A Balance Measure for Amputees

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Introduction

- 52.4% of LL amputees have reported falling in the previous year [1] and 66% of above-knee amputees report falling annually, which is 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.
- Inclination angles have been used to provide information about fall risk for elderly patients [3].

Methods

- Developed the Dynamic Corrective Force Device (DCFD) to measure balance during ambulation.

Pressure-sensing insoles

- Developed in partnership with Sandia National Laboratories.
- Measure Ground Reaction Forces (GRF) and Center of Pressure (COP).
- Novel shear sensors calculate COP with improved accuracy

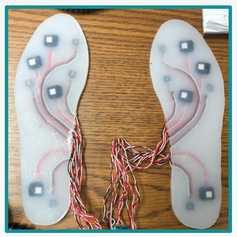


Figure 1 *– Custom pressure-sensing insoles*

Inertial Measurement Units (IMUs)

- Cost of commercially-available systems has decreased, making them a cost-effective option.
- Down selected to 12 Xsens MTw Awinda IMUs placed on the key body segments.
- Measure segment movement in the body coordinate frame.

Figure 2 *– Xsens IMU system*

- Collected data on 7 BK amputee subjects.
- Developed a custom amputee-specific articulated hierarchical model of the human body.

Methods (cont.)

- IMU data and anthropometric measures determine Center of Mass (COM).
- COP data collected from the instrumented insoles.
- Anterior-Posterior (A/P) and Medial-Lateral (M/L) Inclination Angles (IA) are calculated – the angles between the COM and COP (Figure 4).

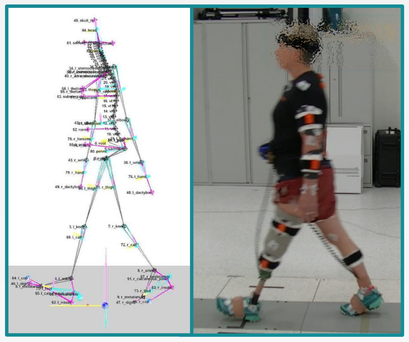


Figure 3 *– Custom amputee model visualization*

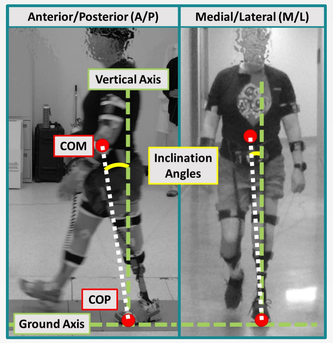


Figure 4 *– Inclination angle diagram*

Results

- DCFD could accurately determine COM within 1.5 cm and COP within 2.0 mm of the gold standard 14 camera Qualisys motion capture system.
- A/P IA plotted against M/L IA produces a "Butterfly" plot that is used to determine gait symmetry and stability [3].

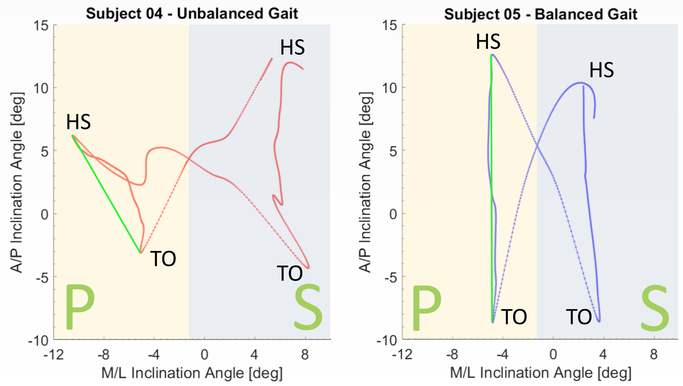
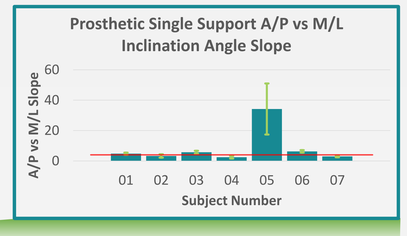


Figure 5 *– "Butterfly" plot shows difference between balanced and unbalanced amputee walkers. Symmetry between Prosthetic (P) and Sound (S) side walking can be seen. Green best fit line shows slope during prosthetic single support. Heel Strike (HS) and Toe Off (TO) events are labeled on plot.*

Results (cont.)

- Slope of A/P vs M/L inclination angle during prosthetic side single support correlated with observed gait stability of subjects by experts in clinical gait analysis.



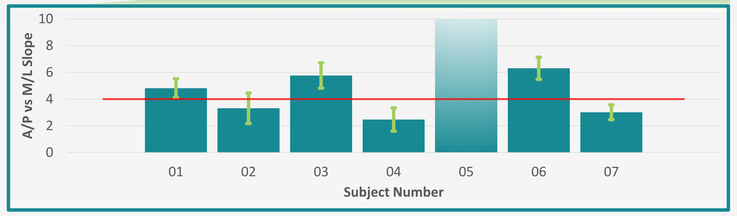


Figure 6 *– Measured slope of A/P vs M/L inclination angle (mean ± 95% confidence interval). Subjects above the threshold value of 4 tended to have greater observed gait stability.*

Discussion

- Initial results indicate that gait stability as determined by inclination angles correlates with that as determined by experts in gait analysis.
- Such quantifiable measurements of balance as these may be able to be used to assist prosthetists in the selection of feet for their patients.
- The DCFD reduces the space and cost needed for traditional motion capture gait analysis.

Conclusions

- Functional and portable system was developed to accurately measure gait parameters.
- Inclination angles may quantify an amputee's balance.

References

[1] Centers for Disease Control and Prevention. *Costs of Falls Among Older Adults*. 2012 [cited 2012 May 22, 2012]; Available from:www.cdc.gov/HomeandRecrationalSafety/Falls/fallcost.htm
[2] Balaban, C. and M. Hoffer, *Mild Traumatic Brain Injury: Vestibular Consequences*. 2009.
[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

Acknowledgements

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