

THE ANTERIOR-POSTERIOR THICKNESS VARIATION OF FEMORAL CARTILAGE IN THE TIBIOFEMORAL JOINT IS INFLUENCED BY THE KNEE FLEXION ANGLES DURING WALKING

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INTRODUCTION

Knee articular cartilage sustains high loading during common activities such as walking. Cartilage morphology has been reported to be regulated by mechanical loading conditions (Kiviranta, 1988, Smith, 2004), suggesting that the joint loading conditions during normal activities can affect knee articular cartilage morphology. While it has been suggested that loading during activities such as walking influence the medial-lateral variations in cartilage thickness (Andriacchi, 2004, Koo, 2007), the factors that affect anterior-posterior (AP) variations in cartilage thickness are still not well understood. However, the mechanics of walking offer the opportunity to test the relationship between gait mechanics and AP variations in cartilage thickness since the femoral contact regions during the stance phase of walking can largely be predicted by the knee flexion angle. The purpose of this study was to test if the AP spatial cartilage thickness distributions in the medial and lateral condyles of the distal femur were influenced by the knee flexion angle during walking.

METHODS

Gait data and knee MR images were obtained for seventeen healthy subjects (age 33.2 ± 9.8 years, 10 males, 7 females, BMI 23.0 ± 2.4 kg/m², no previous knee injuries) after IRB approval and informed consent were obtained. In this study, only the data from the left knee of the subjects were processed. The knee flexion angle at heel

strike and the average knee flexion angle during the stance phase of normal walking were measured using the previously describe six marker link system. Three-dimensional models of the distal femoral cartilage were created from the knee MR images using custom software (Koo, 2005) (Figure 1 left).

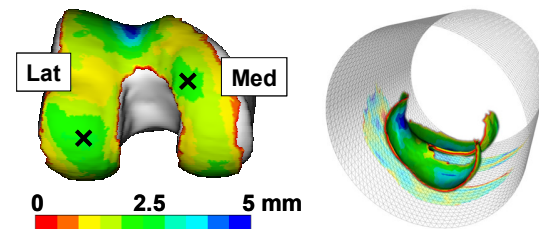


Figure 1: The locations of the centroids of the thickest cartilage in the medial and lateral condyles (left); Creating a two-dimensional cartilage thickness map by projecting a three-dimensional map onto a cylindrical surface (right).

To identify the locations (centroids) of the thickest cartilage on the condyles of the distal femur (Figure 1 left), two dimensional thickness maps were generated by projecting the three-dimensional models onto a cylindrical surface (Figure 1 right). These centroids, determined through the use of a Gaussian optimization algorithm over the regions of interest, were used to determine a sagittal plane angle relative to the femoral axis to locate the AP position of the centroid of thickest cartilage (Figure 2). The associations between the angular AP location of the centroids in the medial and lateral condyles and the knee flexion angles

(at heel strike and average over stance phase) during walking were tested.

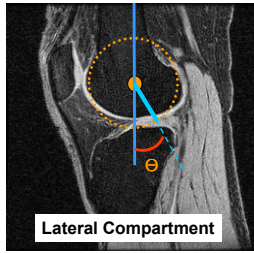


Figure 2: The angle between the femoral axis and the location of the centroid of the thickest cartilage

RESULTS

The angular AP location of the medial femoral cartilage centroid was correlated with the knee flexion angle at heel strike ($R^2=0.41$, $P<0.01$) (Figure 3) and the average knee flexion angle during the stance phase of walking ($R^2=0.34$, $p=0.01$). No correlation was found on the lateral side. The subjects with more hyper-extended knee positions at heel strike had the thickest cartilage in the more anterior part of the medial femoral cartilage.

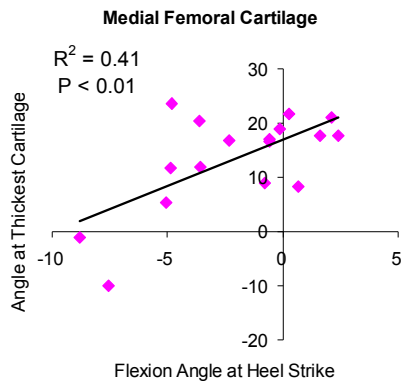


Figure 3: The angle of the thickest cartilage in the medial femoral cartilage and the knee flexion angle at heel strike

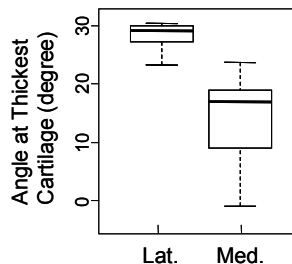


Figure 4: Distribution of the angle of the thickest cartilage in the medial and lateral femoral cartilage

The centroids of the thickest cartilage in the lateral femoral condyles had smaller variations (Standard deviation 5.3° vs. 8.9°) and were located in more posterior regions (median location 29.1° vs. 16.9°) than the medial femoral cartilage (Figure 4).

DISCUSSION

The results showed that the angular AP position of the thickest femoral cartilage morphology in the tibiofemoral joint was influenced by the knee flexion angle during walking only in the medial compartment. The tibiofemoral contact surfaces in the medial compartment are more conforming (convex-concave), so the contact location is sensitive to small differences in knee joint kinematics. On the other hands, the contact regions in the lateral compartment may not vary as much as in the medial compartment with the differences in the knee joint kinematics because of the shape of contact surfaces (Andriacchi, 2005), which may have resulted in a small variation of the centroids in the lateral compartment. This result supports the functional adaptation of the knee articular cartilage morphology to the mechanical loading conditions in the knee (Koo, 2007).

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