A METRIC TO QUANTIFY THE "DEAD SPOT" PHENOMENON IN PROSTHETIC FEET

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INTRODUCTION

The "dead spot" phenomenon (DSP) is a period of limited motion during the stance phase of amputee gait during which the prosthetic foot is neither yielding nor returning energy to the user. Amputees describe this phenomenon as a "flat spot" or "stall" in the foot and as a feeling of having to "climb over the prosthetic foot."[1,2] The occurrence of the DSP is clinically significant as it requires the amputee to produce additional force to resume progression of the foot through stance which can result in an inefficient, compensatory gait pattern. This increased ambulatory energy requirement can reduce walking speed, stability, and activity.[3]

Some prosthetic manufacturers claim the DSP is absent or minimized with use of their feet, however, the DSP has not yet been clearly identified kinetically making it difficult to make such a determination. Correspondingly, a definitive metric to quantify the DSP needs to be developed..

METHOD

Center of pressure (CoP) is used to quantify motion in the prosthetic foot. Rate of change (RoC) is calculated and an ideal mean is found by dividing the length of the foot by the stance time for each individual step. A threshold value is then calculated to isolate DSP data by multiplying the mean RoC by a constant coefficient of 0.60. Data within 10-50% stance phase is analyzed to determined DSP. Data before this timeframe is excluded due to confounding of double stance and data after is excluded as it is specific to action of the toe lever. The metric developed and used here compares RoC data to the threshold value to determine DSP time, DSP magnitude, and total DSP area.

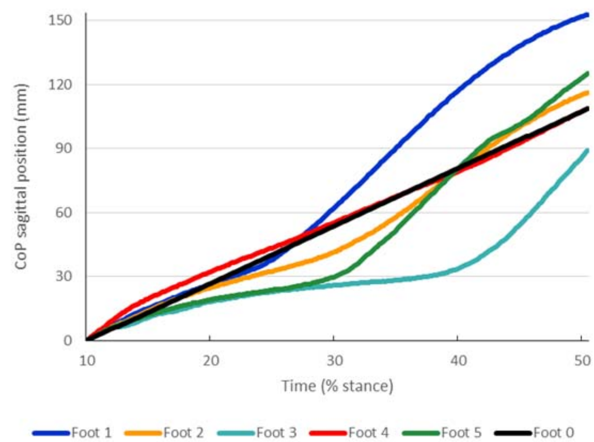
The study utilized a randomized, double-blinded, repeated-measures design. Four amputees (2 TT, 2 TF) were tested on 5 foot conditions by an 8-camera Vicon system with 2 AMTI force plates. A 2-way ANOVA was used to compare conditions and a 1-way ANOVA was used to compare feet to a hypothetical ideal condition with no DSP. The level of significance was set at $p<0.05$.

RESULTS

DSP time was lowest in feet 1 and 4 and highest in foot 3. DSP Magnitude was lowest in foot 3 with all other feet being similar. DSP area was lowest in foot 4 and highest in foot 1. No value was found to be similar to the ideal condition in the primary analysis.

An *ad hoc* analysis of metric values was performed by subject and 18 metric values were found similar to the ideal condition. 17 occurred in TT subjects. Foot 1 and 4 accounted for 10 of 18 (55.6%).

Figure 1. CoP slopes for all foot conditions vs. ideal. Prolonged plateaus indicate the dead spot.



DISCUSSION

A favorable trend in DSP metric values was found in feet that utilize continuous plantar rockers as a design element. These feet had no detectable DSP when tested on the TT subjects. Only 1 of 18 findings of similarity to the ideal condition was found in TF subjects, indicating that further research is needed to determine if this metric can be implemented in TF subjects in its current form.

CONCLUSION

A viable methodology to quantify the dead spot phenomenon in prosthetic feet was developed and implemented. The results of this work found that continuous-lever prosthetic feet had the smallest dead spot and that different calculations may be needed between subjects of differing amputation level.

CLINICAL APPLICATIONS

This work allows the dead spot to be evaluated in an objective way which may guide future prosthetic foot design and prescription guidelines.

REFERENCES

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Note: The RUSH™ Foot is "FOOT 4" in this study and the ONLY continuous plantar rocker lever foot on the market today.