GROUND REACTION FORCE CHARACTERISTICS OF DIFFERENT PROSTHETIC FEET: AN IMMEDIATE RESPONSE CASE STUDY

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INTRODUCTION

Adapting to a prosthetic limb is a profound challenge for an amputee regardless of age, overall health, or the reason for amputation. The majority of research that addresses the gait biomechanics of lower limb amputees uses cross-sectional research designs (e.g., Silverman et al., 2008). Prosthetists gain much from these cross-sectional studies and from research that examines the adaptation to new prosthetic limbs (Graham et al., 2007). Researchers examining differences in prosthetic limbs typically allow for long term adaptation to occur prior to testing (Graham et al., 2007). Motivated by the suggestions of clinicians, the present study examined the immediate response of a single, unilateral transtibial amputee to different prosthetic feet. In general, prosthetists do not use the tools of a gait lab to evaluate the fit and alignment of prosthetic legs. In addition, Linden et al. (1999) introduced an approach that examined the biomechanical response of individual subjects to new prosthetic legs. Because amputees often exhibit unique gait patterns, they justified a statistical approach that tested differences of each subject rather than a group. The purpose of the present study was to compare the GRF characteristics of different prosthetic limbs immediately after initial fit and alignment. Multiple trials for each condition were assessed for a single subject so that the mechanics of the initial strides could be assessed.

METHODS

A unilateral, transtibial amputee volunteered for this case study and provided consent (age = 46 yr, mass = 72.7 kg, height = 170 cm, post-amputation = 18 yr, cause = trauma from work-related accident). A certified prosthetist was present for proper fit and alignment of different prosthetic feet. After multiple overground walking trials at the participant's preferred speed and with his existing foot (BioQuest model), three additional conditions were examined: True Life 1 (Seattle, low stiffness); True Life 2 (Seattle, high stiffness); new BioQuest foot (foot plate 10 g less than original). For each new condition, the prosthetist fit and aligned the foot on the participant's endoskeletal prosthetic shank. The participant then completed overground walking trials immediately after the fit and alignment.

GRF data were recorded for four ground contacts for each foot condition and each limb (AMTI force platform, 480 Hz). The following variables were assessed for each trial: 1st peak GRF_v; 2nd peak GRF_v; AP-Braking Impulse; AP-Propulsive Impulse; Lateral Impulse; Vertical Loading Rate over the initial 0.05 s of contact. Repeated measures ANOVA was used to test for differences in gait speed (across conditions) and GRF variables (across limb and conditions). The probability of a Type I error was set at 0.05.

RESULTS AND DISCUSSION

The participant walked slower than the original condition in two of the three foot conditions (see Table 1 below).

Table 1: Preferred walking speed ($m \cdot s^{-1}$) for each foot condition. * slower than Orig ($p < .05$)

	Orig	C1	C2	C3
Means	1.58	1.54	1.52*	1.47*
SDs	0.06	0.05	0.02	0.03

The order presented in Table 1 was the order of testing, and so the decrease in preferred walking speed may be from fatigue. Mean peak GRF values and impulses are shown in Figures 1 and 2 respectively, and mean loading rate values are shown in Table 2.

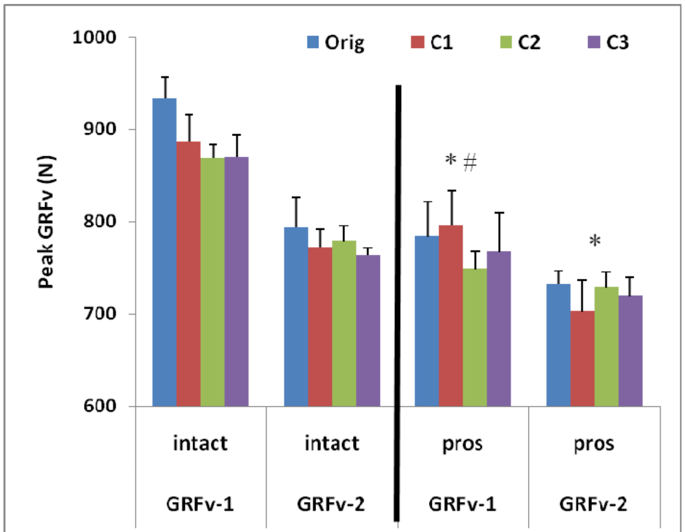

Figure 1: 1st and 2nd mean peak GRF_v for each limb and foot condition. Statistical differences between limbs (*) and conditions (#) are shown on the right side of the figure.

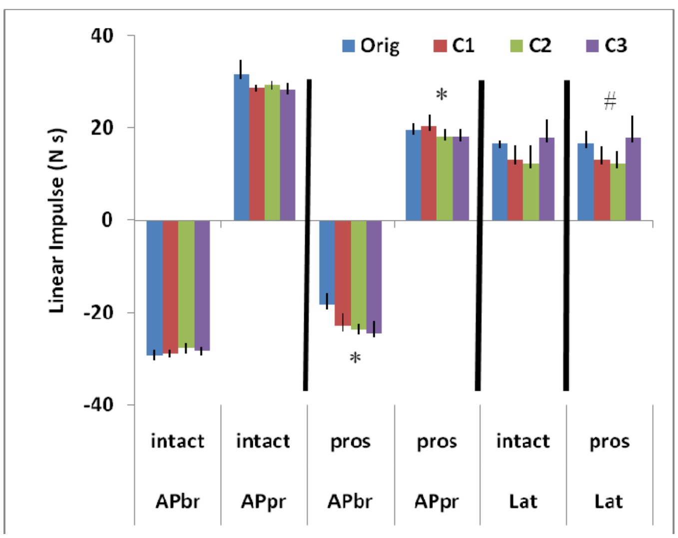

Figure 2: Mean linear impulse associated with AP-braking (APbr), AP-propulsion (APpr), and lateral GRF (Lat) for each limb and foot condition. Statistical differences between limbs (*) and conditions (#) are shown.

Intact limb peak vertical GRFs were greater than prosthetic limb and the initial peak was different across foot conditions (Figure 1). Braking and propulsive impulses also were greater in the intact limb (Figure 2), but no differences across conditions were found in these variables. Limb differences are consistent with previously reported group data (Sanderson & Martin, 1997) and individual data (Linden et al., 1999). Differences across conditions were limited to the initial GRF_v peak and lateral impulse. Loading rate was significantly greater in the intact limb and the Orig condition was greater than other foot conditions (see Table 2).

Table 2: Mean GRF_v loading rate ($kN{\cdot}s^{-1}$) for each limb and for each foot condition. *Intact > Prosthetic ($p < .001$). **Orig > C1, C2, C3 ($p < .05$)

	Orig**	C1	C2	C3
Intact*	12.5	12.1	11.2	11.1
SD	1.5	0.6	1.1	0.6
Prosthetic	7.5	5.7	6.5	6.9
SD	0.4	0.7	0.5	0.5

Taken collectively, the results presented here are consistent with others who reported higher GRFs in the intact limb compared to the prosthetic limb of unilateral amputees (e.g., Linden et al., 1999). Loading rate was identified as a discriminator between nonamputees who do and do not suffer chronic knee pain (Radin et al., 1991). Radin and colleagues suggested that higher loading rates may be a contributing factor to the development of osteoarthritis. Ironically, a reason given for amputees to increase the overall loading of the intact limb is to reduce, and thus spare, the residual limb from high loads (Sanderson & Martin, 1997).

CONCLUSIONS

The initial GRF_v peak, lateral impulse, and GRF_v loading rate displayed statistical differences across prosthetic foot conditions. The expected differences between intact and prosthetic limbs were not affected by different prosthetic feet.

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ACKNOWLEDGEMENTS

The authors appreciate the help of Ben Struzenburg, of Hanger Prosthetics and Orthotics.