Introduction/Background
Below Knee Amputations

- Approx. 185,000 in US each year
- Diabetes is leading cause
- More than 25.8 million people affected
- Number of amputees is projected to increase by 47% by 2020 and more than double by 2050
- 55% of diabetic amputees will require second leg amputation in 2-3 years
Types of Prosthetic Feet

- Models for walking, dancing, running, cycling, swimming, etc
- Rigid connections vs. hinged ankle
- Six main groups
  - Solid Ankle Cushioned Heel (SACH)
  - Elastic Keel Foot
  - Single-Axis Foot
  - Multi-Axis Foot
  - Dynamic-Response Foot (also called Energy Storage and Release: ESAR)
  - Microprocessor Foot
Previous Investigations
Gait Analysis and Energy Cost

- 6 feet studied
  - SACH, S.A.F.E II, Seattle Lightfoot, Quantum, Carbon Copy II, and Flex-Walk
- 2 groups: Vascular and Traumatic
- Duration of Study: 3 weeks for each foot by each subject
- Motion analysis used to evaluate foot followed by energy cost test on same day

<table>
<thead>
<tr>
<th></th>
<th>Both Groups (n=6)</th>
<th>Vascular Group (n=3)</th>
<th>Traumatic Group (n=3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs.)</td>
<td>51.7 ± 15.3</td>
<td>64.0 ± 5.3</td>
<td>39.3 ± 9.9</td>
</tr>
<tr>
<td>Time from Amputation (yrs.)</td>
<td>13.3 ± 13.0</td>
<td>5.0 ± 2.6</td>
<td>21.6 ± 14.4</td>
</tr>
<tr>
<td>Residual Limb Length (cm.)</td>
<td>13.4 ± 1.8</td>
<td>13.6 ± 2.7</td>
<td>13.1 ± 1.0</td>
</tr>
<tr>
<td>Percentage of Body Height (%)</td>
<td>7.5 ± 1.0</td>
<td>7.6 ± 1.4</td>
<td>7.3 ± 0.6</td>
</tr>
</tbody>
</table>

Mean ± Std. Dev.
Gait Analysis and Energy Cost Results

- Significant differences in linear measurements, late-stance ankle dorsiflexion, the amount of ankle dorsiflexion change from early to late stance, weight acceptance foot-floor reaction forces, and right and left step lengths
  - SACH Foot best when maximum late-stance stability by limited dorsiflexion is required
  - S.A.F.E II best when increased early-to-late stance change in dorsiflexion required
  - Seattle Lightfoot provides sound-limb and prosthetic limb symmetry for amputees; it is good for average activity level amputees with no gait abnormalities.
  - Quantum and Carbon Copy II are optimal for diabetic or dysvascular amputees.
  - Flex-Walk is best for early to late stance change in dorsiflexion and maximum late stance dorsiflexion; accommodates increased ankle range of motion.
Foot Type and Visual Alteration on Postural Steadiness

- 3 different feet studied
  - SACH (A), SA (B), and ESAR (C)
- Vascular and Traumatic
- Overall stability, anterior-posterior stability index, and medial-lateral stability index were computed
- Activity specific confidence score then awarded
- Results:
  - SACH: lowest stability when eyes open
  - SA: lowest stability when eyes closed
  - Trend of instability occurred more in medial-lateral compared to anterior-posterior direction for all foot types
*Concluded that postural steadiness not affected by type of prosthetic foot during quiet standing, but significantly affected when no visual cues
Effects of Prosthetic Alignment

- These tests were performed using a cardiopulmonary device that determined metabolic rate and, thus, energy expenditure.

- Patients walked on a treadmill at different speeds with the prosthetic in different alignments.

- Oxygen consumption increased when the prosthetic was aligned in dorsiflexion or plantarflexion away from the optimal alignment.

- There was a minimal difference in the prosthetics with and without carbon-fiber springs; the only noticeable difference was in the transition from walking to running.
Proposed Research
Hypothesis

• There is one foot that can do it all for otherwise healthy patients with normal to active lifestyles

• Dependent on the activities the patient is involved in, different prosthetics may not make a difference
Impact of Research

• To find or create the most versatile foot, for below the knee amputees, to resume as close to normal life as possible

• Allow for an easy transition between activities (i.e. walk to run, sit-to-stand, water to land) without the interchanging of feet

• Considerably reduce the cost to patients--only one foot will be needed for all activities
Specific aims

• Compare 6 main type of feet to determine
  • Which functions are performed the best
  • Overall Metabolic Costs

• Combine best aspects of each to create “super foot”

OR

• Be able to provide brochure for best possible foot selection for patients
Our Proposal

• Criteria
  • Ages: 21-35 that are otherwise healthy
  • At least 10 participants per activity, sit-to-stand and walking will be tested in each activity group

• Tests will consist of 10 minute intervals of activity

• Gait will be analyzed pre and post study on patient’s personal prosthetic as well as “best fit” prosthetic determined by the study

• This will be analyzed using force plates and a motion capture system
Our Research

• We will use a COSMED K4b2 cardiopulmonary metabolic rate measuring system to determine which of the different prosthetics is more energy efficient in the different activities our patients will be performing.

• This is a wireless device that will give the patient complete freedom to perform each of the different activities, and gives a breath-by-breath analysis.

• The different activities we will be testing include sit-to-stand, walking, running, dancing, cycling, and swimming.

• Written feedback will be requested after each trial to gain the patient’s perspective on which prosthetic they felt helped them perform the best.

• Patient feedback will be compared to quantitative data in final analysis.
<table>
<thead>
<tr>
<th>Pre-Study</th>
<th>Day 1</th>
<th>Day 2</th>
<th>Day 3</th>
<th>Day 4</th>
<th>Day 5</th>
<th>Day 6</th>
<th>Day 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-gait analysis on personal</td>
<td>Foot 1</td>
<td>Foot 2</td>
<td>Foot 3</td>
<td>Foot 4</td>
<td>Foot 5</td>
<td>Foot 6</td>
<td>Post-gait analysis on</td>
</tr>
<tr>
<td>prosthetic</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>subject’s “best fit” foot</td>
</tr>
</tbody>
</table>

* Each activity will be tested on each prosthetic, one prosthetic per day
Conclusion

• Technological and cost limitations affect the ability of the subject to be able to afford and utilize current high-tech prosthetics that promote performing the tested activities with ease

• The goal of our research is to use basic gait and metabolic analysis to create or compare a device that is simplistic and cost effective

• It may also be found that a certain type of prosthetic has no effect on subjects’ ability to perform a task
References

Harmen van der Linde, M., PhD; Cheriel J. Hofstad, MsC; Alexander C. H. Geurts, MD, PhD; Klaas Postema, MD, PhD; Jan H. B. Geertzen, MD, PhD; Jacques van Limbeek, MD, PhD (2004). A systematic literature review of the effect of different prosthetic components on human functioning with a lower-limb prosthesis. Journal of Rehabilitation Research and Development, 41(4), 555-570.


