EFFECT OF WEIGHT LOSS ON SUBCHONDRAL BONE CYST IN THE KNEE JOINT DURING GAIT: A 3D FINITE ELEMENT ANALYSIS

Julius Dahlgren (1), Gustavo A. Orozco (1), Lauri Stenroth (2,3), Tine Alkjær (2), Hanna Isaksson (1)

1. Lund University, Sweden 2. University of Copenhagen, Denmark 3. University of Eastern Finland, Finland

Introduction

Obesity increases the risk of osteoarthritis (OA) by five times in men and four times in women when compared to non-obese men and women [1]. Subchondral bone cysts (SBC) appear in patients with knee OA causing pain and cartilage loss. However, the effect of weight loss and SBC on the biomechanical response of the cartilage-bone unit remains unknown. Here, we present a case study where we developed a patient-specific finite element (FE) knee joint model to investigate this effect in the knee during the stance phase of gait. We hypothesized that cartilage and bone stresses and strains would decrease as body weight is reduced while the inclusion of the SBC would lead to larger deformations.

Methods

The FE knee model was developed using magnetic resonance imaging (MRI) data of the left knee (age: 63 y/o, height: 1.55 m) from the CAROT trial [2]. MRI data at baseline was used to segment the knee joint tissues (3DSlicer). Segmented geometries of femoral and tibial cartilages, femoral and tibial bones, and menisci were imported into Abaqus (v.2021, Dassault Systémes, Providence, USA) where meshes and boundary conditions were implemented (Fig. 1a). Tibia regions were differentiated in cortical, trabecular, and subchondral bone. In addition, another FE model was created including a spherical SBC (diameter: 6 mm), which was placed centrally in the medial tibial compartment ~1 mm below the subchondral bone plate. Bone, menisci, and the SBC were modeled as homogeneous, isotropic linear elastic materials, while cartilage was modeled as a neo-Hookean hyperelastic material (Fig. 1b).

The patient´s weight at baseline and 68-weeks of follow-up was 85 and 72 kg, respectively. Patient specific knee axial force and flexion-extension angle during the stance phase of gait were computed using motion analysis data at baseline with OpenSim [3] (Fig. 1c).

Results

At the first force peak of gait, FE models at baseline and 68-weeks showed a decrease in contact pressure, Von Mises stress, and maximum principal strain by 9.5%, 8.8%, and 7.7% respectively in the lateral cartilage. In the medial compartment, the same parameters decreased by 7.7%, 4.5%, and 2.3% respectively. Minimum principal stress and strain in the lateral cortical bone decreased by 10.4% and 11.0 %, respectively.

The inclusion of the SBC caused an increase in the minimum principal stress and strain by 8.5% and 9.1% respectively in the medial cortical bone (Fig. 1e-f).

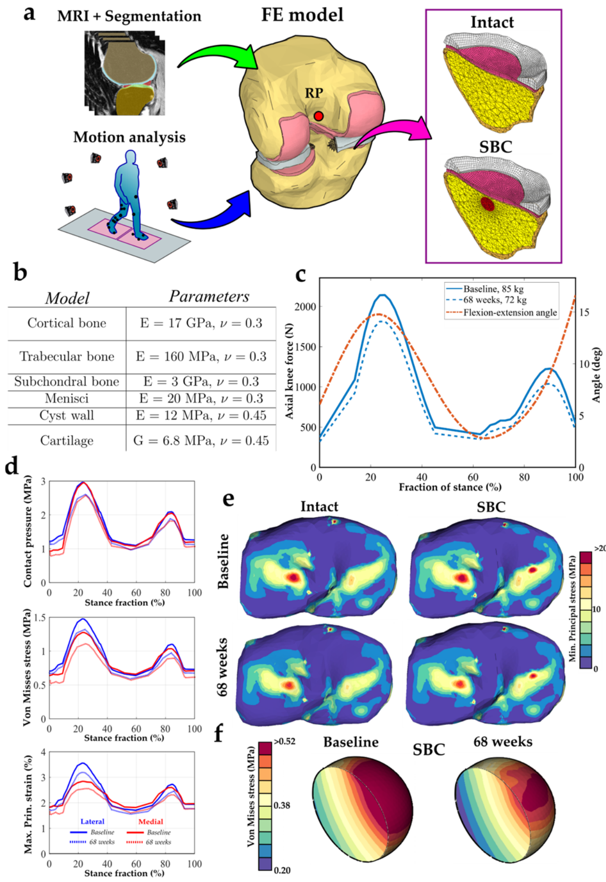

Figure 1: a) Workflow of the study. b) Material properties used in the FE model. c) Patient´s gait data. d) Average contact pressure, Von Misses stress, and max. principal stress in tibial cartilage. e) Min. principal stress in tibial cortical bone for the intact and SBC models. f) Von Mises stress in the SBC.

Discussion

Based on the presented case study, weight loss reduces critical stresses and strains in articular cartilage and bone, which may lead to slowing down degenerative processes. On the other hand, while the inclusion of an SBC had a minimal impact on the cartilage biomechanics, medial cortical bone experienced large compressive stresses and strains. This case study will be extended to more subjects in the clinical trial to elucidate further pain and OA progression mechanisms.

References

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Acknowledgements

Swedish Research Council (2019-00953), Innovation Fund Denmark (9088-00006B) and Academy of Finland, (334773), all under ERA PerMed.