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KINEMATIC ADJUSTMENTS OF TRANSFEMORAL AMPUTEE GAIT ON CROSS-SLOPES.

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INTRODUCTION

Mobility impaired persons like people with lower limb amputation must cope with numerous difficulties in their daily environment. Particularly, locomotion on cross-slopes is a common situation in urban environment which can be a barrier for safe locomotion. Among patients with transfemoral amputation (TF) cross-slope walking is described as limiting especially when the prosthetic limb is uphill.

No study in the literature already investigated gait adjustments of people with transfemoral amputation on cross-slopes. Thus, only the few existing studies interested in describing gait of asymptomatic subjects on cross-slopes [1,2,3] and recognized strategies of gait of people with transfemoral amputation on flat surface allow to understand their adjustments on cross-slopes.

Regarding the stance phase of gait, [1] showed that to adapt to cross-slopes (as a comparison to level walking) ten young healthy males modified the functional lengths of their lower limbs (the uphill limb was shortened and the downhill limb was lengthened) by altering ankle kinematics in the frontal plane. In fact, no adaptation of the pelvis inclination and no adaptation of the lower limb joints kinematics in the sagittal plane were observed between level and cross-slope walking. Adjustments were mainly made by the ankle in the frontal plane. Thus we assumed that transfemoral amputees would adapt to cross-slopes as asymptomatic subjects by altering during stance phase the prosthetic ankle angle in the frontal plane. We hypothesized that a limiting adaptation of prosthetic components in the frontal plane would explain transfemoral amputees' difficulties on cross-slopes.

Regarding the swing phase of gait, muscular loss and management of prosthetic knee flexion complicate toe clearance for transfemoral amputees, already during level walking [4,5]. Several strategies are used on flat surfaces to ensure toe clearance and avoid falling: vaulting of sound ankle (up on tiptoe during stance phase), increase of pelvis contralateral inclination to elevate residual hip or circumduction of residual hip [4,5]. Our hypothesis is that transfemoral amputees will use all the more these strategies to ensure prosthetic clearance when the prosthetic limb will be uphill on cross-slopes. This study aims at analyzing kinematic adjustments of transfemoral amputee gait when walking with uphill prosthetic limb compared to level walking.

METHODS

Sixteen transfemoral amputees and sixteen asymptomatic subjects were recruited to participate in the study. All subjects were wearing their own prosthesis.

Subjects were equipped with 54 markers to record the kinematics of the whole body with a motion analysis optoelectronic system (Vicon V8i, UK). First a static trial was performed in order to define a static reference position. Subjects were then asked to walk back and forth at a comfortable speed on a flat pathway and on a cross-slope inclined of 6° both instrumented with four force platforms (AMTI, 100Hz). Gait parameters such as gait speed, step width and length, percentage of the stance phase were calculated for the prosthetic limb during level walking and during cross-slope walking. Anatomical frames, segmental and articular kinematics of the lower limbs (ankle, knee, and hip), the pelvis and the trunk were also computed according to [6] for both conditions.

Particularly, to study kinematic adjustments during stance phase, peak of prosthetic ankle valgus (angle of the ankle in the frontal plane) between 0% and 60% of gait cycle was computed for level walking and when the prosthetic limb was uphill on the cross-slope. Strategies during prosthetic swing phase were estimated by computing sound ankle flexion angle at 30% of sound limb gait cycle (for the vaulting strategy), peak of pelvis contralateral inclination and peak of residual hip abduction (circumduction strategy), both between 60% and 100% of prosthetic limb gait cycle. The adjustments to cross-slopes were all computed as the difference between the values during cross-slope walking when the prosthetic limb was uphill minus the values during level walking.

RESULTS AND DISCUSSION

Firstly, the control group of asymptomatic people adjusted to cross-slope walking (uphill condition) by decreasing gait speed by 0.13m/s and increasing ankle valgus angle by 7°±3°. No alterations of kinematics in the sagittal plane were observed. These results were consistent with [1].

Transfemoral amputees also showed a decrease of gait speed. In addition when the prosthetic limb was uphill, valgus angle of prosthetic ankle increased by 5°±2° compared to level walking (Figure 1). As observed for asymptomatic subjects, no adjustments were measured in the sagittal plane of lower limb joints of the residual limb. Thus similar adjustments as control subjects were observed during stance phase of gait which did not appear to be limiting for patients who participated to the study.

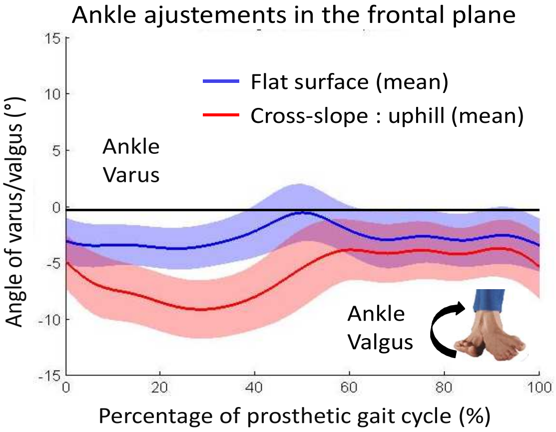

Figure 1: Ankle angle in the frontal plane on flat surface and on cross-slopes with prosthetic limb uphill among the group of patients (mean ± 1 std).

On the other hand, swing phase of the residual limb when uphill on cross-slopes showed several adjustments of gait compared to level walking. Table 1 summarizes obtained results for swing phase adjustments. Although seven of the recruited patients did not show any vaulting on flat surface, an increase of flexion angle of sound angle at 30% of sound limb gait cycle was observed for all amputees except for two of them (see Table 1). Among the patients eight also exhibited alteration of pelvis kinematics in the frontal plane. Indeed an increased peak of contralateral inclination of the pelvis during swing phase of residual limb was observed along with vaulting strategy in order to provide security for prosthetic clearance. Finally two patients showed increased residual hip abduction during swing phase which can be identified as circumduction strategy to ensure toe clearance on the top of the cross-slopes.

CONCLUSIONS

The aim of the study was to investigate the kinematic adjustments of transfemoral amputee gait on cross-slopes. As asymptomatic subjects, this population adapted to cross-slopes by altering ankle kinematics in the frontal plane. However results confirmed that walking on cross-slopes is a difficult task for transfemoral amputees. Toe clearance during swing phase appeared to be the main issue for adaptation to cross-slopes. Thus, compensatory strategies are developed by patients to ensure no falling. This study highlighted the need to better understand gait of amputee people in limiting situations to develop new prosthetic components or/and rehabilitation protocols to reduce those compensatory strategies that could entail pathologies.

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Table 1: Kinematic variations during swing phase of prosthetic limb between level walking and cross-slope walking (prosthetic limb uphill).

Patients	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Mean (Std)
Vaulting Adjustment : Variation of peak of plantiflexion angle of sound foot (°)	4*	4	5	0*	1	3	9	5	4*	5	9	15*	4*	11*	2*	7*	6 (4)
Pelvis Adjustment : Variation of peak of pelvis contralateral inclination (°)	2	2	2	2	4	-3	1	6	0	2	4	0	4	0	0	2	2 (2)
Circumduction Adjustment : Variation of peak of residual hip abduction (°)	3	2	2	4	18	3	2	7	2	2	8	11	3	3	2	1	5 (4)

* Patients using vaulting strategy already on flat surface (planti-flexion of sound ankle at 30% of gait cycle was positive).