THE EFFECT OF A NEW MICROPROCESSOR CONTROLLED PROSTHETIC KNEE ON OBSTACLE CROSSING IN PATIENTS WITH UNILATERAL TRANSFEMORAL AMPUTATION

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INTRODUCTION
Obstacles are commonly encountered during walking and therefore it is important for individuals with lower limb amputation to be able to safely and effectively negotiate over obstacles. Safe negotiation of an obstacle requires sufficient clearance of the swing foot over the obstacle to avoid tripping. Individuals without amputation accomplish this by increasing lower extremity joint flexion, with the greatest importance placed on knee joint flexion, during the swing phase [1]. However, individuals with transfemoral (above the knee) amputation (TFA) are unable to actively control the knee joint during obstacle clearance. This results in persons with TFA commonly adopting a circumduction strategy to cross the obstacle [2].

Recently a new microprocessor controlled prosthetic knee (X2, Ottobock, Duderstadt, Germany) was developed with the goal of allowing persons with transfemoral amputation to cross obstacles without requiring circumduction. The X2 knee uses variable flexion/extension resistance to allow the user to flex the knee during the swing phase, contact the ground with a knee that has been preflexed to 4° and load the limb without the knee collapsing [3].

The purpose of this study was to compare the kinematics of obstacle crossing in persons with unilateral TFA while using the X2 and a conventional microprocessor controlled knee. It was hypothesized that persons with TFA would have increased prosthetic knee flexion during swing when the prosthetic limb was both leading and trailing while using the X2 device.

METHODS
7 male young adults with unilateral TFA (30.1 ± 5.8 years, 1.78 ± 0.08 m, and 87.2 ± 11.6 kg) participated in the study. Participants were assessed: 1) wearing their clinically prescribed prosthetic knee (CONV), and 2) wearing the X2. The two visits were separated by approximately 12 weeks and identical biomechanical testing was conducted during each visit.

Participants were instrumented with 57 reflective markers. A 26 camera optoelectronic motion capture system (120 Hz; Motion Analysis, Santa Rosa, CA) was used to track full-body movement. Marker data was filtered with a low pass Butterworth filter (6 Hz).

Participants were asked to cross a 10 cm x 135 cm x 10cm (height x width x depth) wooden obstacle that was placed in the middle of the walkway. Participants were allowed to cross the obstacle at a self-selected pace and were asked to lead with both their prosthetic and intact limbs. For each lead limb condition a minimum of three good trials were collected.

2x2 repeated measures ANOVA’s were used to determine lead limb and device main effects (prosthetic lead and intact lead; CONV and X2) for both the leading and the trailing limbs. Estimated marginal means and a bonferroni correction were used to identify pairwise differences.

RESULTS AND DISCUSSION

Lead Limb (Fig. 1A): During obstacle clearance the intact limb knee was significantly more flexed than the prosthetic knee in both the X2 and CONV conditions (p < 0.001). Contrary to the hypothesis, peak prosthetic knee flexion during swing was not significantly different between devices (p = 0.136). While using the X2 device the knee was, however, more flexed than the CONV at initial contact after crossing the obstacle (p = 0.006). The approximately 4° increase was consistent with the design intentions of the device.
Figure 1: Kinematics of the leading limb (A) and trailing limb (B) knee during obstacle clearance while using both CONV (blue) and X2 (red) knees for both the intact (dashed) and prosthetic limb (solid).

Trail Limb (Fig. 1B): The intact limb knee was again significantly more flexed than the prosthetic knee in both the X2 and CONV conditions (p < 0.001). However, the X2 knee had approximately 40° greater peak knee flexion than the CONV device (p = 0.023; Table 1). Individuals primarily used a circumduction strategy with the CONV device and a knee and hip flexion strategy with the X2.

Additionally, the strategy difference resulted in significantly greater peak swing hip flexion while wearing the X2 compared to CONV (p = 0.019). As a result, the X2 peak trailing limb hip flexion values were not different between the prosthetic and intact limbs (p = 0.472).

Additionally, there was a trend (5 out of 7 participants) towards increased prosthetic knee flexion at initial contact after obstacle clearance when wearing the X2 compared to the CONV device. Increased prosthetic knee flexion at loading may suggest an increased user confidence that the device would support their body weight without collapsing.

CONCLUSIONS
A circumduction strategy is commonly used while crossing obstacles with a CONV device to ensure a fully extended knee at initial contact. While using the X2 participants were less likely to use a circumduction strategy, using greater hip and knee flexion when the device was the trailing limb. They also increased knee flexion at initial contact when leading with the X2 which may be indicative of greater confidence in the device.

Further study is underway to examine how increased knee and hip flexion while using the X2 affects toe clearance of the trailing prosthetic limb to aid in trip avoidance.

<table>
<thead>
<tr>
<th></th>
<th>CONV</th>
<th>X2</th>
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<tbody>
<tr>
<td>Lead Knee Flex - SW (deg)</td>
<td>59.9 (8.2)</td>
<td>64.2 (3.1)</td>
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<tr>
<td>Lead Knee Flex - IC (deg)</td>
<td>-0.3 (3.1)</td>
<td>3.6 (3.4)</td>
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<tr>
<td>Trail Knee Flex - SW (deg)</td>
<td>8.2 (5.1)</td>
<td>49.0 (37.2)</td>
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<tr>
<td>Trail Knee Flex - IC (deg)</td>
<td>0.2 (2.8)</td>
<td>8.0 (12.5)</td>
</tr>
<tr>
<td>Trail Hip Flex - SW (deg)</td>
<td>36.8 (5.1)</td>
<td>49.1 (11.5)</td>
</tr>
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Table 1: Mean (SD) peak kinematic values of interest for the prosthetic limb. (IC - Initial contact post obstacle clearance, SW – Swing)

REFERENCES

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