INSIGHT FROM DIRECT IN VIVO MEASUREMENTS ON THE FORCE DISTRIBUTION ACROSS THE HUMAN KNEE IN FLEXION: CAN IT BE MODIFIED, AND CAN THE INTERNAL LOADS BE PREDICTED FROM EXTERNAL MEASUREMENTS?

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Purpose: An understanding of the medio-lateral distribution of the tibiofemoral (TF) contact forces and the factors influencing this distribution is essential for the targeted development and evaluation of interventions aiming to influence the progression of osteoarthritis. Mechanical models of the human knee have provided a basic understanding of the load distribution at the joint, suggesting a strong correlation between frontal plane alignment and medial loading during walking, when the knee is loaded in a rather extended position. The results obtained here are, however, sensitive to the many assumptions necessary to establish the models, and it remains unclear whether those relationships still hold when the knee is loaded in flexion. Goal of this study was to quantify the medio-lateral force distribution in deep knee flexion using direct measurements of the in vivo knee loading conditions and to examine whether and if so by how much the load distribution can be changed in flexion. In addition, we aimed to assess whether more readily available measures such as the dynamic external knee adduction moment (EAM) or static frontal plane alignment were able to predict the internal loading conditions in deep knee flexion.

Methods: Gait analysis was performed on 9 total knee replacement (TKR) patients with a post-op mechanical axis angle (MAA) ranging from 4.5° valgus to 7° varus. Telemetric implants provided access to the in vivo TF contact forces and the ratio of the medial to total contact force (MR), while kinematics and external knee moments were determined using inverse dynamics analyses based on synchronously collected ground reactions forces and skin marker data for variants of squatting. While maintaining the reference position of their feet established for the neutral squat (approximately shoulder-width apart, 9 subjects), additional data from 6 of these subjects was available where they were asked to squeeze their knees together (valgus squat) or push their knees apart (varus squat). To assess whether knee loading can be modified in deep flexion, the medial contact force (Fmed) and the MR were compared between varus and valgus squats, while linear regression analyses assessed the relation between the external adduction moment (EAM) and either Fmed or the MR and whether the MAA explained any variance in the internal forces. All subjects provided written informed consent to participate in the procedures and the study was approved by the local ethics committee.

Results: The mean MR for the valgus squats (0.33 ± 0.09) was lower (p<0.05) than for the varus squats (0.47 ± 0.06), but there was no significant difference in Fmed (0.84 ± 0.31BW vs. 1.08 ± 0.19BW, p > 0.05). During the neutral squats the patients reached a similar mean peak knee flexion of 95.6°, while the mean MR and Fmed were 0.40 ± 0.08 and 0.96 ± 0.32BW, respectively. Linear regression analysis across the 9 subjects revealed a stronger association between EAM and MR (R2 = 0.88) than between EAM and Fmed (R2 = 0.62) (Figure 1).

There was no substantial relationship between either MR or Fmed with the EAM (R2 = 0.01 and 0.21 respectively).

Conclusions: This study revealed that the MR but not Fmed was substantially modified in deep flexion, a condition under which static frontal plane alignment did not explain any substantial variation in either measure of internal knee loading. Here, the EAM derived from inverse dynamics analysis was a better predictor of the MR than Fmed directly measured in 9 subjects, corroborating the notion that the EAM is a proxy for the medial-to-lateral force distribution rather than for Fmed. Clarification of whether changes in kinematics, muscle activation patterns or their combination can explain the changes in MR between varus and valgus squats could help to better understand key mechanisms that enable modification of knee loading and its control.

POSTURAL STABILITY AND PAIN IN OBESE LADIES WITH MILD KNEE OSTEOARTHRITIS AFTER INTRA-ARTICULAR HYALGAN INJECTION

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Purpose: Knee osteoarthritis is a common cause of disability which influences the quality of life. It is associated with pain and impaired knee joint proprioception which effects postural stability. Postural stability is critical for mobility and physical activities. Current...
treatments for knee OA are anecdotals or nonsteroidal anti-inflammatory drugs (NSAIDs), surgical treatments, intra-articular injections, physiotherapy, weight reduction, exercise, orthotic (braces), and patient education. Hyaluronic acid (HA) injection is a nonsurgical new popular treatment used worldwide. The aim of this study was to demonstrate the effect of HA injections on postural stability and pain in obese women with bilateral mild knee osteoarthritis.

**Method:** This study was approved by Medical Ethics Committee in University Malaya Medical Centre (919.18/May/2012). Twenty-four obese women with mild bilateral knee osteoarthritis age above 50 years participated in this study. All participants underwent clinical assessment and knee X-ray. Knee X-rays were graded using Kellgren-Lawrence grading scale. Participants were categorized into treatment (n = 12), and control (n = 12) groups. Treatment group received five weekly HA injections – Hyalgan 20mg/ 2mL (Fidia, S.p.A, Abano terme, Italy) into both knees; and control group did not receive any treatment. All the participants were asked to stop taking medicine two weeks prior to first assessment session (washout period) and instructed not to use any medicine or undergo any other treatment during this study.

Postural stability (dynamic and static balance) and pain of participants were assessed before injection or week one and a week after injection or week six. They were assessed using Biodex Stability System, “Timed Up and Go” test and visual analog scale (VAS) for pain. The SPSS Statistics version 17.0 was used for all statistical analysis. Paired sample t-test and descriptive analysis were used, and the alpha level of 0.05 was defined as statistically significant for all the tests.

**Results:** Total of 24 obese female participated in this study. The mean age of participants was 58 years, and the mean of BMI was 32.41 (kg/m²). Table 1 demonstrates the mean and standard deviation of static balance, dynamic balance, TUG and VAS of all the participants in week one and week six.

<table>
<thead>
<tr>
<th></th>
<th>Treatment mean (SD)</th>
<th>Control mean (SD)</th>
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<tbody>
<tr>
<td></td>
<td>Week 1</td>
<td>Week 6</td>
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<tr>
<td>TUG (seconds)</td>
<td>10.52 (0.9)</td>
<td>8.45 (0.8)</td>
</tr>
<tr>
<td>VAS</td>
<td>5.08 (1.4)</td>
<td>1.5 (0.8)</td>
</tr>
<tr>
<td>Static balance</td>
<td>0.7 (0.4)</td>
<td>0.5 (0.1)</td>
</tr>
<tr>
<td>Dynamic balance</td>
<td>1.75 (0.7)</td>
<td>0.76 (0.4)</td>
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</tbody>
</table>

Results of paired sample t-test indicated that there is a significant difference in postural stability and pain between week one and week six. There was a significant decrease in TUG [t(11) = 12.22, P < 0.000], VAS [t(11) = 8.7, P < 0.000] and dynamic balance [t(11) = 8.47, P < 0.000] scores in treatment group after five intra-articular HA injection; however, no difference was shown in static balance [t(11) = 1.58, P = .142]. In contrast, there was significant increase in TUG [t(11) = -4.33, P < 0.001], VAS [t(11) = 3.08, P = .01], static balance [t(11) = -2.303, P = .042] and dynamic balance [t(11) = -2.493, P < 0.03] from week one to week six in control group. This illustrates that control group condition got worse over the period of this study.

**Conclusion:** Five weekly intra-articular HA injection improves pain and dynamic balance in obese women with bilateral mild knee osteoarthritis; however, it does not have any effect on static balance.

**158 THE MECHANICAL EFFECTS OF CHONDROCYTE HYPERTRPHY: A FINITE ELEMENT STUDY**

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**Purpose:** It is well-established that some chondrocytes will assume a new hypertrophic phenotype with the onset and progression of osteoarthritis (OA). The biological processes of these cells have been shown to be drastically altered, but the mechanical effects due to simply having a larger geometry are less understood. Whether an increased volume would be beneficial or detrimental to the cellular mechanics is not a trivial problem, given the competing factors from the solid and fluid phases. A larger cell would behave more softly in the solid phase, but the decreased surface area to volume ratio could lead to more fluid pressurization, creating stiffer transient behavior.

This study investigated the mechanical effects of chondrocyte hypertrophy through state-of-the-art multi-scale finite element (FE) analysis.

**Methods:** A simplified three-dimensional FE model of the medial compartment of the human knee was constructed with the cartilage, meniscus, and bone regions represented (Figure 1). The cartilage was divided into deep, middle, and superficial zones. The thicknesses of the deep and middle zones were 45% of the total thickness each and the remaining 10% was superficial layer cartilage. All materials were hyperelastic and biphasic. Cartilage and meniscus were anisotropic in both the solid and fluid phases. Anisotropy was defined by ellipsoidal fiber distribution functions appropriate for each cartilage zone and the meniscus (Figure 2). A 15% nominal compression of the joint space was applied over a 0.5 s time interval. The compression was held constant for an additional 4.5 s, allowing the early transient phase to be explored. Cellular scale models were constructed of normal and hypertrophic chondrocytes, with 10 and 20 μm diameters, respectively. These were embedded in a cube of extracellular matrix and surrounded by a 2.5μm thick layer of pericellular matrix (PCM). The hypertrophic cell was modeled with and without the PCM, since the PCM often disappears in OA. The internal fluid pressures and displacements over time calculated by the tissue scale model were interpolated to the surfaces of the cellular scale models to serve as prescribed boundary conditions. This was done considering a cell positioned in the middle zone of femoral cartilage. In other words, the mechanical environment of a cell located in this position was simulated.

**Results:** The hypertrophic cell experienced elevated deformation relative to the normal cell as indicated by the effective strain over time (Figure 3). The effect was further amplified with the removal of the PCM. The fluid pressurization of the cell was surprisingly not affected by the change in diameter or PCM deletion.

**Conclusions:** This preliminary investigation indicates that the cell may be sacrificing mechanical integrity when assuming the hypertrophic phenotype as indicated by nearly a threefold increase in cellular deformation. The analyses performed are most applicable to physiologic loading rates and durations, since the majority of the relaxation phase in which fluid exudation occurs was not modeled. Indeed, no difference in cell fluid pressurization was observed between models, indicating that the middle zone of cartilage had not yet begun to relax. The cartilage permeability is known to be reduced in early stage OA, but this was not explored. It is possible that this reduction would result in earlier relaxation of the middle zone cartilage, where a larger cell diameter may then be advantageous for fluid support. The methods employed here can be extended to explore this in the future.