INTRODUCTION

Excessive movement between the residual limb and the prosthetic socket (pistoning) has been correlated with a decrease in prosthetic user comfort (Newton et al., 1988). In addition, traditional kinematic models used to calculate joint moments do not take into account this movement and that could affect the validity of laboratory data. Thus, measurement of pistoning becomes important for clinical outcomes as well as studies in the biomechanics of prosthetic users.

Methods used to evaluate pistoning have been traditionally limited to a radiographic approach. These methods expose the subject to radiation and cannot be used during ambulation. Saunders et al. (2006) presented a non-contact sensor that measured movement about the vertical axis during ambulation. Their results suggest measurement systems should measure about multiple axes to improve accuracy.

The purpose of this research was 1) to develop a system to measure pistoning in sagittal plane (2-D), 2) test this system during a dynamic task (cycling), 3) determine the effect of pistoning in the calculation of joint moments, 4) determine the effect of prosthetic suspension.

METHOD

Two subjects with uni-lateral transtibial amputation secondary to trauma (31 +/- 11 yrs, 82 +/- 15 kg) volunteered to participate in the study. Each subject provided separate written consent with IRB approval.

Subjects pedaled on a stationary electromagnetically braked ergometer at 150 watts and 90 rpm and adjusted to their preferred position. Pistoning was measured using a custom made limb/socket measurement device (LSM). This device consisted of an aluminium frame attached to the lateral side of the prosthetic socket. Two linear potentiometers were attached to the frame and aligned with the longitudinal and orthogonal axes of the prosthesis. The subject wore a small metal bracket adhered to the skin over the distal tibia that protruded through a slit cut into a prosthetic liner. The opposite ends of the linear potentiometers were connected to the bracket. Pistoning of the residual limb was calculated via the intersection of two radii. The system was calibrated using an X-Y coordinate table and produced an accuracy and repeatability of +/- 0.2mm.

Two prosthetic suspension systems tested consisting of a mechanical pin/lock system and a cuff strap system. These suspension systems were selected because each held the distal and proximal ends of the residual limb separately.

A two-tailed paired T-test was used to determine statistical significance between suspension methods.

RESULTS

The pin suspension produced less displacement in the superior/inferior direction (Table 1). Suspension type had no effect on the magnitude of displacement in the anterior/posterior direction.

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<th>Ant./Post. Movement (mm)</th>
<th>Sup./Inf. Movement (mm)</th>
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<tbody>
<tr>
<td>Pin Suspension</td>
<td>4.3 ± 0.7</td>
<td>2.0 ± 0.6</td>
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<tr>
<td>Cuff suspension</td>
<td>4.2 ± 1.9</td>
<td>4.4 ± 3.1</td>
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Table 1. Displacement of the distal portion of the residual limb relative to the prosthetic socket.

DISCUSSION

A pin suspension showed a trend toward reduced pistoning yet this was not statistically significant due to the small sample size.

CONCLUSION

The LSM device could measure limb pistoning with high resolution in two dimensions and produced consistent results during a dynamic task. The device could measure differences between two different prosthetic suspension systems but these differences were very small. The relatively small amount of movement measured during cycling is within the typical error allowed for motion capture systems thus would not increase error associated with joint moment calculation. Future research should address movement of the knee center within the prosthetic socket and use the LSM to measure pistoning during gait.

REFERENCES