PROSTHETIC KNEE JOINT CENTER OF ROTATION ERROR IN GAIT ANALYSIS

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INTRODUCTION

Data generated from gait analysis is an important tool in a number of research and clinical endeavours, particularly as it pertains to prosthetics. Like human knees, polycentric prosthetic knees have a center of rotation that moves throughout flexion and extension[1]. There is therefore a resulting risk in placing too much faith in data derived from these estimated joint centers. Small differences between estimated and actual knee joint centers (KJC) may propagate through the calculations and derivations of forces, as well as joint powers and moments. In addition, variations in prosthetic design influence knee joint center placement, and likely result in different degrees of variation between estimated and actual KJC. For example, a single-axis knee has been shown to transition to a flexion moment more quickly than a polycentric knee during swing phase[2]. The purpose of this study was to quantify the difference between a single chosen estimated knee center marker and the instantaneous center of rotation throughout flexion and extension for a variety of models of prosthetic knee.

METHOD

Seven prosthetic knees from a number of manufacturers and with multiple mechanisms were tested. The estimated center of the knee was a single marker placed at a location on the knee component that would be used during a typical gait analysis. The actual instantaneous KJC is defined as the point of intersection of lines defined by 2 markers each on pylons distal to (shank) and proximal to (thigh) the knee component. The two markers on the thigh and the two markers on the shank were placed so as to be collinear at full extension. Markers were tracked using seven infrared Vicon cameras as the knees were moved manually through their full range of motion. Angle position, instantaneous KJC and the resultant 3-D difference in estimated and calculated KJC were determined using MATLAB™.

RESULTS

Errors were present with every knee model (Figure 1). The single marker was closest to the actual KJC between 60 and 120 degrees of flexion, and several asymptotic errors were present at end-ranges of motion. Even the single axis knee showed multiple-centimeter errors (Table 1) since the prosthetic knee joint was offset from the intersection of the segments.

DISCUSSION

The errors found in this study were alarming, given the importance in the knee joint angle calculated from standard gait analysis. The angles at which the errors were minimized are amounts of flexion beyond those encountered in walking, increasing the concern.

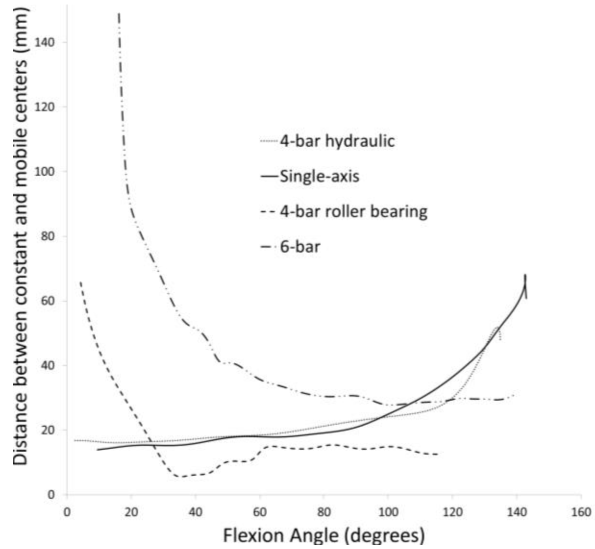

Figure 1. Difference between calculated and estimated knee joint center across the range of motion for four types of prosthetic knee.

	Peak Difference (cm)	Angle of peak difference (deg)
Single Axis	6.8	143
4-bar roller	65.7	4
4-bar hydraulic	5.1	134
6-bar	14.8	16

Table 1. Maximum difference between estimated and calculated knee joint center for four representative knees, and the angle at which it occured.

CONCLUSION

These results indicate that extreme caution should be taken when applying a shared-marker model in gait analysis involving a prosthetic knee. Future research should address improved means to measure the KJC in gait.

CLINICAL APPLICATIONS

Interpretation of data for gait involving a prosthetic knee should consider the potential for error in knee joint placement.

REFERENCES

1. Greene, Orthot Prosthet. 37, 15-27, 1983
2. Miller and Childress, Robotica. 23, 329-335, 2005.

American Academy of Orthotists & Prosthetists
41st Academy Annual Meeting & Scientific Symposium
February 18 - 21, 2015