MECHANICAL PROPERTIES OF DYNAMIC ELASTIC RESPONSE PROSTHETIC FEET

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INTRODUCTION

In comparison with basic prosthetic feet, dynamic elastic response (DER) prosthetic feet more closely mimic the native ankle joint, storing and returning energy throughout the gait cycle [1, 2]. This is particularly beneficial to amputee patients who lead active lives.

With countless prosthetic foot manufactures and models, it can be difficult to compare various options when prescribing a prosthetic foot. Both functional and mechanical testing of prosthetic feet provide important information to prosthetists and patients [2]. While many groups have studied the functional characteristics of DER feet, few have focused on the more objective testing of the mechanical properties that is not influenced by intersubject variability [1]. Therefore, the purpose of this study was to test the mechanical properties of DER feet in a standardized and repeatable manner. In particular, the stiffness and hysteresis of the heel and forefoot regions of commercially available DER feet was investigated.

METHODS

DER feet, coded as L5986 and L5987, from four different manufacturers (Table 1) were compared. All feet were 27 cm and recommended for a hypothetical male patient, described as high activity with a right side below-knee amputation, weighing 200 lbs. An MTS 858 Mini Bionix II servohydraulic test system (Eden Prairie, MN) was used to test each specimen in compression. Stiffness testing was conducted adhering to the Static Proof Test detailed in ISO Standard 10328 [3]. Testing was not conducted to failure.

Each foot was tested with the manufacturer-provided foot cover. A compressive load was applied to the foot at 100 N/s until the load reached 2240 N, per ISO 10328. The system was then completely unloaded at the same rate. Both the heel and forefoot regions of all feet were tested in three successive compression trials. During compression, the load and displacement were measured using a uniaxial load cell and linear variable differential transformer, respectively. Data were collected using Multipurpose TestWare software (MTS, Eden Prairie, MN) at 20 Hz. Heel and forefoot stiffness was observed as the slope of the load-displacement curve for each prosthetic foot. Hysteresis, the difference between the loading input energy and unloading energy, was calculated for the heel and forefoot testing of each DER foot.

RESULTS AND DISCUSSION

There were differences in stiffness for the heel (Fig. 1) and forefoot (Fig. 2) of all DER feet tested. During walking over level ground, a person will experience a peak ground reaction force of approximately 1.2 times body weight [4]. At this loading level, the heel and forefoot of feet A and B were stiffer than feet C and D. If that same patient was to run at a moderate pace, they would experience a peak ground reaction force of approximately 2.5 times body weight [4]. At this loading level, the stiffness was increased, and heel stiffness was greater than forefoot stiffness. The relative rank of stiffness for feet A and B changed for heel loading, but not for forefoot loading. A greater displacement was observed for all DER feet when loaded at the forefoot.

Hysteresis varied between samples under the different loading configurations (Fig. 3). Feet with higher stiffness had greater energy loss at both the heel and forefoot.
CONCLUSIONS

When used with the functional kinematic data already present in literature, the stiffness and hysteresis data for commercially available prosthetic feet can be used to guide prosthetic prescriptions of DER feet.

REFERENCES


ACKNOWLEDGEMENTS

Fellowship funding (Webber) provided by the Mayo Graduate School.

<table>
<thead>
<tr>
<th>Foot Code</th>
<th>Manufacturer</th>
<th>Model</th>
<th>Primary Material</th>
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<tbody>
<tr>
<td>A</td>
<td>Ability Dynamics (Tempe, AZ)</td>
<td>RUSH 87</td>
<td>Glass Composite</td>
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<tr>
<td>B</td>
<td>Freedom Innovations (Irvine, CA)</td>
<td>Renegade AT</td>
<td>Carbon Fiber</td>
</tr>
<tr>
<td>C</td>
<td>Össur (Reykjavik, Iceland)</td>
<td>Talux</td>
<td>Carbon Fiber</td>
</tr>
<tr>
<td>D</td>
<td>Ottobock (Duderstadt, Germany)</td>
<td>Triton 1C61</td>
<td>Carbon Fiber</td>
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