INTRODUCTION

Given that discomfort and injury are major complaints of amputees, it is important to minimize the forces (transverse and otherwise) arising from the prosthetic socket acting on the residual limb. While several Transverse Rotation Adaptors (TRAs) are available to reduce tissue loading in the transverse plane, little objective data exists documenting the effects of these devices. Two studies explored lower limb prosthesis rotation during straight-ahead walking (Lamoureux and Radcliffe 1977; Van der Linden, Twiste, et al. 2002). However, except for manufacturers’ claims, there are no published reports on the influence of TRAs during more complex gait activities. Additionally, without again depending on the manufacturers’ literature, there is no way to ascertain the differences between TRAs or between different setups on the same TRA.

METHODS

Three subjects with no gait pathologies consented to this IRB approved study. Each subject performed five trials walking straight and turning right around a 1m-radius circle at their self-selected speeds. Thirty-six reflective markers were placed on each subject according to the Plug In Gait model (Oxford Metrics). A ten-camera Vicon 612 system recorded the 3D coordinates of the markers. A Kistler force plate (Winterthur, CH) mounted flush with the laboratory floor recorded kinetic data. Torque is reported as moments generated by the subjects to counter environmental moments. The data include two conditions: right footstrikes during straight walking, and right turns on the right (inside) foot. The data were analyzed with Vicon’s Workstation and Polygon software.

Five TRAs (Endolite TT and Demountable adaptors, Otto Bock Delta Twist and 4R39, and the Century XXII Total Shock) were purchased and tested in a servo-hydraulic material testing system (MTS, MTS System Corporation). Each elastomer for each TRA was tested over the full rotational range at 0.5 °/s, and 60 °/s. For all tests, the MTS rotated under displacement control from center to one end, back through the full range, then back to the center.

RESULTS AND DISCUSSION

The physiological torque vs. displacement curves were highly asymmetrical (figure 1). The greatest torques were applied during stance in the direction of internal rotation. The general pattern is external rotation under small external torque post heel-strike to mid-stance. At mid-stance, the foot is relatively immobile in the transverse plane but the torque reaches its maximum internal value. From mid-stance to toe-off, the torque declines, again with minimum angular displacement. During the swing phase, the foot rotates internally back to its neutral position under no torque. The
notable exception to this pattern is the inside-right foot during right turns (red dashed line, fig. 1). In this condition, the foot angle changes at a more constant rate over the whole gait cycle.

The main difference between human performance and TRA mechanical performance lies in the asymmetry of the physiological data. While walking straight-ahead and turning, nearly all of the rotation occurs externally relative to the angle at heel strike (figure 1). Also, internal torque is 6.6 times greater than external torque for the (inside) right leg during right turns. During straight-ahead walking, this asymmetry persists, with internal torque 2.2 times higher than external torque (figure 1). Despite this asymmetry, all the adaptors tested were capable of encompassing the maximum physiological torques.

All the adaptors tested have equal rotation, both internal and external, relative to their resting position (where the device would be at heel-strike). Given this, the necessary full range for the maneuvers tested in this study would be 52° (twice the maximum external rotation of 26°). If matching the physiological range of rotation is the critical performance measure, then only the Endolite adaptors in this study meet the needs indicated.

SUMMARY

These data allow the prosthetist to interpret qualitative issues raised by the amputee and direct him/her to the correct rotation adaptor and/or elastomer setup. The data from this study will also be useful in modeling a controllable TRA that can respond appropriately to minimize transverse tissue loading as the amputee maneuvers in the environment.

REFERENCES


ACKNOWLEDGEMENTS

This study was funded by the Department of Veterans Affairs project # A2661C