INFLUENCE OF AN INTEGRATED MPC KNEE-ANKLE SYSTEM ON TRANSFEMORAL GAIT

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INTRODUCTION

Microprocessor controlled (MPC) knees and feet have been in the market for some time and have shown some benefits (Buckley et al. 1997, Portnoy et al., 2012). A next step in the evolution of artificial limbs might be the integration of knee and foot under a single controller following the biological role model of inter-joint coordination.

This is a true integrated lower limb prosthesis, where the knee joints functions interacts with ankle-foot functions. The aim of the integrated MPC knee-ankle system is to further reduce the compensation efforts amputees make in dealing with ADL.

METHOD

The aim of the study was to correlate the relationship between damping at the knee and the foot, based on the hypothesis that the ankle influences the bending moment used to control knee stability and thus control to fully optimize limb function for situations like ramp walking there needs to be reciprocated knee and ankle joint control resistance changes in both the foot and the knee joints. Data from activities such as standing and the impact on damping characteristics are collected as well.

Lower limb kinematics and kinetics of 4 unilateral transfemoral amputees were studied using onboard sensors of the integrated control system for outdoor and 3D motion analysis for indoor.

The integrated control system consists of an MPC hydraulic ankle-foot and a hybrid MPC knee joint with hydraulic stance and pneumatic swing control combined under a single controller.

The test protocol comprised walking up and down an incline of 5° at normal self-selected speed, comparing control 2 control methods; 1 integrated knee-ankle joint control and 2 independent and separate knee-ankle control. Post-processing of the raw data was done with Matlab using a 5th order low-pass Butterworth filter.

RESULTS & DISCUSSION

The measurement showed that damping resistance changes in the foot change the resulting range of movement of the hydraulic ankle and have an influence on the ankle bending moment thus validating part of our hypothesis. The resulting range of movement of the hydraulic ankle is changed by the adaptive control setting allowing the hydraulics to absorb more or less energy generated due to inertia which affects the loading of the composite springs. Therefore the overall in series spring-dashpot system behaviour can be perceived as a “virtual spring”. The adaption of the bending moment influences the loading response during stance which directly affects the pressure of the stump-socket interface.

When comparing the two control methods in some instances where joint control was separated it was shown that the magnitude of change to ankle moment used for knee control had a detrimental effect on function, thus the requirement for reciprocated control and the second part of our hypothesis was shown to be valid.

CONCLUSION

Our study shows there is a clear need for the knee to know what the ankle is doing and then based on that to adapt its control strategy. Further work is required to establish other areas of ADL where integrated and reciprocated inter joint control may be advantageous over the separated control of individual joints.

There is a first indication of reduced compensatory activities by amputees using integrated prosthesis.

Further research is also needed to investigate inter-limb coordination and to characterise the underlying biomechanics in more detail with a view to understanding in more detail the mechanism of control which enable further reduction in amputee compensation.

CLINICAL APPLICATIONS

The study has shown indications of benefit when using an integrated MPC knee-ankle system compared to a separate MPC knee and MPC foot system.

REFERENCES

1. Portnoy S, et al. *Gait & Posture*; 35(1), 121-125, 2012
2. Buckley JG, et al. *Arch Phys Rehabil*, 78,330-333,1997