In vivo kinematics of patellofemoral joint during dynamic stair ascending

INTRODUCTION:

Though a common daily activity, repetitive stair ascending is reported as one of the risk factors of patella disorders such as patellofemoral pain syndrome and osteoarthritis. The knowledge of normal patellar tracking is essential for understanding the function of the knee joint and for diagnosing patellar instabilities. The objective of this study was to investigate in-vivo patellofemoral joint kinematics and articular cartilage contact path during dynamic stair ascending.

METHODS:

Knees of twelve normal subjects with a mean age of 35 years were investigated. Patellofemoral kinematics were determined during a step ascending exercise using a combination of magnetic resonance imaging (MRI), dual fluoroscopic imaging and advanced computer modeling. Three-dimensional MRI-based bony models were matched to bony outlines on the pair of fluoroscopic images captured by two orthogonally oriented fluoroscopes during ascending stair. The start and end points of the whole ascending activity were determined as the heel strike on the stair, and when the knee was fully extended, respectively. The patellar kinematics, including shift, flexion, tilt and rotation were measured relative to the femur in 10% increments of the entire activity. Definition of patellar and femoral coordinate system is shown in figure 1. Patellofemoral cartilage contact points were also calculated by finding the centroid of the intersection of the patellar and femoral cartilage surfaces. The study was approved by our institutional review board and informed consent was collected from each subject prior to the experiment.

RESULTS:

Patella shifted 3.8 mm medially along with knee extension, and then changed direction toward lateral side at 80% of ascending phase (corresponding to ~ 10° of knee flexion) (Fig. 2A). During stair ascending, the patella shifted anteriorly and superiorly. Also, patella tilted 2.6° medially up to 50% of stair ascending activity. It then laterally tilted about 2.0° (Fig. 2B). The patella did not rotate considerably.

The path of patellofemoral contact points are shown in the Figure 3. At the start point, contact point occurred slightly lateral on the side of the patellar cartilage (Fig. 3A). By progress of the activity, the contact points shifted laterally and inferriorly. Total lateral shift of patella was measured 2.5 mm from the start to the end of activity. Patellofemoral contact points on femoral cartilage were also found in lateral side (Fig. 3B). Lateral and superior shift of articular cartilage contact points were observed on the femoral side as well.

DISCUSSION:

The dynamic motion of the patella was quantitatively determined during stair ascending which is one of the most commonly performed exercises daily or during physical therapy postoperatively. Even though small, patellar shifted towards medial from the start of stair ascending (50° of knee flexion) up to about 10° of knee flexion. From 10° of knee flexion to full extension, the patella showed a lateral shift. The contact points of patellar and femoral cartilage surfaces during this dynamic activity were observed to be on the lateral side of the patella and lateral femoral condyle. Varadarajan et al. showed that trochlear geometry had considerable effect on the patellar tilt and shift [1]. By flexion, the trochlear groove moves and twists laterally. Therefore, by extending the knee, the patella shifted and also tilted medially until about 20°-30° of knee flexion. After the patella exited the sulcus, patella tilted and shifted towards lateral. Basically, the tibia rotates laterally with respect to the femur along with knee extension, and patella tends to move laterally with rotation of tibial tuberosity. However, trochlear groove shifts and rotates medially by knee extension. This relation of opposite force direction between patella and femur could explain why the patellofemoral cartilage contact points happen on the lateral side of patella and femur cartilage.

SIGNIFICANCE:

These data provide baseline knowledge for understanding normal physiology of patellofemoral joint and can also be used to study the changes in knee joint kinematics in injured or degenerated joint.

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