PRELIMINARY EVALUATION OF A MICROPROCESSOR CONTROLLED KNEE ANKLE PROSTHESIS (MKAP) FOR ABOVE KNEE AMPUTEES

"Dauriac, B.1,2, Bonnet, X. 2, Dijan, F.2, and Pillet, H. 1"
"Institut de Biomecanique Humaine Georges Charpak, Arts et métiers ParisTech 1, R&D Department, PROTEOR 2"

INTRODUCTION
Microprocessor-controlled prosthetic knees (MPK) have improved the safety and the functional outcomes of above knee amputees (Sawers & Hafner 2013). Knee flexion control during stance improved the walking ability both during stair (Schmalz et al. 2007) and slope descent (Burnfield et al. 2012). In spite of this knee control, patients continue to report some difficulties during outdoor activities (Samuelsson et al. 2012). Some of these difficulties could be attributed to the ankle lack of adaptations to different terrain (Vickers et al. 2008; Schmalz et al. 2007). The objective of the study was to evaluate a Microprocessor-controlled Knee Ankle Prosthesis (MKAP) able to mimic various adaptations quantified for asymptomatic people in slopes and stairs (Bonnet et al. 2014)

METHOD
Six above-knee amputees were fitted with the MKAP prototype. Motion was captured with a 54 marker set placed on the patient according to the protocol described by Pillet (Pillet et al. 2014). Acquisitions were made in 3 daily living situations simulated using instrumented devices: level ground, 12% (7°) inclined ramp and a 4-step staircase. From the marker set, kinetic and kinematic of 18 body segments were computed. A control group was formed with ten above knee amputees fitted with a conventional Microprocessor-controlled Prosthetic Knee and an Energy Storing And Return Foot. To evaluate the benefit of ankle joint control, several parameters were computed to compare MPK users and MKAP users such as the foot flat motion time (Dauriac et al. 2015)

RESULTS
Fig. 1 presents the sagittal kinematic of the hip, knee and ankle of the prosthetic limb during slope ascent and descent and stair descent for the ten MPK users (shaded area) and for the six MKAP users (solid lines). Compared to MPK, MKAP allows a wider range of motion of both the prosthetic knee (especially during stair descent) and prosthetic ankle both during stance and swing phase. MKAP users showed longer foot flat period compared to MPK users.

<table>
<thead>
<tr>
<th></th>
<th>Slope descent</th>
<th>Level</th>
<th>Slope ascent</th>
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<tbody>
<tr>
<td>MKAP group</td>
<td>20</td>
<td>19</td>
<td>14</td>
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<tr>
<td>MPK group</td>
<td>11</td>
<td>15</td>
<td>16</td>
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Table 1 - Slope and level walking foot-flat period in % of the gait cycle for the two presented groups

DISCUSSION
The limited range of ankle motion in conventional prosthetic feet does not allow amputees to keep the foot flat on the floor during ramp descent. Using the prototype, the reduction of “equivalent” stiffness allows restoring a large foot flat period during the unipodal stance phase on the prosthesis, securing this critical phase of gait. During slope ascent, the ankle dorsiflexion during swing helps the user to increase toe clearance reducing falling risk. During stair descent, the ankle range of motion during stance allows avoiding the placement of the prosthetic foot on the edge of the step conventionally used to perform the tibial forward movement. All these adaptations were felt by the user as a gain in comfort and stability in these situations.

CONCLUSION
This prototype allows several adaptations in different daily living situations by allowing a greater ankle range of motion and adaptation and by restoring the ankle-knee synergy. These adaptations have been quantified and demonstrate strategies closer to asymptomatic people than the MKP users.

CLINICAL APPLICATIONS
This prototype permits to adapt both ankle and knee behavior during gait cycle. Compared to MKP, it should enable users to walk with more comfort and stability during slopes or stairs locomotion.

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