Comparative Performance of a Fiberglass Dynamic Elastic Response Foot

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INTRODUCTION

Dynamic elastic response (DER) feet are prostheses that store and release energy during gait. They are designed for active lower-limb amputees[1] and believed to be beneficial by enhancing mobility and function[2]. However, the design of a DER foot appears to be based on a trial-and-error basis[3]. At present, there is little scientific evidence to guide the clinical prescription of DERs[4]. Prosthetic guidelines are currently based on clinical consensus among experts[5].

Recently, a new type of prosthetic foot appeared on the market. This device is composed of a fiberglass composite material. Knowledge is lacking regarding the performance of this new device. Comprehensive studies are needed to form a solid basis for prosthetic prescription. Therefore, the purpose of this study was to compare the functional performance of individuals with transtibial amputation using two types of prosthetic foot designs: carbon fiber vs. fiberglass composite. We hypothesized that the fiberglass composite material would provide more energy return and improved ankle kinematics.

METHODS

Study Design: The study used a cross-over design. Half of the subjects started on the fiberglass foot (FF), while the other half started on a carbon fiber foot (CF).

Subjects: Ten male subjects with a unilateral transtibial amputation (age: 49±9 years, BMI: 29±7 kg/m^2, 10.4±9.8 years of prosthesis use, K-Level III) were studied after giving informed consent.

Prosthetic Feet: The FF was an Ability Dynamics Rush foot. The CF studied were Otto Bock Triton, Ossur Variflex, Ossur Variflex EVO, Ossur Reflex Shock, Freedom Renegade, Freedom Pacifica, Freedom Thrive with Vertical Shock, Freedom Highlander, and Freedom Agilix.

Procedures: Gait analysis was performed using a 10 camera, high resolution system (Motion Analysis, Santa Rosa, CA) and 6 force plates (Kistler, AMTI, Bertec). Data was collected over level ground at self-selected and normalized speed (Froude) as well as ascending and descending a 10 degree ramp. Patient satisfaction was measured using the Prosthesis Evaluation Questionnaire (PEQ), a reliable and valid tool for evaluating persons with lower-limb amputations[6].

Data Analysis: A multivariate approach was used to compare all conditions (gait data) or subscales (PEQ) simultaneously using a single factor repeated measures ANOVA. Statistical significance was set at p=0.05.

RESULTS

The gait data demonstrated increased ankle dorsiflexion ($p<0.01$), similar ankle moments ($p=0.07$) and increased ankle power generation ($p=0.01$) when using the fiberglass foot (Figure 1). The increased power generation occurred at the correct time such that the timing and magnitude of peak knee flexion was unaffected ($p>0.19$). The subjects expressed greater satisfaction with the fiberglass foot as measured by the PEQ ($p=0.02$).

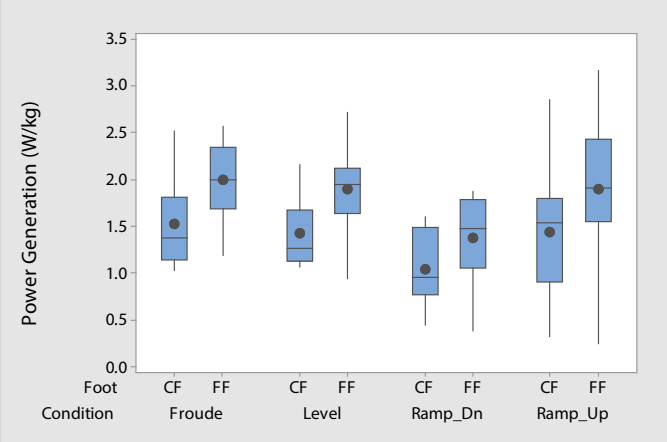

Figure 1. Box plot of ankle power generation during gait for four ground conditions. CF=carbon fiber foot. FF=fiberglass foot. The central line represents the median, the dot represent the mean, the edges of the box are the 25th and 75th percentiles, and the whiskers extend to ±1.5 of the interquartile range. The fiberglass foot (FF) generated significantly more power than the carbon fiber foot (CF) for all walking conditions.

DISCUSSION

Ankle muscles generate and absorb mechanical energy necessary to create movement. The single variable that summarizes that role of the ankle plantarflexors is mechanical power, which is the product of the joint moment of force and joint angular velocity. This study showed that walking with a fiberglass composition foot resulted in a 31% increase in power production (1.79 W/kg with FF vs 1.36 W/kg for CF). However, the power is still 50% lower than that produced by an intact limb (3.4 W/kg 95% CI: 2.2 – 4.7 W/kg)[7]. Nonetheless, the subjects reported greater satisfaction when using the fiberglass foot as measured by the PEQ. The PEQ is composed of 9 validated scales. All scales were improved when using the fiberglass foot, with significant increases reported for appearance and utility.

REFERENCES

1. Kobayashi T, et al., Clin Biom, 29:47-56, 2014
2. Hafner BJ, et al., JRRD, 39:1-11, 2002
3. Strike S, Hillery M, Proc Int Mech Engr, 214:603-614, 2000
4. Hofstad C, et al., Cochrane Sys Rev, CD003978, 2004
5. van der Linde H, et al., JRRD, 41:555-570, 2004
6. Legro MW, et al., Arch PM&R, 79(8):931-938, 1998
7. Winter DA, CORR, 175:147-154, 1983

DISCLOSURE

The authors have no financial conflicts to disclose.

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*In summary, the study showed results supporting the use of **FIBERGLASS COMPOSITE MATERIALS** in prosthetic foot design relating to both performance, as well as patient satisfaction. This is the same material utilized in the entire **RUSH™ Foot collection.***