The Knee 21 (2014) 142–146

Contents lists available at ScienceDirect

The Knee

Predictors of patellar alignment during weight bearing: An examination of patellar height and trochlear geometry

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ARTICLE INFO

Article history:
Received 16 February 2013
Received in revised form 9 August 2013
Accepted 16 August 2013

Keywords:
Alignment
Femoral trochlea
Patella height
Patellofemoral joint
MRI

ABSTRACT

Background: Patellar malalignment is thought to be an etiological factor with respect to the development of patellofemoral pain. Although previous studies have suggested that the geometry of the femoral trochlea and the height of the patella play an important role in determining patellar alignment, no investigation has systematically examined these relationships during weight bearing. The aim of this study was to determine whether patellar height and/or trochlear geometry predicts patellar alignment (lateral patellar displacement and lateral patellar tilt) during weight bearing.
Methods: MR images of the patellofemoral joint were acquired from 36 participants during weight bearing (25% of body weight) at 4 knee flexion angles (0°, 20°, 40° and 60°). Using the axial images, patellar alignment (lateral displacement and tilt) and femoral trochlear geometry (sulcus angle and inclination of the lateral femoral trochlea) were measured. Patellar height (Insall–Salvati ratio) was measured on reconstructed sagittal plane images.
Results: Stepwise regression analysis revealed that at 0° of knee flexion, the height of the patella was the best predictor of lateral patellar tilt while the lateral trochlea inclination angle was the best predictor of lateral patellar displacement. Lateral trochlear inclination was the best predictor of patellar lateral displacement and tilt at 20°, 40° and 60° of knee flexion.
Conclusion: Similar to a previous study performed under non-weight bearing condition, our findings suggest that lateral trochlear inclination is an important determinant of patellar alignment in weight bearing.
Level of Evidence: Level III

1. Introduction

Patellofemoral pain (PFP) is a common condition seen in sports medicine clinics [1–4]. The hallmark symptom of PFP is retropatellar pain during weight bearing activities, such as squatting and descending stairs [5,6]. Although the cause of PFP is multifactorial, patellar malalignment has been proposed as an important etiological factor [7–11]. Patellar malalignment can reduce patellofemoral joint contact area [12], increase patellofemoral joint stress [13,14] and cause excessive soft tissue strain [5]. Structural factors such as a high riding patella (patella alta) and/or abnormal trochlear geometry are thought to underlie patellar malalignment and, therefore, may contribute to PFP.

The importance of patellar height with respect to patellar alignment has been described previously [15–17]. Using weight bearing magnetic resonance imaging, MRI, the height of the patella has been shown to be positively correlated with lateral displacement of the patella during terminal knee extension [15,16]. In addition, subjects with lateral patellar instability have been found to exhibit a higher vertical position of the patella at full knee extension when compared to healthy controls [17]. These findings suggest that patellar height may be an important contributing factor with respect to patellar malalignment.

Recent literature also suggests that the femoral trochlear geometry is an important determinant of patellar alignment. For example, studies by Powers [18] and Varadarajan et al. [19] have shown that the sulcus angle is significantly correlated with mediolateral patellar displacement and tilt. In contrast, Harbaugh et al. [20] found that the inclination of the lateral anterior femoral condyle, as opposed to the sulcus angle, was more important in determining mediolateral tracking of the patella. In addition, the angle of inclination of the lateral trochlea has been shown to be associated with cartilage and bone marrow lesions on the lateral aspect of the patellofemoral joint [21].

While previous studies disagree as to which structural characteristic of the patellofemoral joint is associated with patellar alignment [18–20], no investigation has systematically examined these relationships in weight bearing. This is important as it has been shown that patellar tracking differs between weight bearing and non-weight bearing conditions [11,22]. In addition, individuals with PFP typically experience symptoms during weight bearing [5,6]. As such, the purpose of the current study was to determine whether patellar height and/or trochlear

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http://dx.doi.org/10.1016/j.knee.2013.08.011

geometry predicts mediolateral patellar alignment (lateral patellar displacement and lateral patellar tilt) in weight bearing. Information obtained from this study will enhance our understanding of the factors that contribute to patellar malalignment.

2. Methods

Thirty-six females participated in this study. Eighteen had a diagnosis of PFP (mean ± standard deviation; age: 28.3 ± 6.9 years; height: 1.68 ± 0.05 m; weight: 62.7 ±6.9 kg), while the remaining subjects were asymptomatic (mean ± standard deviation; age: 26.2 ±5.4 years; height: 1.65 ± 0.06 m; weight: 58.6 ± 6.8 kg). Both symptomatic and asymptomatic individuals were studied to obtain a wide range of potential patellofemoral joint alignment and morphological variations.

Individuals with PFP were admitted to the study if their pain originated from behind the patella (i.e., retropatellar pain). Only subjects that reported an insidious onset of symptoms were accepted. Subjects were screened through physical examination to rule out evidence of large knee effusion and peri-patellar pain. The screening procedure also included a functional assessment of activities commonly associated with PFP (squatting, stair climbing, isometric quadriceps contraction). Subjects were included in the study if they reported pain of at least 3 out of 10 (based on a visual analog scale) with one or more of the aforementioned functional tasks [23]. Any subject was excluded from participation if they reported any of the following: (1) previous history of knee surgery; (2) pregnancy or possibility thereof; (3) any implanted biological devices that could interact with the magnetic field (i.e., pacemakers, cochlear implants, or ferromagnetic cerebral aneurysm clips) [11,16]. Prior to participation, all subjects signed an informed consent as approved by the Institutional Review Board of the university.

Axial images of the patellofemoral joint were obtained from a 1.5-T MR system (General Electric Medical Systems, Milwaukee, WI) using a fat suppressed fast spoiled gradient recalled echo (FSPGR) pulse sequence (TR: 8.2 ms, TE: 1.5 ms, field of view: 20 cm × 20 cm; matrix: 256 × 256; slice thickness: 2 mm). MR images were acquired at four knee flexion angles (0°, 20°, 40°, 60°) using a custom-built, non-ferromagnetic loading apparatus that resembled a leg press device (Fig. 1). The trunk and shoulders of the subject were strapped to a mobile sled loaded with epoxy weights that equaled 25% of the subject's body weight. The subject was then asked to push against the footplate with the leg being imaged until the desired knee flexion angle was achieved. A load of 25% body weight previously has been shown to induce sufficient quadriceps activation but avoid motion artifact during imaging [16].

MR images were analyzed using ImageJ software (NIH, Bethesda, MD). The image containing the largest mediolateral width of the patella was selected from the set of axial images at each knee flexion angle and used to assess patellar alignment and femoral geometry. Mediolateral displacement of the patella was quantified using the bisect offset index (BSO) [24,25]. This measurement consisted of drawing a line connecting the posterior femoral condyles and then projecting a perpendicular line anteriorly through the deepest point of the femoral trochlear groove (Fig. 2A). This perpendicular line intersected the patella width line, which connected the most medial and lateral points of the patella. The BSO represented the percentage of the patellar width lateral to the deepest point of the trochlear groove. Mediolateral patellar tilt was assessed using the patellar tilt angle (PTA), which was defined as the angle formed between the line connecting the widest points of the patella and the line joining the posterior femoral condyles (Fig. 2B) [24]. PTA was reported in degrees. A positive value indicated lateral tilt, whereas a negative value represented medial tilt.

With respect to trochlear geometry, the sulcus angle (SA) was measured as the angle formed by the highest point of the medial and lateral anterior femoral condyles and the deepest point of the femoral trochlear groove (Fig. 2C) [18,26]. Using this method, a greater SA represented a flatter trochlear groove. The inclination of the lateral anterior femoral condyle was assessed using lateral trochlear inclination angle (LTI) [27]. The LTI was measured as the angle formed by a line connecting the highest point of the lateral anterior femoral trochlea and the deepest point of the femoral trochlear groove, and a line joining the posterior femoral condyles (Fig. 2D). A greater LTI angle was indicative of a steeper lateral anterior femoral condyle.

When the posterior condyles were not observed on the image containing the widest patella, coordinates of the posteriomedial and posteriolateral femoral condyles and the deepest point of the trochlear

Fig. 1. Subject positioning and loading device used for imaging. (Reprinted with permission from Salsich GB, et al.: In vivo assessment of patellofemoral joint contact area in individuals who are pain free. *Clin Orthop Relat Res* 2003; (417): 277–284).