# Males have Thicker Load-bearing Patellofemoral Joint Cartilage than Females

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**Introduction**: Characterizing the morphology of articular cartilage is important to understanding normal and pathological joint mechanics. Cartilage stress, resulting from joint contact forces, is affected by the thickness of the articular cartilage at the joint [1]. Joint disorders, such as patellofemoral pain, are thought to be caused by increased cartilage stress. In vivo measurements of cartilage thickness may help to understand the causes of these disorders and the difference in incidence between genders. Magnetic resonance imaging (MRI) allows one to accurately and non-invasively measure cartilage morphology [2]. Articular cartilage experiences loads in regions of joint contact; thus, it may be more relevant to measure the thickness in these locations. Previous studies have not selectively examined cartilage thickness in load-bearing regions. The goals of this study were to (i) define regions of load-bearing articular cartilage and (ii) compare the load-bearing cartilage thickness between genders.

**Methods:** We examined 8 males (age: 28 ± 3 years, height: 1.78 ± 0.08 m, mass: 71.8 ± 4 kg) and 8 females (age: 29 ± 5 years, height: 1.65 ± 0.05 m, weight: 57.4 ± 5.1 kg). All subjects were free of knee pain and had no history of knee injury or surgery. Sagittal plane images were acquired with a 1.5T MR scanner (GE Healthcare, Milwaukee, WI) while subjects were supine with their knee in full extension to minimize cartilage deformation and load at the patellofemoral joint. A 3D fat-suppressed spoiled gradient echo (SPGR) sequence was used with a transmit/receive extremity coil and the following scan parameters: TR/TE: 40/5ms, flip angle: 30°, matrix size: 256x256, field-of-view: 12cm, slice thickness: 1.5mm, slices: 60, receive bandwidth: 122Hz/pizel, acquisition time: 15min (Figure 1).

**Figure 1**: Sample Sagittal MR Image of Knee

The subchondral bone and articulating cartilage surfaces of the patella and distal femur were manually segmented from the SPGR images to generate 3D point clouds. Using solid modeling software, 3D triangulated surfaces were created. The cartilage thickness distribution was estimated by computing the minimum distance between the subchondral bone surface and the articulating cartilage surface, for every point on the articulating surface (Figure 2).

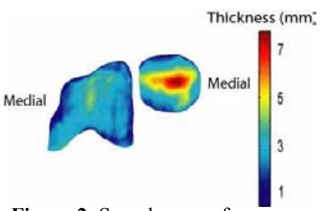


**Figure 2**: Sample map of cartilage thickness distribution.

To define the load-bearing regions of patellofemoral joint cartilage, we acquired images of subjects in an upright, weight-bearing posture at three angles of knee flexion (0°, 30°, and 60°) [3]. Sagittal plane images were acquired using a GE 0.5T Signa SP open MR scanner. A custom-built backrest [3] reduced motion artifact during image acquisition. A 3D SPGR sequence was used with a transmit/receive coil, and the following scan parameters: TR/TE: 33/9 ms, flip angle: 45°, matrix size: 256x160, field-of-view: 20cm, slice thickness: 2mm, slices: 32, acquisition time: 2:13min [3]. Contact areas were segmented and generic regions were defined to approximate the location of contact during loaded knee flexion for a typical subject (Figure 3).

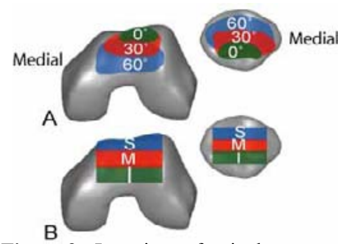


**Figure 3:** Locations of articular contact during loaded knee flexion (A). Generic regions approximating joint contact (Superior, Middle, Inferior) (B).

Within each region, the peak and mean cartilage thicknesses were computed. To account for potential outliers due to segmentation, the peak thickness was defined as the average of the top 10% of data points in the region. Furthermore, to account for differences in body mass between males and females, we scaled the measurements by $(\text{mass})^{0.45}$ [4], to compute a "scaled thickness". Differences between cartilage thickness in males and females were assessed using a repeated-measures Analysis of Variance.

**Results:** Male subjects had 22% thicker cartilage on the patella ($p < 0.01$) and 23% thicker cartilage on the femur ($p < 0.05$) than females when averaged over all regions of contact. The mean patellar cartilage of the male subjects was significantly thicker than that of the females in both the superior and middle contact regions ($p < 0.01$) (Figure 4A). The mean femoral cartilage of the males was significantly thicker than that of the females in the inferior region ($p < 0.01$) (Figure 4B). The scaled mean cartilage thickness was not different between genders in any of the contact regions; however, differences in peak patellar cartilage thickness between genders remained following scaling.

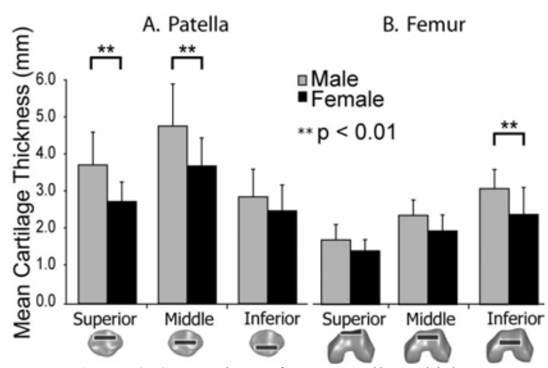


**Figure 4**: Comparison of mean cartilage thickness between genders for patella (A) and femur (B).

**Discussion:** We found that males had thicker load-bearing cartilage on the patella and anterior femur than females. Our results imply that differences in body mass may be one reason for the difference in cartilage thickness between genders, but that there may be other gender-related factors influencing peak articular cartilage thickness of the patella. Furthermore, this study highlights the feasibility and relevance of estimating the load-bearing articular cartilage thickness using MRI.

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