



Changes in Gait Using the Rush™ Foot: A Preliminary Study

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INTRODUCTION

Carbon fiber has become the dominant material used in high activity prosthetic feet due to its high strength and deflection/deformation properties. The Rush® foot (Ability Dynamics, Tempe, AZ) was designed, however, utilizing a glass fiber marketed under the name Flexeon®. The Rush® foot is marketed as capable to improve amputee gait due to the enhanced material properties of Flexeon® compared to carbon fiber. In this preliminary study, we examined multiple parameters of gait to determine if, and how, the Rush® foot improves amputee gait compared to a high activity K3 carbon fiber foot. Comparisons to a low activity K2 foot were also performed.

METHOD

Subjects: Five transtibial amputees consented to participate in this IRB approved study (age: 48.2 ± 9.9 yrs; ht: 174.4 ± 6.4 cm; mass: 101.0 ± 26.6 kg; time since amputation: 9.5 ± 10.4 yrs).

Procedures: Subjects were fitted with the Rush® foot according to the manufacturer's guidelines. The subjects' previously fitted socket and suspension were utilized. Following a minimum of 3 weeks wear time (English, 1995), the subjects were tested in the biomechanics lab. Subjects walked across a 10 meter walkway while kinetics (600Hz; Kistler Instruments) and kinematics were acquired (60Hz; Motion Analysis) for 10 trials. Subjects also completed a 3 minute treadmill walking trial at their self-selected pace (60 Hz; Motion Analysis). The same exact procedures were repeated for the K2 foot and K3 carbon fiber foot in a randomized fashion. All prostheses were aligned by a certified prosthetist

Data Analysis: Kinetics and kinematics of ankle, knee, and hip were calculated using inverse dynamics (Vaughan, 1992; Visual 3D, Germantown, MD) with the exception of the ankle powers (calculated using Takahashi, 2012). Spatio-temporal measures were calculated from heel and toe marker data. The Lyapunov exponent (LyE) for the sound and prosthetic ankle was calculated from the treadmill trials (Wurdeman, 2013). Dependent t-tests were used to test for differences between feet instead of an ANOVA. This was due to the presence of unequal sample sizes between factors (i.e. feet) since of the 5 subjects only 3 were able to do testing in all 3 different designs of feet.

RESULTS

For spatio-temporal measures, comparisons with the K3 foot revealed that subjects have decreased prosthetic step time (R: 0.62 ± 0.06 s, K3: 0.66 ± 0.03 s; $p < 0.05$), shorter double support time for sound and prosthetic side ($p < 0.05$), and decreased double support percentage for sound and prosthetic side

($p < 0.05$). For kinematics and kinetics, comparisons with the K3 foot revealed that for prosthetic leg the Rush® foot had increased dorsiflexion angle in midstance (R: 16.0 ± 1.5 deg, K3: 12.2 ± 2.4 deg; $p < 0.05$), increased ankle power absorption in midstance (R: -1.3 ± 0.5 W/kg, K3: -1.0 ± 0.2 W/kg; $p < 0.05$), and increased hip power generation in early stance (R: 1.2 ± 0.5 W/kg, K3: 1.0 ± 0.5 W/kg; $p < 0.05$). For the same parameters, comparisons with the K2 foot revealed that for the prosthetic leg the Rush® foot had increased dorsiflexion angle in midstance (R: 16.0 ± 1.5 deg, K2: 7.4 ± 1.2 deg; $p < 0.05$), decreased dorsiflexion moment at heelstrike (R: -0.5 ± 0.2 N*m/kg, K2: -0.6 ± 0.1 N*m/kg; $p < 0.05$), increased plantarflexion moment in late stance (R: 1.5 ± 0.1 N*m/kg, K2: 1.2 ± 0.3 N*m/kg; $p < 0.05$), increased ankle power absorption in midstance (R: -1.3 ± 0.5 W/kg, K2: -0.7 ± 0.5 W/kg; $p < 0.05$), and increased ankle power generation in late stance (R: 1.85 ± 0.5 W/kg, K2: 0.7 ± 0.4 W/kg; $p < 0.05$). For kinematics and kinetics, comparisons with the K2 foot revealed that for the sound leg the Rush® foot had decreased dorsiflexion moment at heelstrike (R: -0.4 ± 0.3 N*m/kg, K2: -0.46 ± 0.26 N*m/kg; $p < 0.05$). We found no differences for the LyE comparisons.

DISCUSSION

The results from this preliminary study showed that the Rush® foot results in changes to the patient's gait. The changes in the spatio-temporal measures seems to indicate either improved balance or increased confidence in balance as the person spends less time and a smaller percentage of the gait cycle in double support. The increased dorsiflexion angle in midstance has been associated (Powers, 1994) with positive benefits to the amputee gait. In addition, the Rush® foot alters powers at the ankle and hip, but further work is needed to determine whether these changes are actual improvements. The LyE analysis showed no difference; however, individual trends did coincide with expressed feelings of preference by the subjects (Wurdeman, 2013).

CONCLUSION

Our preliminary work seems to indicate that the Rush® foot alters the biomechanics of the amputee gait as compared to both the K3 and the K2 foot.

CLINICAL APPLICATIONS

The Rush® foot appears to provide benefits for the transtibial amputee during walking.

REFERENCES

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