Influence of Prosthetic ankle-angle and walking speed on Pylon moments in the Two Axis aDaptable Ankle

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INTRODUCTION

Persons with lower-limb amputations can replace their lost limbs using passive, active, or semi-active prostheses. Semi-active prostheses attempt to recover more of the biological ankle mechanics and can give functional benefits of prosthetic adaptability, low cost, and low weight compared to passive and active devices [1]. The Two Axis aDaptable Ankle (TADA) [1] is a novel semi-active prosthetic ankle that allows for independent modulation of sagittal and frontal ankle angle (±10 degrees).

Boone et al. (2013) found that sagittal and frontal misalignment of transtibial prostheses at the pylon joint significantly affects pylon (socket) moments around 75% of stance, compared to nominal alignment (clinically-based) [2]. The TADA allows more biomimetic ankle angle control that can give users influence over their joint mechanics.

This study aims to investigate the influence of various TADA angles and walking speeds on prosthetic pylon moments while users walk over flat ground. The main hypothesis is that the peak averages of sagittal and frontal pylon moments will be higher at non-neutral TADA angles and larger walking speeds.

METHODS

Ten participants with no amputations will be chosen for this study, approved by the UW-Madison IRB. This abstract presents preliminary data for one participant (n=1). The participant walked on flat ground at three consistent self-selected speeds (slow, medium, fast) while wearing a full-body set of Xsens motion sensors. The TADA was mounted laterally to the participant's right foot using a custom-made ankle bypass orthosis.

The participant walked with various TADA stance angles including neutral (90° ankle dorsiflexion and no eversion), Plantarflexion (PF), Dorsiflexion (DF), Eversion (EV), and Inversion (IV). Three successful strides were collected for each TADA angle and speed totaling 45 strides. The peak pylon moments (sagittal and frontal) of the successful trials were averaged for each speed.

The TADA controller uses the Robotic Operating System (ROS) programs (C++/Python), involving dual motor control with hall sensor feedback, load cell between the TADA and pylon, shank IMU motion reconstruction, data collection, and a user interface. In addition, the Xsens suit will give a secondary source of validation for the kinematic data of the ankle/foot, lower and upper legs, and center of mass.

Table 1: a partial set showing the typical anatomical ankle angles, polar coordinates, and their respective average peak sagittal and frontal pylon moments for the medium speed.

TADA Ankle angles	Polar coordinates (PF, EV)	Average Peak Sagittal Pylon moments (Nm)	Average Peak Frontal Pylon moments (Nm)
Plantarflexion	(10, 0)	1374	543.7
Dorsiflexion	(-10, 0)	1400	355.3
Neutral	(0, 0)	1235	433.3
Eversion	(0, 10)	1315	289.0
Inversion	(0, -10)	1206	496.0

RESULTS AND DISCUSSION

These results show the average peak sagittal pylon moments decrease with increasing walking speed and that the frontal pylon moments than sagittal pylon moments are more sensitive to changes in TADA angles. The hypotheses were not supported, but the results can be used to create a moment-targeting controller to accommodate for walking speed and attempt to lower peak pylon moments by adjusting the TADA angles. For example, at a medium speed, moving a neutral foot (peak of 433Nm) to a more dorsiflexed angle would lower the peak frontal moment (peak of 355Nm).

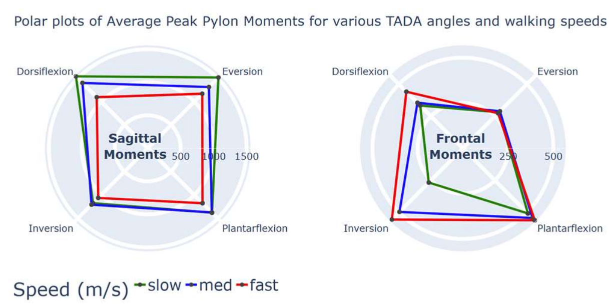

Figure 1 Polar graphs showing average peak sagittal and frontal pylon moments for various TADA angles and walking speeds. The background grid represents the TADA angles, and the line colors represent the peak pylon moment for a given walking speed.

CONCLUSIONS

The TADA could enable modulation of lower-body mechanical outcomes by controlling the 2D TADA angles due to its systematic relationship with ankle angle, walking speed, and pylon moment. Automated, real-time moment-targeting control could allow users to adapt to terrain conditions such as stairs and ramps, or to alter biomechanical loads such as undesirable knee moments.

REFERENCES

[1] Adamczyk P. *Powered Prostheses*: 201-259, 2020.
[2] Boone D et al. *Gait & Posture* **37**: 626-30, (2013).