In vivo Tibiofemoral Cartilage Contact Area and Deformation during the Stance Phase of Gait

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INTRODUCTION:
Osteoarthritis is caused by the breakdown and eventual loss of the cartilage. Topography of tibiofemoral cartilage contact area and deformation during daily physiological loading conditions such as gait could provide us with vital information to study the progression of osteoarthritis in vivo. However, in vivo tibiofemoral cartilage contact deformation during functional activities such as walking remains unclear. Recent advances in the imaging modalities, have demonstrated great potential in studying the deformation patterns of the knee cartilage. The purpose of this study was to accurately measure in vivo tibiofemoral cartilage contact deformations during the stance phase of gait on a treadmill.

METHODS:
8 healthy subjects (aged 32 - 49 years, six males, two females, average body mass index of 23.5 kg/m2) without a history of injury to the knee joint were recruited for this study. The study was approved by our institutional review board. Each participant had one knee scanned using a 3-Tesla MR scanner that employed a double-echo water excitation sequence. The images were used to create 3D models of the bone and cartilage surfaces of the tibia and femur in solid modeling software (Rhinoceros® 4.0). Dual fluoroscopic images of the knee of each subject were acquired at a frequency of 30 snapshots per second during their gait on the treadmill at a speed of 1.5 miles per hour i.e. 0.67 m/s. Two thin pressure sensors were attached to the bottom of each shoe to record the heel strike and toe-off of each gait cycle. Three consecutive gait cycles of each subject were imaged by using the dual fluoroscopic system for this analysis. The contact area was determined as the area of overlap of the cartilage models of tibia and femur at each 10% of the stance phase (Fig. 1). The cartilage deformation was calculated as the maximum penetration of the tibial and femoral cartilage divided by the sum of tibial and femoral cartilage thickness at that location.

RESULTS:

Medial compartment
From heel strike to 30% stance, the cartilage contact area increased from 235±111 mm² to 46±41 mm² (p<0.05) with an increase in cartilage contact deformation from 8±5% to 23±6%. Thereafter, cartilage contact area decreased to 35±147 mm² at 50% stance and increased to a second peak at 80% stance where it was measured to be 428±87 mm², and again decreased to 260±140 mm² (p<0.05) at toe-off (Fig. 2, 3). The peak deformation at 30% significantly decreased until 60% of the stance phase (p<0.05) where it was measured to be 16±2% followed by an increase to a second peak at 80% of the stance phase. Finally, at toe off the peak deformation was determined to be 17±4% (Fig. 3).

Lateral compartment
Both the cartilage contact area and deformation had a similar pattern as in the medial compartment where the two peaks occurred at 30% and 80% of the stance phase. From heel strike to the first peak at 30% stance, the cartilage contact area and deformation increased from 200±84 mm² to 411±159 mm² and from 7±3 % to 16±4 % (p<0.05) respectively. Thereafter, they decreased until 50% stance phase and increased again to reach a second peak at 80% stance. The second peak further decreased until toe-off, where the contact area and deformation were determined to be 331±167 mm² and 9±4 % respectively (Fig. 2, 3).

DISCUSSION:
This study elucidated the normal tibiofemoral cartilage contact area and deformation during the stance phase of gait. The present results indicated that there are two peaks in the cartilage contact area and deformation patterns both in the medial and lateral compartments corresponding to two peak ground reaction forces at 30% and 80% of the stance phase. Furthermore, during the stance phase, the average cartilage contact deformation of the medial compartment was higher than that of the lateral compartment, implying higher contact forces in the medial compartment. Results of the current study indicate that the medial and lateral compartments of the knee experience different contact biomechanics. These data could be useful for investigation of biomechanical mechanisms of cartilage degeneration.

REFERENCES: