In Vivo Determination of Joint and Muscle Forces During Gait and Deep Knee Flexion From Fluoroscopy

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INTRODUCTION:

Understanding the forces across the human lower extremity joint is of considerable interest to the clinician. In the past, telemetric hip implants have been used to determine the forces across the hip joint, but the forces at the knee joint remain unvalidated. Recently, video fluoroscopy has been utilized to accurately determine the in vivo kinematics of human joints during various activities (Dennis, et al., 1996). The objective of this study was to predict muscle and joint forces from a mathematical model utilizing fluoroscopy as the input motion data.

METHODS:

Initially, two subjects (one with a total knee and a second with a total hip arthroplasty) were asked to perform normal gait and a deep knee bend while under fluoroscopic surveillance. A fully automated computer model-fitting algorithm was employed to convert the two dimensional (2D) fluoroscopic videos to 3D, and the in vivo motion of the implanted joint was determined. The kinematic data then served as input to a mathematical model in which the relative motions of the segments and the interaction forces between the foot and the ground were also treated as input data (Figure 1). The predicted forces for the implanted joint, quadriceps muscles and patellar ligament were plotted with respect to time, percent gait cycle and knee flexion angle.

RESULTS:

The resultant force at the implanted knee joint ranged from 2.0 to 3.5 times body weight (BW) during gait, depending on walking speed and walking motion (Figure 2). A forward leaning pattern resulted in significantly higher knee joint forces. During a deep knee bend, the knee joint forces could rise as high as 3.5 BW. The resultant forces at the implanted hip joint ranged from 2.0 to 4.0 BW, depending on the activity (greater during deep knee bend), walking speed, walking motion and the incidence of hip separation. The patellofemoral forces were minimal during walking (<0.5 BW), but increased significantly with greater knee flexion to a maximum of 3.5 BW (Figure 3). The quadriceps muscle and patellar ligament forces were similar during gait (1.0 BW), but the quadriceps force was 40% greater in deep knee flexion (Figure 4).
DISCUSSION:

The present study has determined that the predicted hip joint forces are similar to telemetrically derived joint forces at the hip joint (Bergmann, et al., 1993, 1997). Both knee, hip and muscle forces were greater in deep flexion compared to gait. A sensitivity analysis determined that the model is extremely sensitive to patellar ligament and patella motion. Altering the kinematics of the patella and patellar ligament could increase the knee joint forces by 1.0 BW.

References:


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