COMPENSATION-STRATEGIES IN UNILATERAL TRANSFEMORAL AMPUTEE WALKING

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INTRODUCTION

Primary goal of prosthetic devices is to mimic the function of biological systems. In recent years, a number of computerized leg prostheses were developed to improve the locomotor function of amputees. However, researchers and prosthetic designers are especially challenged when trying to help amputees walk naturally. Here, we aim to understand to what extent different state-of-the-art knee prostheses can replace the function of a healthy leg. We expect that deficits in the prosthetic leg will lead to speed-dependent compensatory gait strategies with asymmetries in kinematics and kinetics between both legs.

METHODS

Five individuals (1F, 4M, 24-61 yrs) with unilateral transfemoral amputations participated in the study. We analyzed walking kinematics and kinetics wearing three different hydraulic knee joints (C-Leg and 3R80; Otto Bock Health Care GmbH, Germany; and Ultimate Knee, Ortho Europe) on an instrumented treadmill (type ADAL-WR, HEF Tecmachine, Andrezieux Boutheon, France) at different speeds (0.5, 0.8, 1.1, 1.4 m/s). The C-Walk prosthetic foot (Otto Bock) was employed in all trials. Additionally, data from one nondisabled control subject (F, 24 yrs) were collected and used as reference.

Ground reaction forces (Kistler, Winterthur, Switzerland) and kinematic data (Qualisys, Gothenburg, Sweden) were collected at a sampling frequency of 240 Hz.

RESULTS AND DISKUSSION

With all three prosthetic knee joints similar but substantial deviations in leg function are observed.

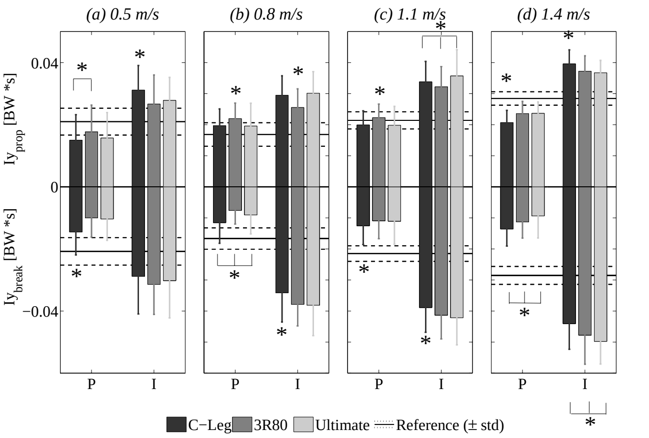

Figure 1: Horizontal breaking and propulsive impulse for the prosthetic (P) and the intact limb (I) compared for the three knee joints at 0.5, 0.8, 1.1 and 1.4 m/s. Significant differences ($p < 0.05$) differences between the prosthetic knee joints are indicated by *.

Part of the reduced functionality of the prosthetic leg is expressed in shorter contact times. As the prostheses do not provide proprioception or motor control, the prolonged contact phase of the intact leg enhances better control. Especially, the load transfer from intact to prosthetic leg seems to be critical, which is shown in prolonged double support times and the delayed force build-up in early contact on prosthetic leg.

According to Michael [1], the observed missing knee flexion during contact with the prosthetic leg can be explained as a compensatory mechanism due to the loss of knee extensor muscles and the disability of the prostheses to generate positive work.

Additionally, we found higher horizontal propulsive impulses compared to the breaking impulses with the prosthetic leg (Figure 1). The surprising acceleration by the prosthetic leg could be explained by the dynamic interaction of both legs (Figure 2).

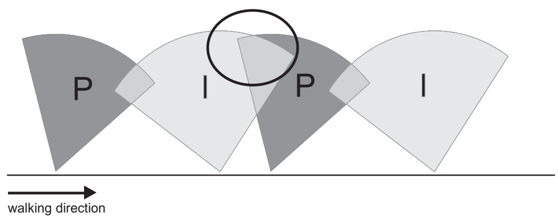

Figure 2: Contact scheme of prosthetic gait: Although contact times for the prosthetic leg (P) are shortened compared to the intact leg (I), the prosthetic leg accelerates the body in horizontal direction, whereas the intact leg decelerates the body in anterior-posterior direction (Figure 1).

The intact leg might actively lift the center of mass in preparation of the contact of the prosthetic leg. In the following step, this high potential energy is transformed into horizontal kinetic energy without active energy supply through the prosthesis. As a consequence, the net forward acceleration found at the prosthetic leg is a consequence of the asymmetry between both legs.

CONCLUSION

The observed gait strategies may help to improve the understanding of underlying mechanisms of both healthy and pathological gait.

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