INTRODUCTION

Acetabular labral tears are a recently recognized source of anterior hip pain (AHP). Excessive forces have been implicated as one cause of these tears. A clinical sign of a tear is AHP with prone hip extension. We propose that the pain is due, in part, to excessive force on the anterior structures of the hip resulting from altered movement and muscle recruitment patterns. In support of this theory, if manual pressure is applied to the proximal femur and maintained in a posterior direction during active hip extension, thus countering the excessive force, the pain is reduced.

The purpose of this study is to use a 3D static musculoskeletal model to estimate the hip joint reaction forces when muscle recruitment is altered while maintaining the leg in the prone hip extended position. We hypothesize that recruitment of muscles which originate close to the axis of rotation yet insert farther from the axis will result in higher joint reaction forces when compared to recruitment of muscles which both originate and insert close to the axis of rotation.

METHODS

A six degree of freedom, 3D musculoskeletal model of a lower leg was developed to calculate joint reaction forces in the hip, knee, and ankle. Musculoskeletal parameters were adapted from Delp 1990. Kane’s Method (Kane and Levinson, 1985) and AUTOLEV 3.1 (OnLine Dynamics, Inc., Sunnyvale, CA) were used to generate the dynamic equations of motion. The general form of the dynamic equations of motion is:

$$M(q)\ddot{q} = T(q, \dot{q}) + V(q, \dot{q}) + G(q) + E(q, \dot{q})$$

where $M$ is the mass matrix, $T$ is the net joint torques contributed by the force in the muscles spanning all joints, $P$ is the torques developed passively in the joints due to viscoelastic damping and passive joint structures, and $V$, $G$, and $E$ are the instantaneous segmental torques caused by the inertial, gravitational, and external forces, respectively. As we were most interested in reaction forces when holding in prone the hip in a static extended, position, the only non-zero torques in the model were those due to muscles ($T$) and gravity ($G$).

Hip position was varied from 0 to 15 degrees of hip extension in one degree increments with the knee extended for all iterations. For each iteration, a pseudoinverse optimization routine was used to solve for the optimal set of muscle forces (Yamaguchi et. al. 1995) needed to hold the leg the desired position. Once the optimized muscle stresses were solved simultaneously across all joints, the model calculated the resulting 3D reaction forces in the hip.

In order to estimate the reaction forces in the hip with different contributions from the gluteal muscles, we simulated four different conditions. In the first condition, the reaction forces were estimated without any restrictions on the system. In the second,
third and fourth conditions, the strength of the gluteal muscles (gluteus maximus, medius, and minimus) was reduced to 50%, 25%, and 5% of normal respectively to replicate weakness or decreased recruitment, and the reaction forces were recalculated.

RESULTS AND DISCUSSION

Failure to appropriately recruit the gluteal muscles which both originate and insert close to the hip axis of rotation, resulted in higher joint reaction forces in both the anterior and superior directions while in prone maintaining the hip in 0 to 15 degrees of extension. When the gluteals muscles were not fully recruited, the semimebranosis was recruited more to develop the appropriate hip extension moment. The utilization of the hamstring muscles, which originate close to the hip joint on the ischium and inserts distally on the tibia and fibula, results in increased muscle contraction to make up for the lost hip moment output of the gluteal muscles. These increased muscle contractions, in turn, result in increased joint reaction forces. Furthermore, as the hip extends, the line of action of the hamstrings changes more quickly due to its distant attachment.

The anteriorly directed joint reaction forces are of particular importance. These forces are thought to result in anteriorly located tears, which are most frequent. Because the acetabulum is rotated 30° anteriorly in the frontal plane, these anteriorly directed forces must be absorbed primarily by the labrum itself, and not the boney acetabulum.

SUMMARY

A 3D musculoskeletal model was modified to estimate joint reaction forces in the hip when performing hip extension in prone with varying contributions from the gluteal muscles. When the gluteal muscles were at full strength (100%), the anterior and superior joint reaction forces were lower than in any simulation with reduced gluteal strength or recruitment. Failure to appropriately maintain strength and recruit the gluteal muscles while performing prone hip extension may result in AHP due to increased joint reaction forces.

REFERENCES