Development of a Balance Measure for Amputees

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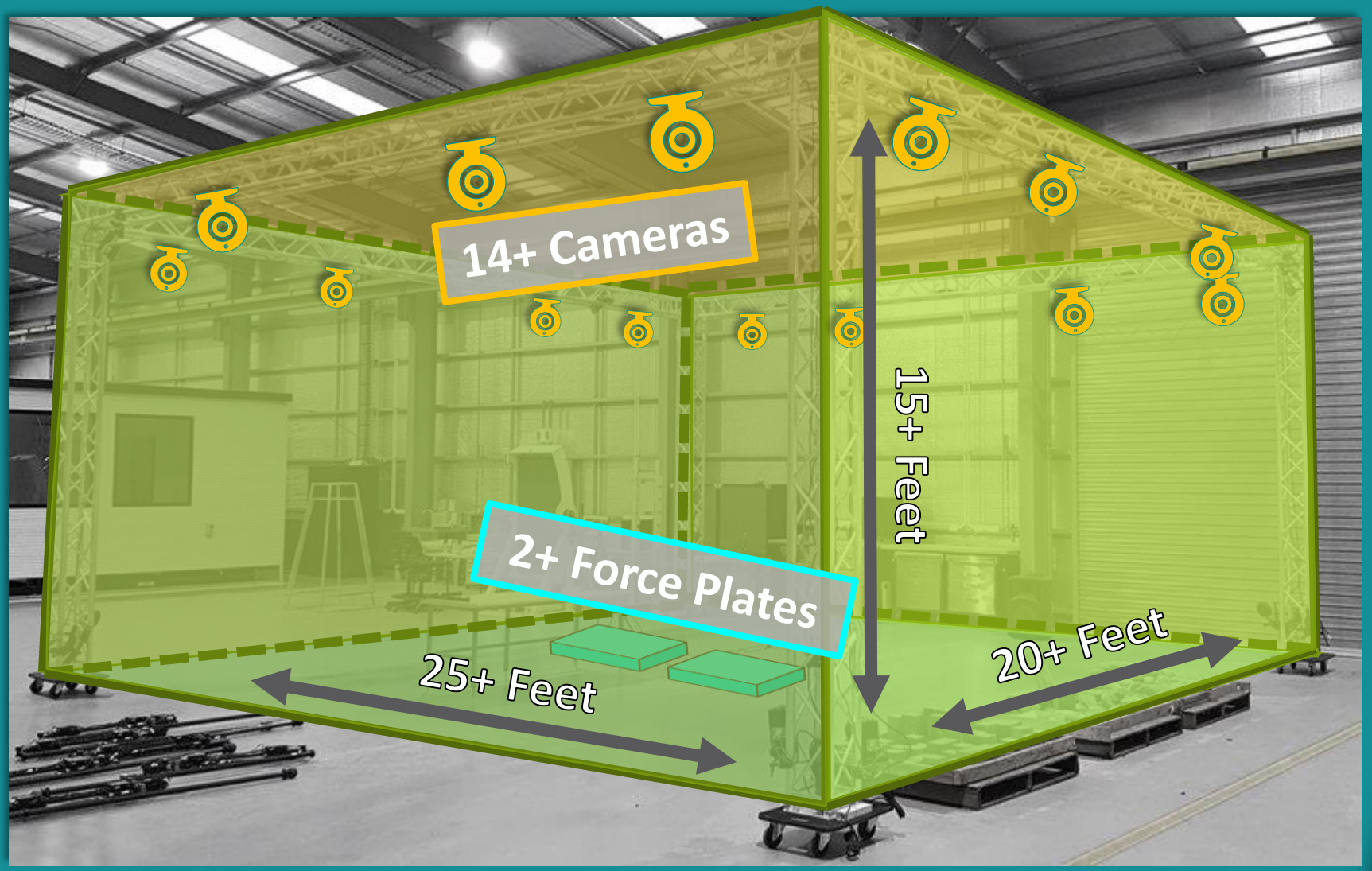
TECHNOLOGY for the HUMAN RACE

The Problem

- 52.4% of lower-limb amputees report falling in the previous year [1]
- 66% of above-knee amputees report falling annually, twice the rate of able-bodied adults over 65 years old [2]
- There are no quantitative, clinic-based outcome measures that determine balance in ambulation for amputees

[1] Centers for Disease Control and Prevention. *Costs of Falls Among Older Adults*. 2012
[2] Balaban, C. and M. Hoffer, *Mild Traumatic Brain Injury: Vestibular Consequences*. 2009.

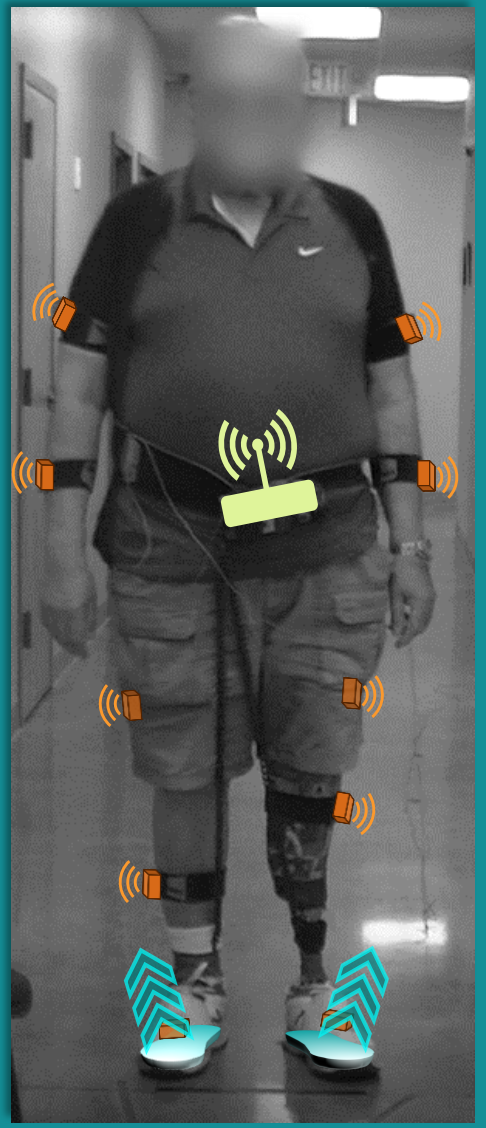
PROBLEM - Motion Capture is space and cost prohibitive



Collins, Jack & Howard, Gerard & Leitner, Juxi. (2018).
Quantifying the Reality Gap in Robotic Manipulation Tasks.

Solution

- Tool for clinicians to fit patients
- **Portable** system
- Accurately measure gait parameters
- Determine **dynamic** balance
- Tell user subtle differences between different prosthetic feet



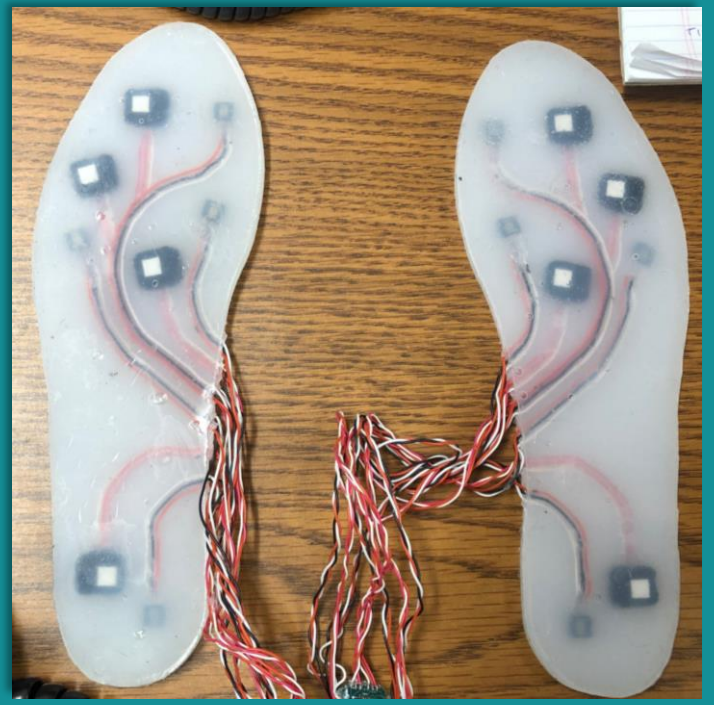
Methods

12 IMUs

- XSENS MTw Awinda
- Motion of each body segment
- Used to calculate COM

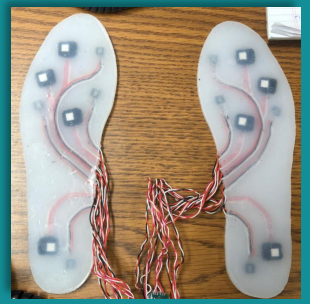
Pressure Sensing Insoles

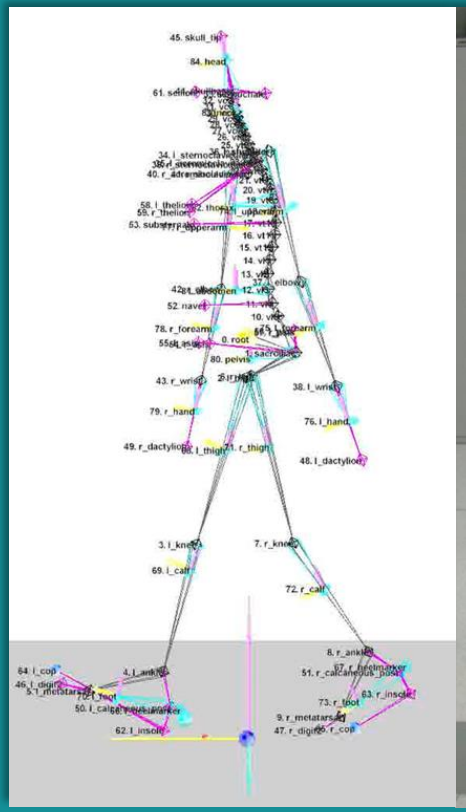
- Developed by Sandia National Laboratories
- Custom shear and pressure sensors
- Used to calculate COP & GRF

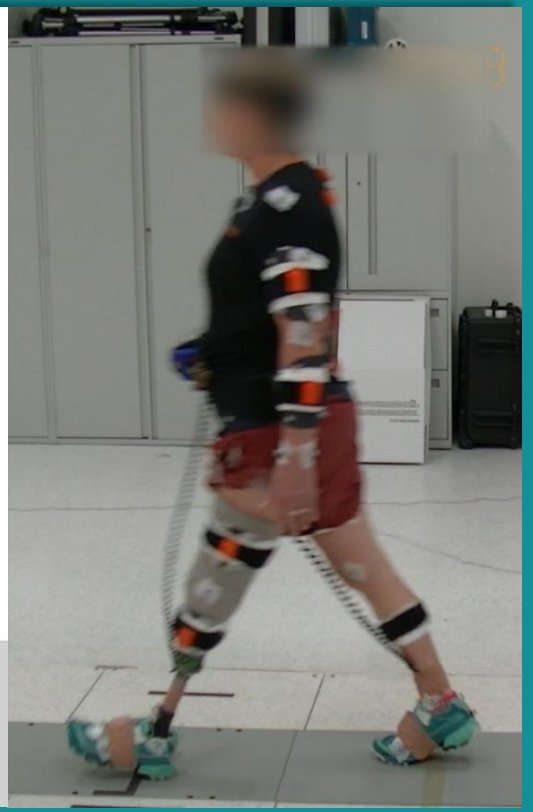


METHODS

- Created **custom** amputee-specific articulated hierarchical model of the human body



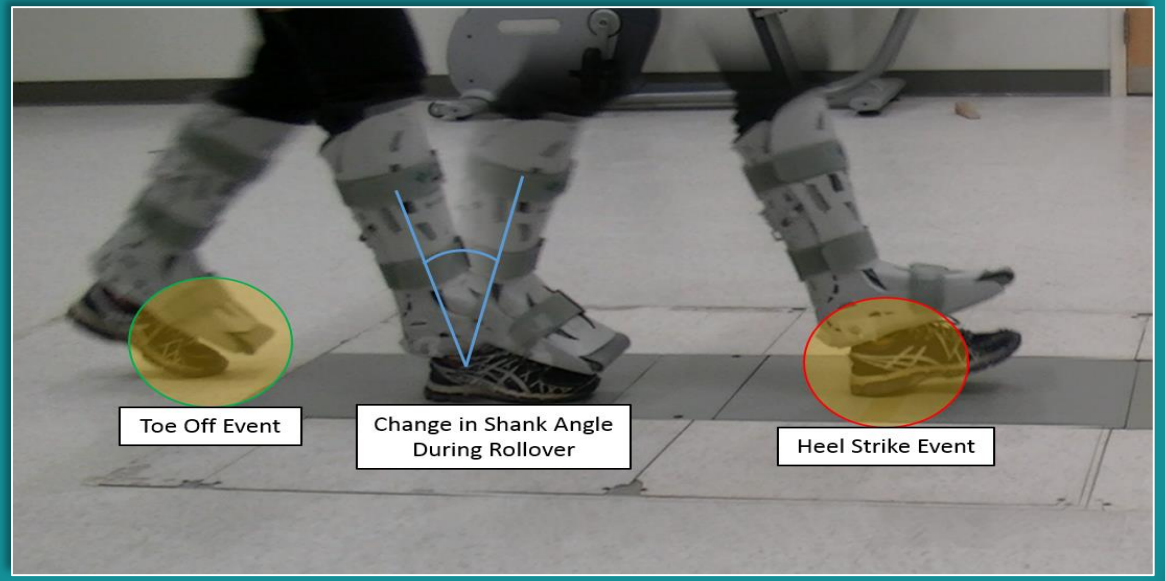




Methods

Goal

- Find 2 feet with similar size but walk differently



Rollover Shape

- Used to quantitatively determine “smoothness”


Breeze


Venture


Soleus


Celsus


Tempo


Velocity

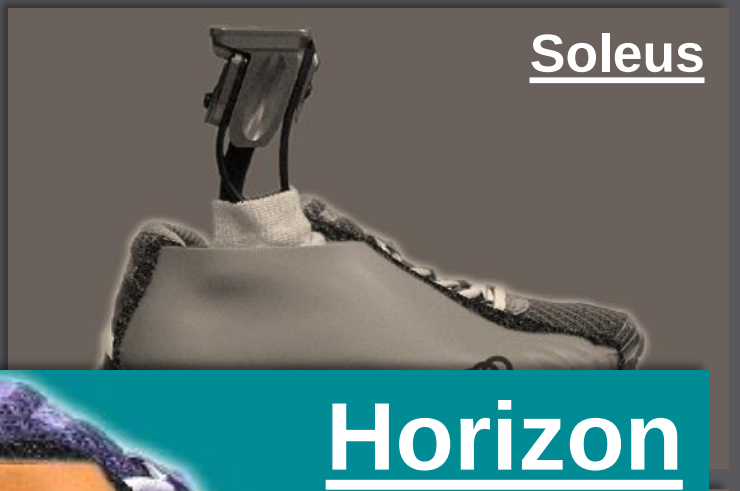

Horizon


Tribute


TruStep


Odyssey K2


Odyssey K3



Height (in)	2.2 – 2.6
Weight (g)	526

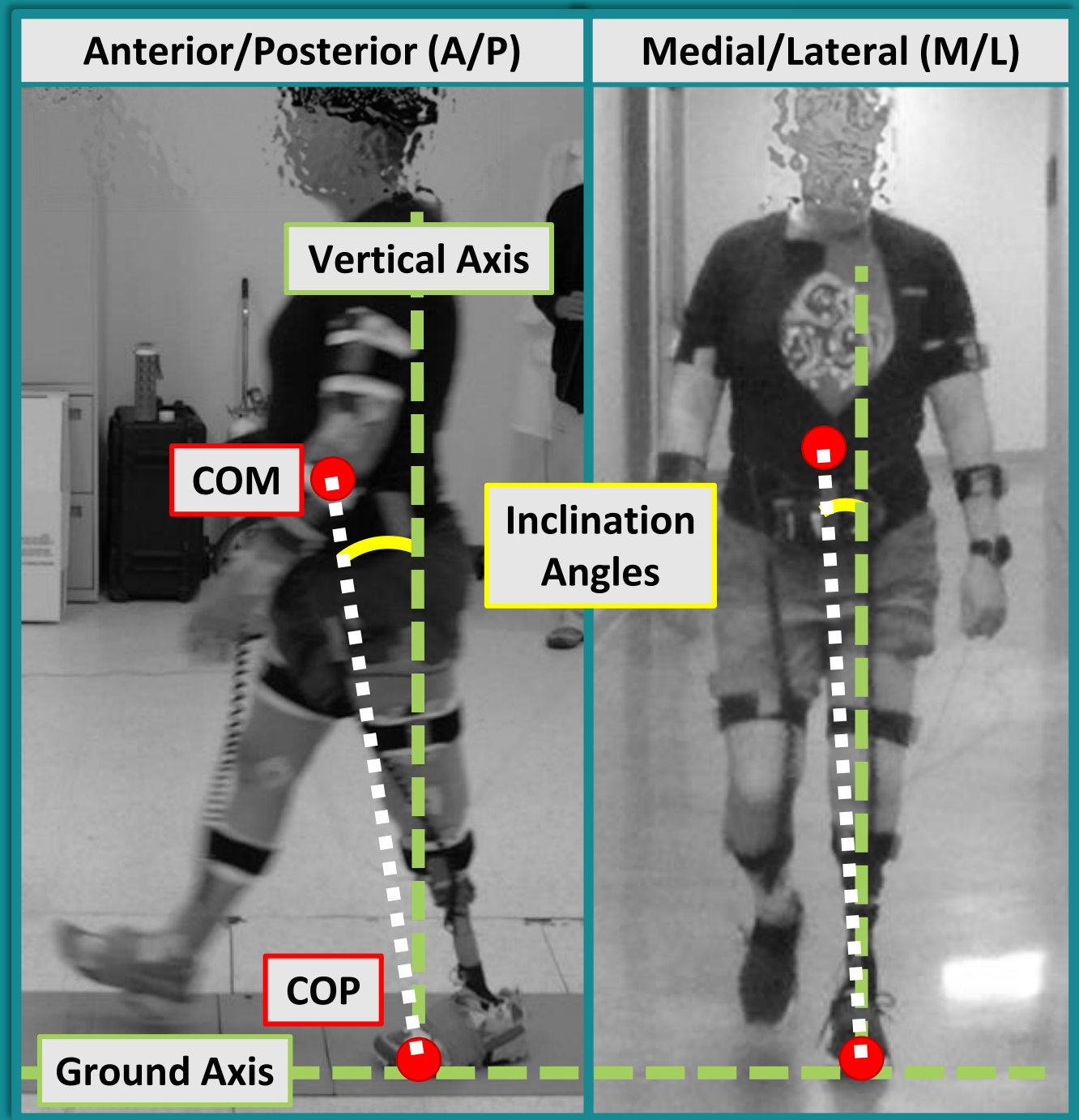
Height (in)	2.3
Weight (g)	518

Methods

- Tested on **7 BK human subjects**
- 5 tested in a mocap lab to compare human models
- **COM within 1.5 cm** and **COP within 2.0 mm** of the gold standard 14 camera Qualisys motion capture system
- Analyzed gait parameters to find relevant measures of dynamic balance

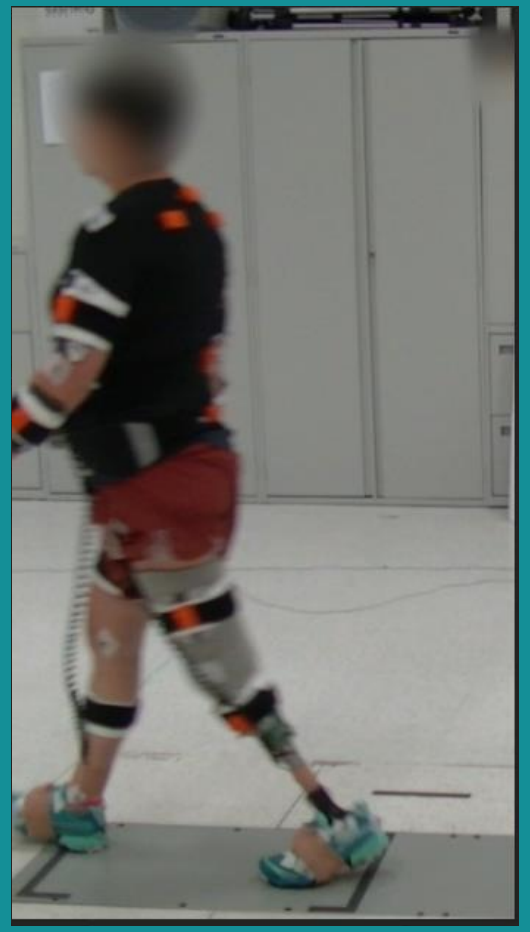
METHODS

- Inclination angles used to detect elderly fallers [3]
- Focusing on prosthetic foot single support

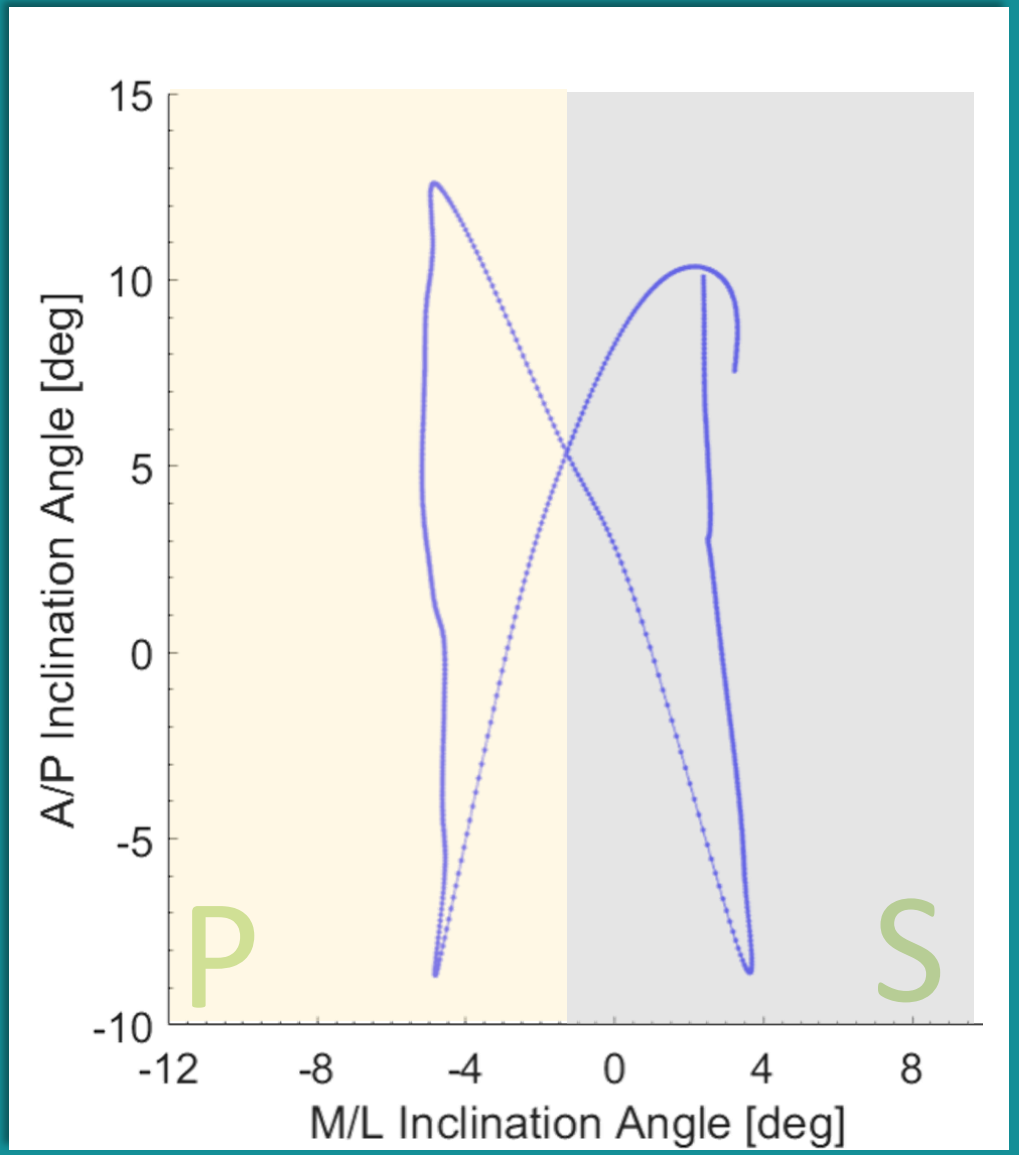


[3] Lee,H.; Chou, L. Detection of Gait Instability Using the Center of Mass and Center of Pressure Inclination Angles. Arch. Phys. Med. Rehabil. 2006, 87, 569-575

Results

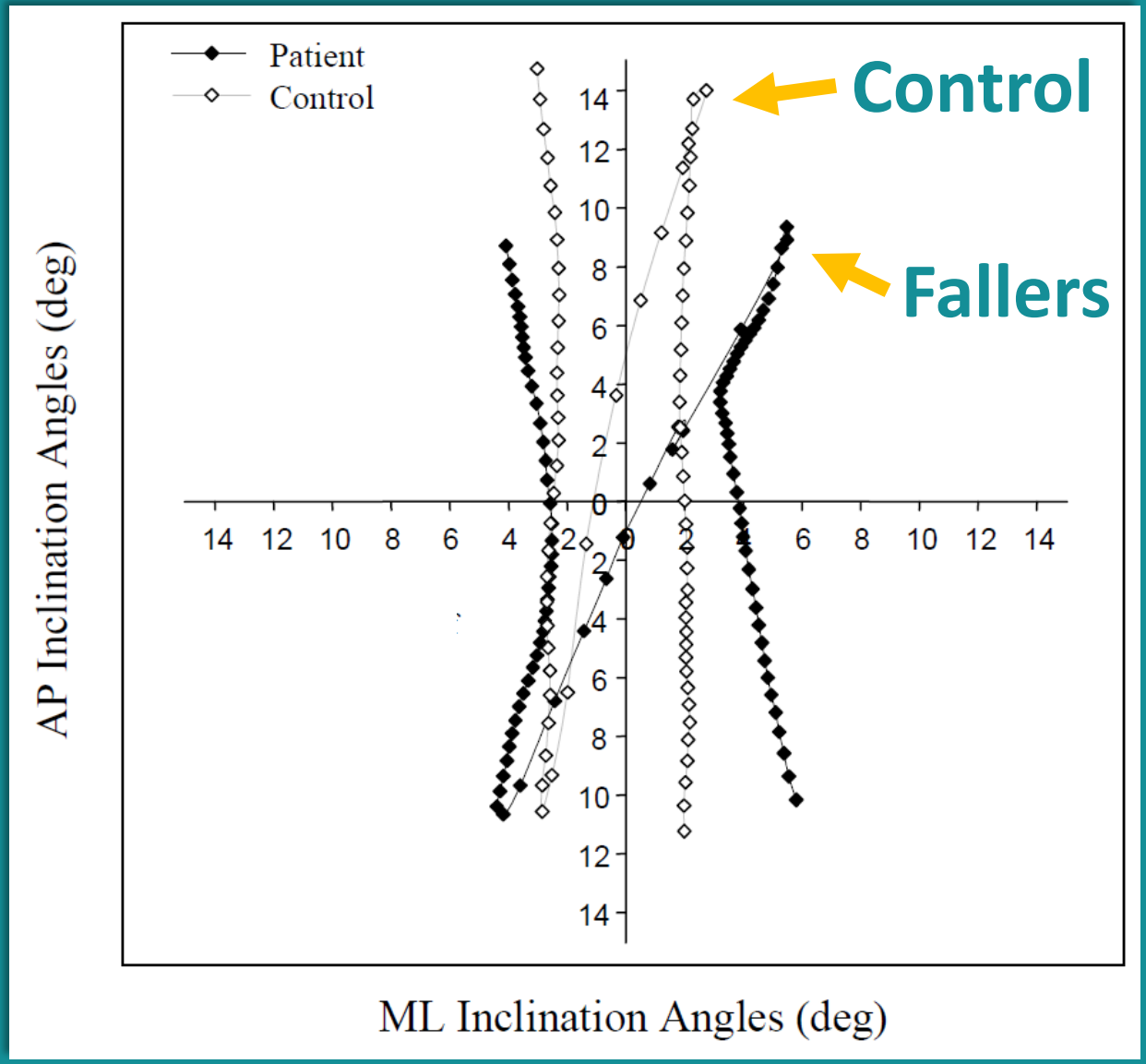


Butterfly Plot



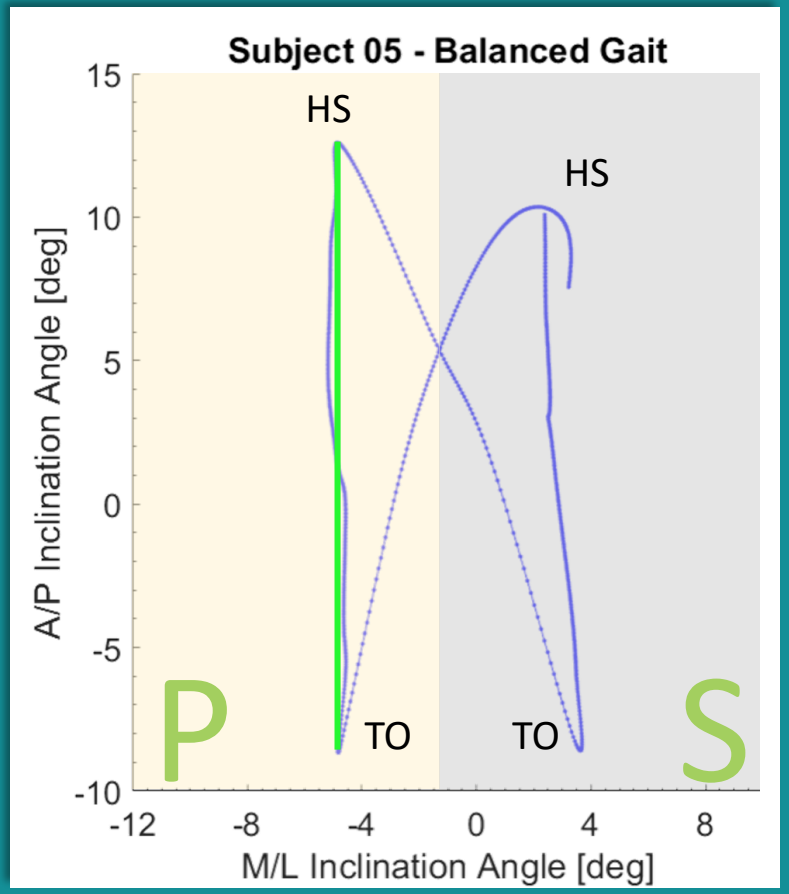
Results

Butterfly Plot

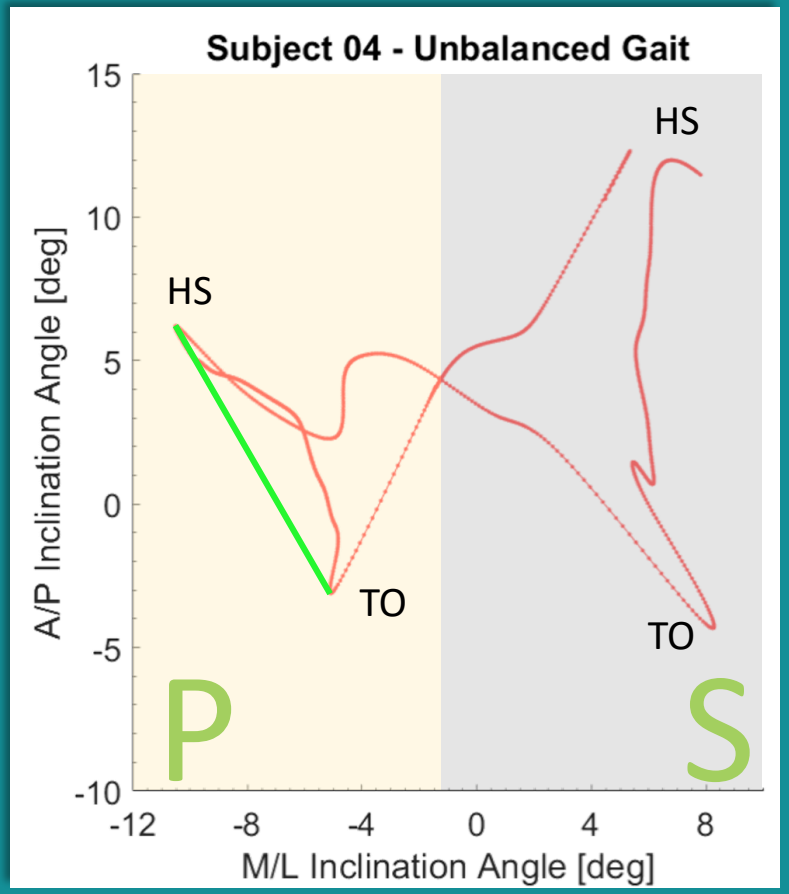


[3] Lee,H.; Chou, L. Detection of Gait Instability Using the Center of Mass and Center of Pressure Inclination Angles. Arch. Phys. Med. Rehabil. 2006, 87, 569-575

RESULTS - Large difference between subject ability



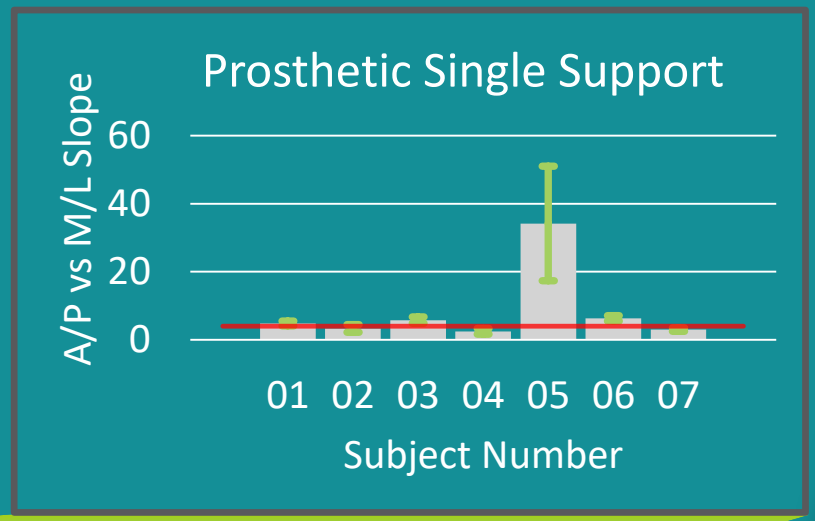
- Slope: **111.5** $\frac{deg}{deg}$
- Gait Score: **4.8/5.0**

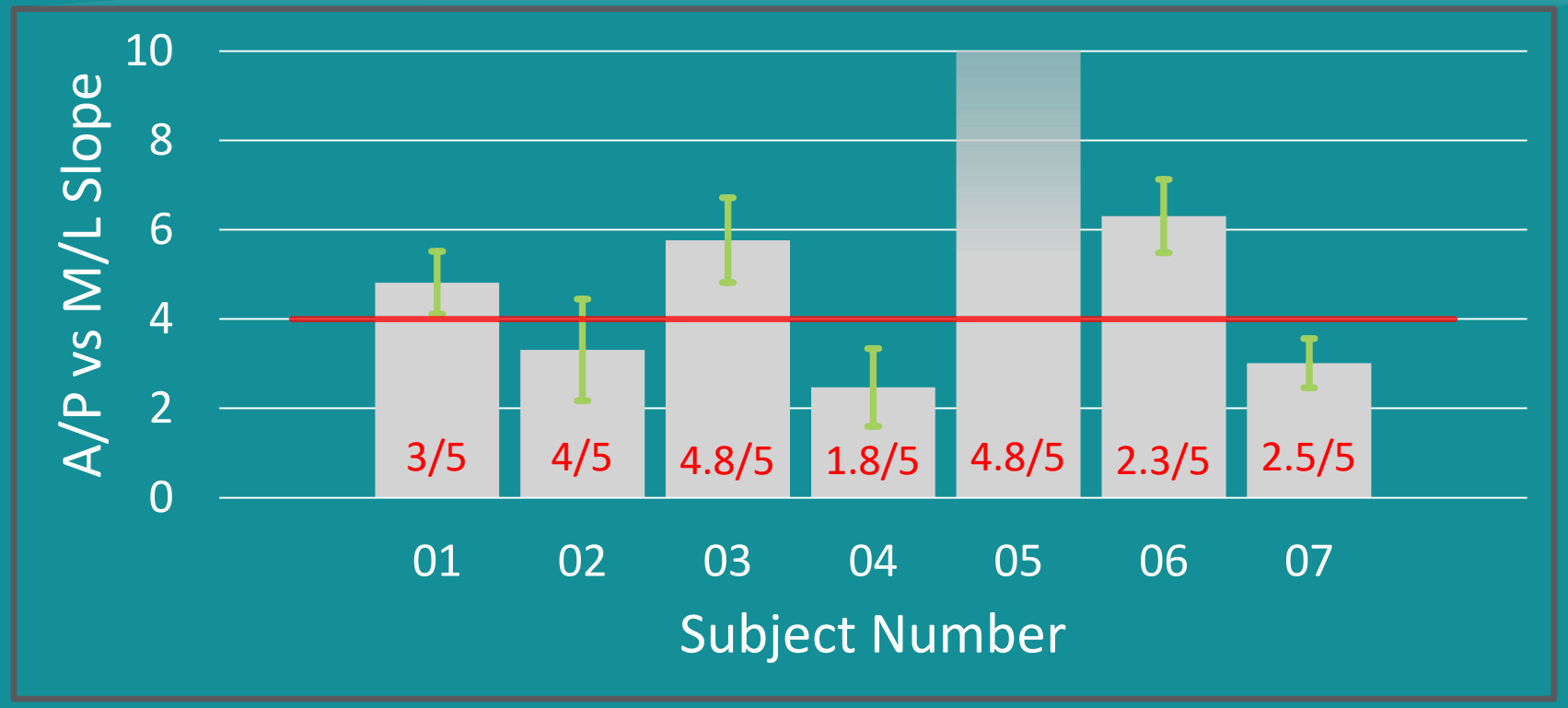


- Slope: **1.5** $\frac{deg}{deg}$
- Gait Score: **1.8/5.0**

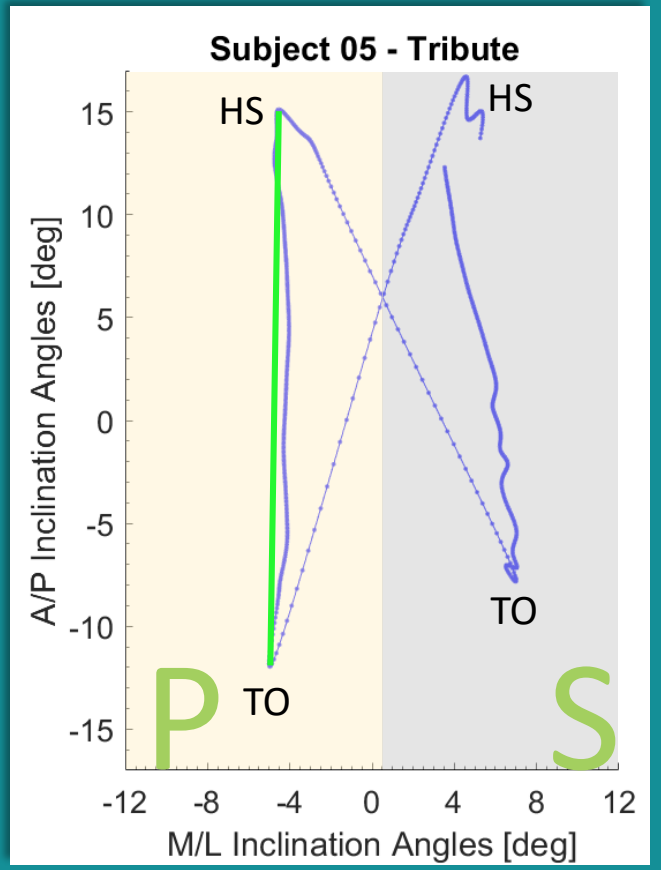
RESULTS

- Human subject balance compared

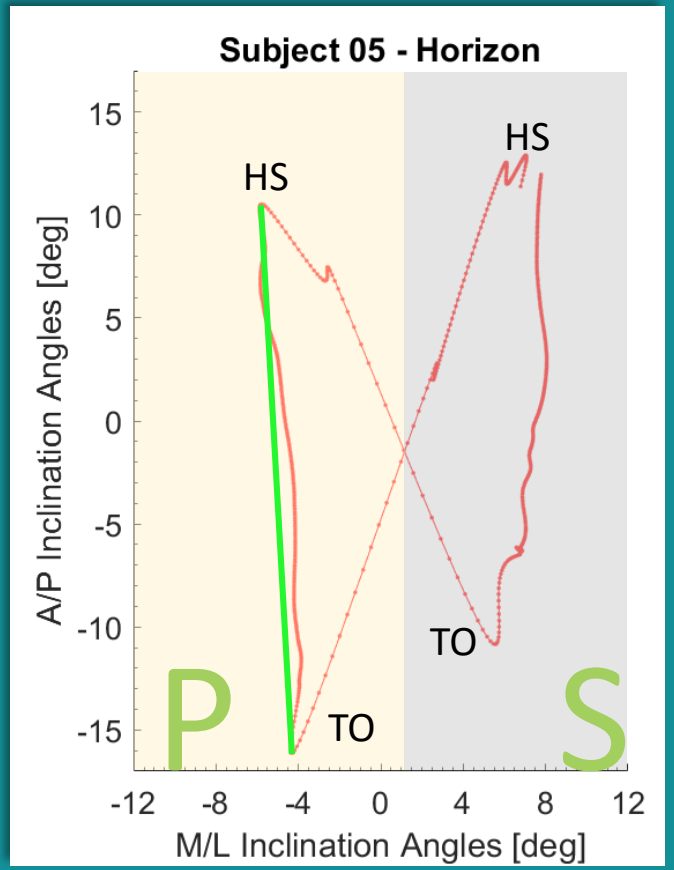




RESULTS - Subtle differences between feet



- Slope: **28.9** $\frac{deg}{deg}$
- Gait Score: **5.0/5.0**



- Slope: **15.9** $\frac{deg}{deg}$
- Gait Score: **4.0/5.0**

Discussion

- Inclination angles may quantify an amputee's balance
- Quantifiable measurements of balance may assist prosthetists in the selection of feet
- Reduces the space and cost needed for traditional motion capture gait analysis
- Further investigation needed to determine accuracy of balance comparison

Acknowledgements – Co-Authors













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