynamic balance control in individuals with TTLL can help lead to improved design of prosthetic feet and ankle components.

Future Directions:

- Increase sample size.
- Investigate longer time period for balance response by altering platform parameters to create more complete understanding.
- Analyze EMG and data from additional stance widths already collected.

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References

[1] Miller W. C., et al. The Influence of Falling, Fear of Falling, and Balance Confidence on Prosthetic Mobility and Social Activity among Individuals with a Lower Extremity Amputation. *Archives of Physical Medicine and Rehabilitation* 82(9):1238-44, 2001.
[2] Maki B.E., Holliday P.J., Topper A.K. A Prospective Study of Postural Balance and Risk of Falling in an Ambulatory and Independent Elderly Population. *Journals of Gerontology*, 49(2), M72-M84, 1994.
[3] Jayakaran P., et al. Instrumented Measurement of Balance and Postural Control in Individuals with Lower Limb Amputation: A Critical Review. *International Journal of Rehabilitation Research* 35(3): 187-96, 2012.
[4] Horak F. B., Henry S. M., ShumwayCook A. Postural Perturbations: New Insights for Treatment of Balance Disorders. *Physical Therapy* 77(5): 517-33, 1997.
[5] Winter, D.A., et al. Stiffness Control of Balance in Quiet Standing. *Journal of Neurophysiology*, 80(3), 1211-1221, 1998.
[6] Horak F. B., Dimitrova D., Nutt J. G. Direction-Specific Postural Instability in Subjects with Parkinson's Disease. *Experimental Neurology* 193(2): 504-21,2005.
[7] Curtze C., et al. The Relative Contributions of the Prosthetic and Sound Limb to Balance Control in Unilateral Transtibial Amputees. *Gait & Posture* 36(2): 276-81, 2012.

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