INTRODUCTION

The locomotor strategy used by individuals with a unilateral transtibial amputation (TTA) will depend on the ability of each limb to generate and effectively direct forces between the limb endpoint and the environment. However, because locomotion involves the coordination of two limbs, the sound limb can compensate for the amputated limb. In this scenario, the central nervous system can coordinate the joints of both limbs (local strategies) such that the total (or global) strategy for movement is similar to an individual with intact limbs. Therefore, it becomes important to understand if these global strategies are maintained in TTA and intact individuals.

Cycling requires effective integration of human neuromuscular control and bicycle systems providing a task to study movement strategies. The cyclist must coordinate output of the lower limbs and utilize a pedaling technique suitable for task performance. The force effectiveness ratio (FE) has historically been used to quantify pedaling technique (LaFortune and Cavanagh, 1983) and provides a window into the global control strategy of the individual.

The purpose of this study was to investigate the pedaling technique employed by transtibial amputees during a cycling task to establish a foundation for future research in motor control as well as potential improvement in prosthetic design.

METHOD

Subjects: A control group of nine intact cyclists (30.4 ± 13.4 yrs, 1.81 ± 0.06 m, 74.0 ± 6.6 kg) and eight TTA subjects (36.4 ± 10.4 yrs, 1.75 ± 0.07 m, 78.7 ± 10.8 kg) volunteered for the IRB approved study.

Procedures: The subjects pedaled a stationary bicycle fitted with dual piezoelectric element force pedals during a simulated time trial. The force pedal system recorded pedal position, crank position, and applied loads in the normal and shear directions on each pedal. The mechanical properties of the subject’s prosthesis were modified by adapting either an inflexible aluminium foot (AL) or a flexible dynamic response prosthetic foot (DR). The total effectiveness of force production at the pedal was used as the measure of task performance. The FE ratio was calculated by dividing the component of force orthogonal to the crank by resultant force at the pedal.

Analysis: The force effectiveness ratio was calculated in this study as the total effectiveness of both limbs combined and was interpreted as the overall quality of the cyclist’s pedaling stroke. The simulated time trial allowed our subjects to cycle at different power output and cadences. Because group means for our data could be affected by the different power outputs and cadences chosen by our subjects a formula was produced to correct our measured total force effectiveness based on data presented by Patterson and Moreno (1990).

Total force effectiveness ratios were compared using a one-way ANOVA with a Tukey post-hoc testing statistical significance between groups.

RESULTS

FE ratios were 0.36 ± 0.07, 0.36 ± 0.09, and 0.45 ± 0.09 for the TTA-AL foot, the TTA-DR foot, and the control group respectively and showed no significant differences. FE ratios corrected for load and cadence were 0.39 ± 0.06, 0.39 ± 0.06, and 0.41 ± 0.05 for the TTA-AL foot, the TTA-DR foot, and the control group respectively and showed no significant differences.

DISCUSSION

The global control strategy employed is not affected by an altered musculoskeletal system nor by the mechanical properties of the prosthesis.

CONCLUSION

These data suggest individuals with lower limb loss are able to compensate for their altered musculoskeletal system to utilize a similar pedaling technique for locomotor performance. As global strategies e.g. force effectiveness, appear similar between groups future research should focus on local strategies, e.g. individual joint kinematics and kinetics. Research involving local strategies and their relationship to net output of the human/prosthesis system will enhance our understanding of this system while allowing for better clinical application of the research.

REFERENCES

LaFortune, M.A. & Cavanagh, P.R. Biomechanics VIII-B 928-936, 1983.