Exploration of semi-active control laws for the Two Axis aDaptable Ankle (TADA)

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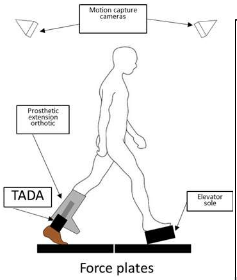
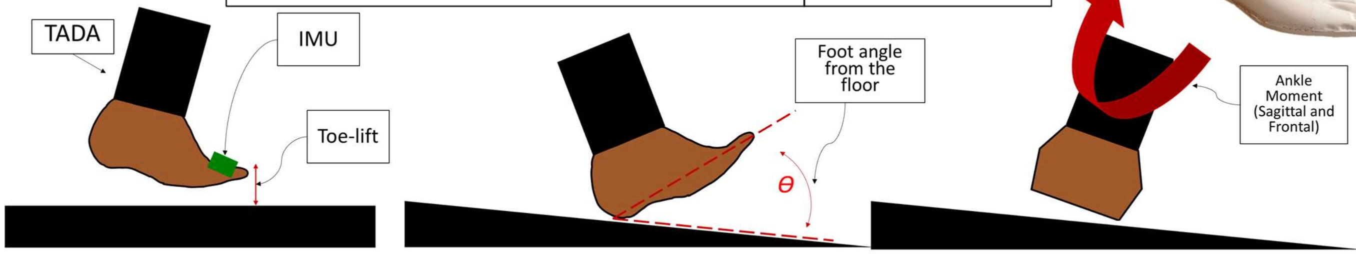


- TADA: semi-active (moves in swing) ± 10 deg sagittal and/or frontal
- Method: walk at a self-selected speed using TADA angles of neutral angle (90° dorsiflexion and no eversion), plantarflexion (PF), dorsiflexion (DF), eversion (EV), and inversion (IV)
- Sensing: IMU – encoders – load cell (Fz, Mx, My)

How to control a semi-active prosthetic ankle?

- Ideal Swing phase trajectory?
- Right way for the TADA to adapt to the slope?
- Optimal ankle angle control to lower ankle moment?

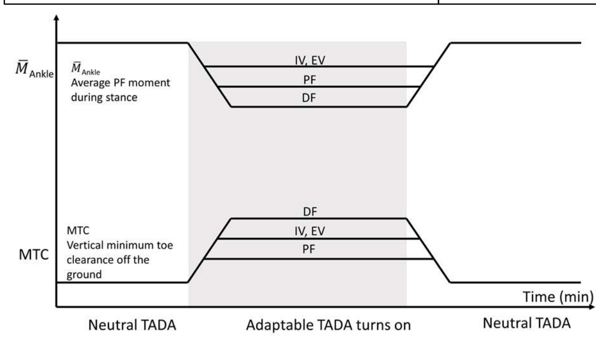


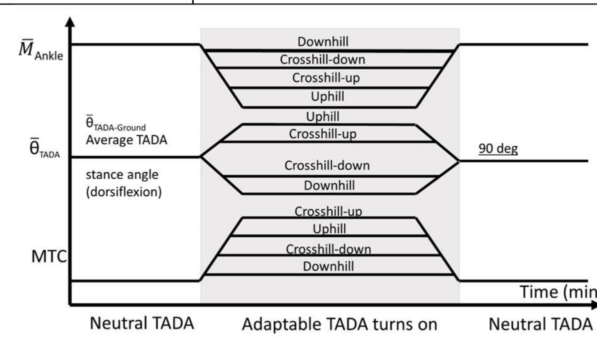
Toe-lift control

Anticipatory Slope-Adapting Control

Moment-Targeting Control

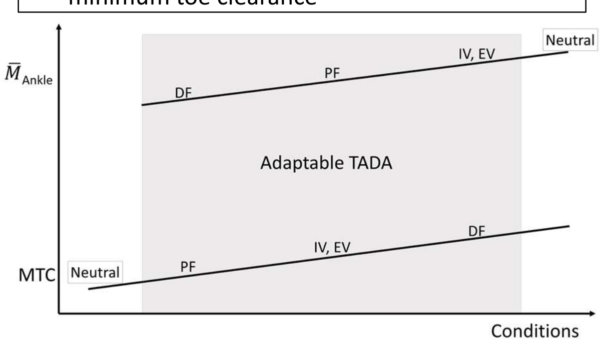
Toe-Lift Control	**Anticipatory Slope-Adapting Control**	**Moment-Targeting Control**
• Initial tuning of mid-swing ankle angle to user-preference • Evaluate minimum toe clearance (MTC) • MTC is lower on passive prostheses[1] and a lower MTC contributes to tripping[2] • Does active dorsiflexion of the TADA raise the MTC?	• Initial tuning of stance angle to user-preference • Evaluate average ankle moments • High average ankle moments in prostheses may contribute to knee injuries • Does preferred stance angle has lower peak ankle moments?	• Initial tuning of stance angle to a chosen multiple (0.5-0.95) of average ankle moment from neutral TADA walking • Evaluate resulting ankle angles • Does ankle angles with targeted lower moments have similar values to intact side or non-disabled ankle angles?

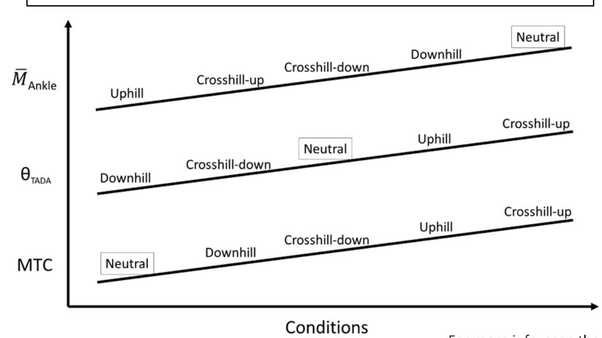




- Lab tests with non-disabled persons
- Validation study for TADA ankle moment and minimum toe clearance

- Outdoor tests with persons with transtibial amputations
- Walk in square laps on a sloped surface





Remaining Challenges

- Sensing terrain
- Remembering slope
- Optimizing preference
- Predictive and volitional control
- Human-in-the-loop optimization
- Osseointegration bi-directional neural interface

References

1) Johnson, L., De Asha, A. R., Munjal, R., Kulkarni, J., & Buckley, J. G. (2014). Toe clearance when walking in people with unilateral transtibial amputation: effects of passive hydraulic ankle.

2) Wu, A. R., & Kuo, A. D. (2016). Determinants of preferred ground clearance during swing phase of human walking. Journal of Experimental Biology, 219(19), 3106-3113.

Acknowledgments

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