CONTROL OF THE RESIDUUM IN THE PROSTHESIS EXPLAINS LOCOMOTOR DIFFERENCES BETWEEN INDIVIDUALS WITH AND WITHOUT AMPUTATION

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INTRODUCTION

Motor control of any movement task involves the integration of neural, muscular and skeletal systems. This integration must occur throughout the motor system and focus its efforts on controlling the system endpoint, e.g. the foot during locomotion. A person with a uni-lateral trans-tibial amputation (TTA) has lost the foot/ankle complex and muscles crossing those joints, hence the residuum becomes the new motor system endpoint. The amputee must now adjust to the challenges of utilizing a compromised motor system to control an external device, i.e. prosthesis, through a mechanical interface, i.e. prosthetic socket.

In this project we studied the relationship between control of the prosthetic interface and control of a locomotor task (cycling). This includes methods designed to measure the movement of the residuum within the prosthesis during locomotion while measuring muscle activity and joint kinetics. These measurements have not been reported previously in the literature and this knowledge would provide a deeper understanding of how the human motor system has adjusted to the amputation. This knowledge may then drive advancements in more “dynamic” sockets enabling better integration between the revised motor system and the prosthesis.

METHOD

Subjects: A group of nine TTA (34.1 ± 8.7 yrs, 1.83 ± 0.08 m, 83.8 ± 14.9 kg) and a group of nine intact subjects (34.7 ± 8.8 yrs, 1.82 ± 0.05 m, 82.4 ± 11.7 kg) volunteered for the IRB approved study.

Procedures: The subjects pedaled at a constant torque of 15Nm and a constant cadence of 90 rpm (~150 watts). Pedaling kinetics and limb kinematics were used to calculate joint moments via inverse dynamics (Broker & Gregor, 1994). Reflective markers on the prosthetic foot and the thigh segment were used to calculate angular movement of the residuum within the prosthesis (Childers et al., 2010). The resi- dum/prosthesis pseudo joint (RPP) is located between the distal portion of the residuum and the prosthesis. Surface electromyography was used to describe the timing of muscle output.

Analysis: The dominant limb in the Intact group (DOM-INT) was compared to the sound (SND-TTA) and amputated (AMP-TTA) limbs in the TTA group. Variables were compared using a one-way ANOVA with a Tukey post-hoc.

RESULTS

Joint moments demonstrated differences between limbs (Figure 1). Angular movement between the residuum and the prosthesis was 4.8 ± 1.8º. Muscle onset, peak and offset in the rectus femoris and the gastrocnemius of the AMP-TTA limb demonstrated significant shifts toward later in the crank cycle compared to both SND-TTA and DOM-INT limbs.

DISCUSSION

The differences noted in the AMP-TTA limb are related to control of the interface between the residuum and the prosthesis. This control should be viewed in the context of tool use in that resi- dum is the end-effector of the motor system and the prosthesis is the tool to extend that end-effector to the environment, i.e. the bicycle.

CONCLUSION

Understanding locomotor behaviour of TTA as tool use explains that the differences between intact and TTA are related to “motor adjustments” made by the nervous system to control the limb/prosthesis interface. Clinical goals in rehabilitation currently focus on minimizing gait deviations whereas these results suggest those “deviations” are motor adjustments necessary to control a tool, i.e. prosthesis. Examining amputee locomotion in the context of tool use shifts the clinical paradigm to improving function of the limb/prosthesis system and lays the foundation for the development of advanced prosthetic sockets.

REFERENCES