THE INFLUENCE OF PATELLA CARTILAGE THICKNESS ON PATELLA BONE STRESS
IN FEMALES WITH AND WITHOUT PATELLOFEMORAL PAIN

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INTRODUCTION

It has been suggested that patellofemoral pain (PFP) is the result of increased pressure on highly innervated subchondral bone. Current literature suggests that individuals with PFP demonstrate thinner cartilage1 and greater patellofemoral joint (PFJ) stress during functional activities (e.g., walking and squatting) [1,2]. Repetitive overloading of the PFJ is thought to adversely affect the shock absorption ability of articular cartilage thereby leading to subchondral bone damage [3]. To date, the influence of patella cartilage thickness on bone stress (i.e. patella) is not fully understood. The purpose of this study was to quantify the influence of patella cartilage thickness on patella stress in persons with and without PFP.

METHODS

Two females with PFP (33.5 ± 5.0 years, 59.7 ± 5.7 kg, 1.65 ± 0.1 m) and 2 female pain-free controls (32.5 ± 5.0 years, 58.9 ± 8.4 kg, 1.64 ± 0.1 m) participated. Each subject underwent 2 data collection sessions: MR assessment and biomechanical testing. Subject-specific PFJ geometry was obtained from high-resolution, sagittal plane MR images acquired with a 3.0 T MR scanner (General Electric Healthcare). Weight-bearing PFJ kinematics were acquired using a separate sagittal plane MR sequence with the knee joint loaded to 25% of body weight at 45° of knee flexion. Quadriceps muscle morphology was assessed from thigh MR images in coronal and axial planes. Cartilage thickness was assessed using an axial plane MR sequence.

For biomechanical testing, subjects were asked to perform squatting at 45° of knee flexion. Lower extremity kinematics were collected using a Vicon (Oxford Metrics LTD.) 8-camera motion analysis system at 60 Hz. Ground reaction forces were recorded at 1560 Hz using 2 AMTI force plates. EMG signals of knee musculature were recorded at 1560Hz, using pre-amplified, bipolar, surface electrodes (Motion Lab Systems).

Input parameters for the FE model included: 1) joint geometry, 2) weight-bearing PFJ kinematics, and 3) quadriceps muscle forces (Fig. 1). The PFJ geometry was manually segmented on high-resolution MR images and the FE mesh of cartilage and bone was created using FE pre-processor (Hypermesh, Altair Engineering Inc.). The FE mesh was then registered to the position of each structure in the weight-bearing MR images. Three-dimensional quadriceps muscle forces were estimated using a previously described subject-specific, EMG driven model [4].

Quasi-static loading simulations were performed using a nonlinear FE solver (Abaqus, SIMULIA). Bone and cartilage of patella and femur were modeled as homogeneous isotropic tetrahedral continuum elements (bone: elastic modulus of 15 GPa and Poisson ratio of 0.3 [5]; cartilage: elastic modulus of 4 MPa and Poisson ratio of 0.47 [1]). The tibia was modeled as a rigid body. Quadriceps muscles were divided into 3 functional groups (rectus femoris/vastus intermedius, vastus medialis, and vastus lateralis) made up of 6 equivalent uniaxial connector elements. Patellar tendon was modeled as six uniaxial, tension-only elements with stiffness of 4334 N/mm [1]. The peak compressive stress on the osseous-chondral interface of the bone was output for data analysis.
To obtain patella cartilage thickness, the cartilage was manually segmented on axial MR images. The thickness was quantified by computing the perpendicular distance between opposing voxels defining the edges of the patella cartilage. The average patella cartilage thickness obtained from all images was used for data analysis.

RESULTS AND DISCUSSION

Individuals with PFP demonstrated thinner cartilage (2.34 ± 0.16 mm) when compared to the pain-free controls (3.37 ± 0.05 mm) (Fig. 2a). Moreover, PFP subjects showed greater peak compressive patella stress (2.86 ± 0.43 MPa) when compared to the pain-free controls (1.04 ± 0.42 MPa) (Fig. 2b). Additionally, more concentrated stress was observed on the lateral facet in PFP subjects while a more evenly distributed stress pattern was observed in the control subjects (Fig. 3).

Previous literature has reported that bone compressive stress is correlated with bone tissue damage [6]. We hypothesize that the elevated bone stress observed in the current study may contribute to bone tissue injury (i.e. bone marrow lesions) and pain in persons with PFP. Future efforts will focus on increasing the sample size to better understand the influence of patella cartilage thickness on patella stress.

REFERENCES