European Journal of Radiology Open 3 (2016) 100–107

Contents lists available at ScienceDirect

European Journal of Radiology Open

journal homepage: www.elsevier.com/locate/ejro

Loaded versus unloaded magnetic resonance imaging (MRI) of the knee: Effect on meniscus extrusion in healthy volunteers and patients with osteoarthritis

Rina Patel[a], Matthew Eltgroth[a], Richard B. Souza[c], Chiyuan A. Zhang[a,b], Sharmila Majumdar[a], Thomas M. Link[a], Daria Motamedi[a,*]

[a] Department of Radiology and Biomedical Imaging, University of California, San Francisco, 500 Parnassus Avenue, San Francisco, CA 94143, United States
[b] Department of Epidemiology and Biostatistics, University of California, San Francisco, 500 Parnassus Avenue, San Francisco, CA 94143, United States
[c] Department of Physical Therapy and Rehabilitation Science, University of California, San Francisco, 500 Parnassus Avenue, San Francisco, CA 94143, United States

ARTICLE INFO

Article history:
Received 13 March 2016
Received in revised form 2 May 2016
Accepted 3 May 2016
Available online 20 May 2016

Keywords:
Stress MRI
Weighted MRI
Axial load
Meniscus extrusion
Osteoarthritis

ABSTRACT

Objective: Assess the impact of knee joint loading on meniscal extrusion in normal individuals and those with varying degrees of osteoarthritis (OA).
Methods: 143 healthy volunteers and patients with OA underwent 3 T MRI of the knee under unloaded and loaded conditions. OA was graded with the Kellgren-Lawrence (KL) system. Menisci were evaluated for presence of tear. Descriptive statistics were expressed as mean ± standard deviation. Loaded and unloaded groups were compared using Student's *t*-test. Statistic significance was defined for all calculations as $p < 0.05$.
Results: The cohort included 87 women and 56 men with an average age of 53 years +/− 9.7 years. Kellgren-Lawrence grade distribution was as follows: 56 with grade 0, 46 with grade 1, 25 with grade 2, 13 with grade 3, and 3 with grade 4. 23% had medial meniscus tears and 16% had lateral meniscus tears. Differences in medial meniscal extrusion between loading and unloading were significant in the entire cohort ($p < 0.0001$). Statistically significant difference in medial meniscus extrusion with loading and unloading were found for KL score group of 0, 1 and 3 ($p < 0.001$, $p < 0.001$ and $p = 0.005$). Interestingly, no significant differences in extrusion with loading and unloading were found for the lateral meniscus ($p = 0.07$).
Conclusion: Our study demonstrated that medial meniscal extrusion significantly increased during loading, specifically in those low KL scores (0 and 1) and in KL score of 3. Loaded MRI may more accurately determine the extent of medial meniscal extrusion in particular in those with no to minimal OA.

1. Introduction

The meniscus is essential in the normal physiologic function of the knee. Important roles of the meniscus include shock absorption, load bearing, and joint stability. The ability of the meniscus to perform these functions is significantly limited by tears of the meniscus and meniscus extrusion. Failure of the meniscus to respond to fluctuating load bearing may lead to articular cartilage damage and progression of osteoarthritis [1]. Multiple studies have shown that meniscal extrusion is an independent predictor of tibiofemoral cartilage loss and degenerative subchondral marrow changes [2–6]. Along with high BMI and MR-depicted degenerative lesions, meniscus tears and extrusion are strong risk factors for more rapid cartilage loss [7]. Accurate determination of meniscal extrusion and the degree of meniscal extrusion is therefore important in the evaluation of osteoarthritis and progression of degenerative changes.

Abnormal medial meniscus extrusion is defined as protrusion of the body of the medial meniscus beyond the tibial plateau, by more than 3 mm [8]. Meniscus extrusion is commonly associated with severe meniscal tears or root tears that disrupt the hoop tension of the meniscus [1]. However, meniscus extrusion may also be present without an associated meniscal tear. Knee malalignment and tibiofemoral cartilage loss are both associated with meniscus extrusion, independent of meniscal tears [1]. Therefore, it is important to evaluate for meniscus extrusion, regardless of the presence or absence of a meniscal tear.

Meniscus extrusion is evaluated with magnetic resonance imaging (MRI), typically with the patient's knee in supine, neutral

* Corresponding author.
E-mail address: daria.motamedi@ucsf.edu (D. Motamedi).

http://dx.doi.org/10.1016/j.ejro.2016.05.002

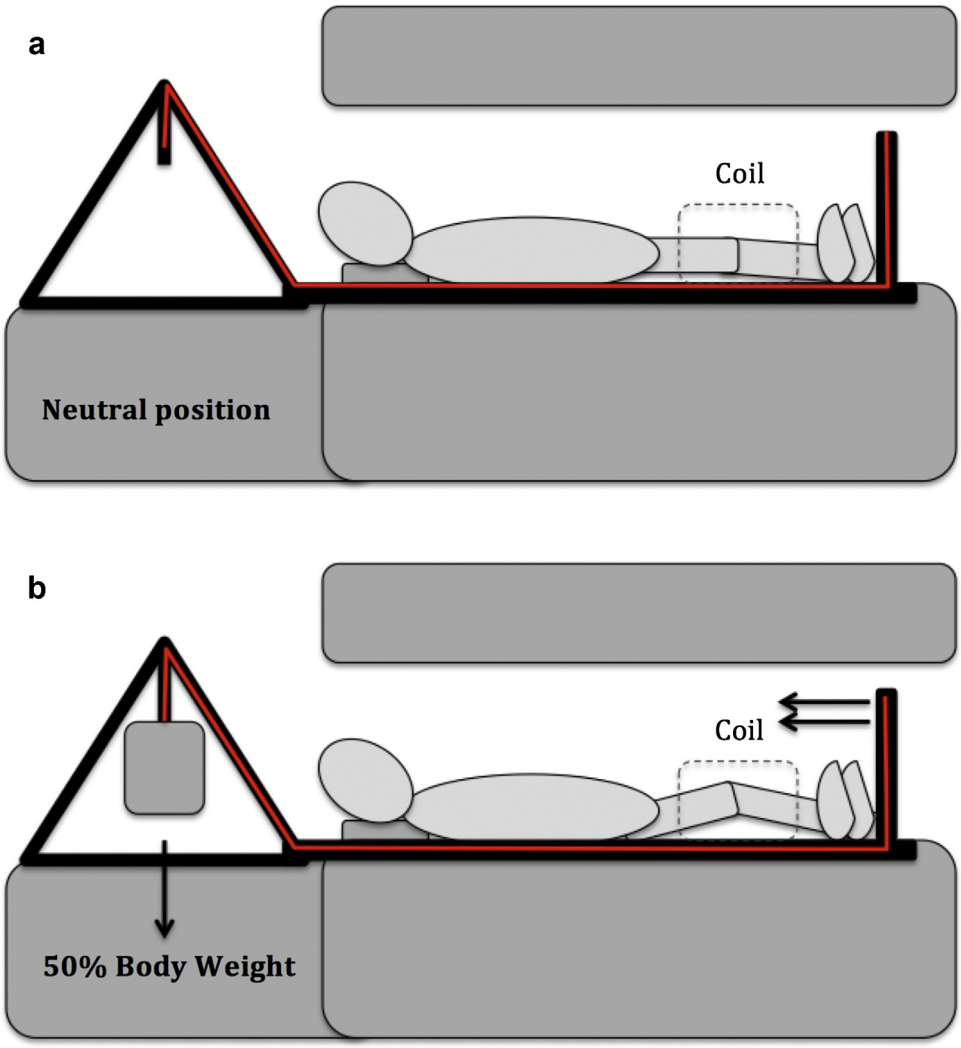

Fig. 1. MRI-compatible axial loading device. (a) For unloaded imaging, the subject is in neutral position with the leg extended. (b) For loaded imaging, hanging weights equaling half of the patient's body weight are applied to the frame that. The force of the weight is transmitted through a series of pulleys to the patient's foot.

position. However, cadaveric and patient studies show that the meniscus is mobile with varying knee position [8,9]. Many dynamic imaging configurations have been evaluated, including flexing or rotating the knee or with the patient sitting or standing [8–10]. Simulation of weight bearing or loading can also be done with the patient in supine position. Stehling et al. [11] examined the effect of weight bearing on meniscus extrusion using a pulley device that transmitted 50% of the subjects' body weight through a footplate position against the test lower extremity. This study showed that medial meniscus extrusion is greater with loaded versus unloaded MRI of the knee in a group of 30 subjects with osteoarthritis. The purpose of our study was to expand on that prior study by examining a larger cohort and also determine if changes in meniscal extrusion were more significant with more progressive osteoarthritis and with meniscal tears.

2. Materials and methods

2.1. Subjects

The study design was approved by the institutional Human Research Protection Program, and all procedures were performed in accordance with the Health Insurance Portability and Accountability Act (HIPAA).

143 subjects were recruited through research flyers. Subjects were initially screened by phone, and if eligible (as outlined below), underwent anterior-posterior knee radiography in an extended, weight-bearing position. These radiographs were scored for the presence of osteoarthritis by musculoskeletal radiologists according to the Kellgren-Lawrence (KL) scoring system. According to this system, KL score 0 is no osteoarthritis, 1 is doubtful osteoarthritis (minute osteophyte), 2 is minimal osteoarthritis (osteophytes but no joint space narrowing), 3 is moderate (osteophytes and joint space narrowing), and 4 is severe osteoarthritis (severe joint space narrowing and subchondral sclerosis) [12,13]. Inclusion criteria for control subjects were age $\geq$35, no history of frequent knee pain, aching, or stiffness over the past year and no use of medication for knee pain in the past year. In addition, radiographs could not show evidence of osteoarthritis. Inclusion criteria for osteoarthritis subjects were age $\geq$35, self-reported pain, aching or stiffness most days of a month in the past year, and radiographic signs of osteoarthritis with a KL score of 2, 3, or 4. Exclusion criteria for both groups included history of fracture or surgery to the study knee and contraindication to MRI. The details of the experiment with all risks, benefits, and alternatives were explained to the subjects, and informed consent was obtained, with use of a form approved by the Committee on Human Research.