LOWER EXTREMITY MECHANICAL WORK OF DIFFERENT PROSTHETIC FEET: AN IMMEDIATE RESPONSE CASE STUDY

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INTRODUCTION

Clinicians and prosthetists often evaluate the introduction of a new prosthesis by observing the gait of a lower limb amputee without the aid of a motion analysis system. Researchers examining differences in prosthetic limbs typically allow for long term adaptation to occur prior to testing (Graham et al., 2007). Limited data exist that focus on immediate kinetic responses to a new prosthetic limb. Noble and Prentice (2006) examined swing leg kinetics in nonamputees during treadmill walking immediately before and after the addition and removal of mass to the left lower limb. They identified immediate changes in mechanics that dissipated after 50 strides, but trial-to-trial changes were not examined because they used averages of 5 trials for analysis. In addition, Linden et al. (1999) introduced an approach that examined the biomechanical response of individual amputees 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 goal of the present study was to examine immediate joint kinetic changes during the initial strides of a unilateral, transtibial amputee after he was fitted to different prosthetic feet. Specifically, the mechanical work performed by the lower extremity joints during stance was examined immediately after a new prosthetic foot was introduced.

METHODS

A unilateral, transtibial amputee volunteered for this case study and provided consent in accordance with the local IRB (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 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: C1-True Life 1 (Seattle, low stiffness); C2-True Life 2 (Seattle, high stiffness); and C3-original BioQuest shank/ankle with a new 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 at his preferred speed of walking.

A single video camera recorded a sagittal-plane view of the participant as he contacted an AMTI force platform. Using coordinate data from a motion analysis system, ground reaction force data, and an inverse dynamics analysis, net joint moments were calculated for the ankle, knee, and hip during ground contact of 8 strides among the first 30 strides for each condition (4 strides for each side of the body). Mechanical power was calculated as the product of net joint moment and angular velocity at each joint. Mechanical work during stance was then quantified by integrating the power-time curves. Resulting positive and negative work values at the ankle, knee, and hip were compared across conditions for each limb. Repeated measures ANOVA was used to test for differences in gait speed and mechanical work.

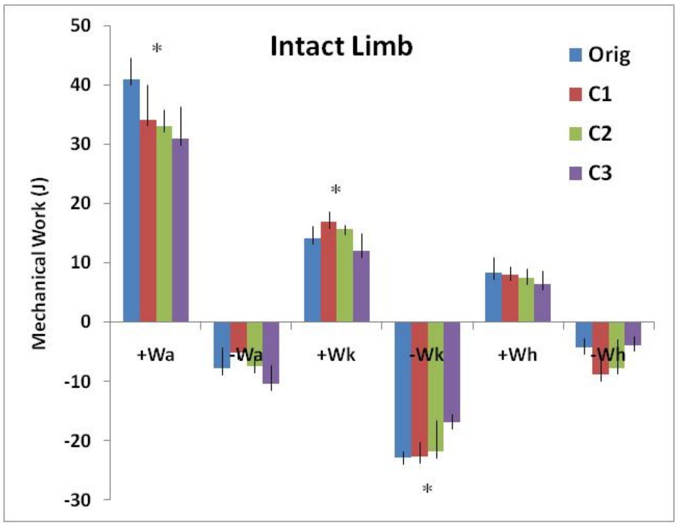
RESULTS AND DISCUSSION

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

Mean positive and negative mechanical work values at the ankle, knee, and hip joints during stance for each prosthetic foot condition are shown in Figure 1. Compared to group data presented by Silverman et al. (2008), the subject of the present study produced greater positive work at the ankle in both limbs, less positive work at the hip in both limbs, and similar levels of positive work at the knee. The negative work at the hip was drastically different between limbs, which was inconsistent with the results of Silverman et al. (2008). In the intact limb, the greatest amount of negative work was observed at the knee joint which is in agreement with Silverman and colleagues.



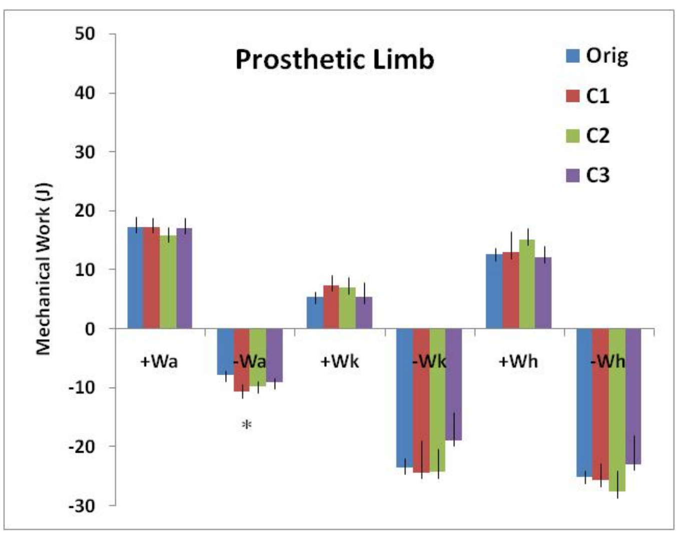


Figure 1: Mean positive and negative mechanical work at the ankle, knee, and hip of the intact limb (top) and prosthetic limb (bottom) for each foot condition. Statistical differences between conditions (*), but within each limb, are shown.

In the intact limb, statistical changes across foot conditions were limited to positive work at the ankle and knee and negative work at the knee. In the prosthetic limb, negative work at the ankle was the only measure that was statistically different across conditions (see Figure 1). Among these changes when comparing the two conditions that were similar in preferred walking speed (Orig & C1) but dissimilar in prosthesis type, the only statistical difference in mechanical work was the increase in negative work at the ankle in the prosthetic limb.

Overall, the gait strategy employed by the single subject of the present investigation relies on greater energy generation at the ankle and knee of the intact limb. In addition, greater energy generation and dissipation were found at the hip on the prosthetic side which is consistent with the results of Silverman et al. (2008). In general, this lower extremity mechanical energy pattern was not disrupted across foot conditions although some minor differences were noted.

CONCLUSIONS

An increase in negative mechanical work at the ankle on the prosthetic side was the only statistical difference between the original prosthetic foot condition and a novel, low stiffness foot condition (C1). Other changes in mechanical work were best explained by the decrease in preferred walking speed from initial to final conditions. Overall, when confronted with different prosthetic feet, more adaptations were made in the intact limb as compared to the prosthetic limb.

REFERENCES

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