PREDICTING KNEE CARTILAGE DEGENERATION IN OBESE ADULTS USING PATIENT-SPECIFIC MODELS: DATA FROM THE CAROT TRIAL

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Introduction

Obesity increases the risk of osteoarthritis (OA) compared to non-obese subjects [1]. Strategies for early prediction to slow down OA progression are important to decrease societal and economical burdens. Numerical finite element (FE) modeling-based approaches have been developed to classify patients at high risk for OA [2]. However, these applications have not been used to estimate knee cartilage degeneration in larger cohorts.

In this study we aimed to predict the degeneration of knee cartilage in obese adults and investigate the importance of the level of patient-specific information. We hypothesized that patient-specific knee geometry is more important than patient-specific gait data for the prediction of cartilage degeneration, when compared to full patient-specific information.

Methods

115 subjects (95 females and 20 males, 63.8 ± 6.3 years, BMI: 37.0 ± 4.4 kg/m^2) were selected from the CAROT trial at baseline [3]. Patient-specific knee axial force, varus-valgus moment, and flexion-extension angle during the stance phase of the gait were computed using motion analysis data (at baseline) in OpenSim. The FE knee models were created from MRI data using a validated template-based approach consisting of femoral and tibial cartilage, menisci, and cruciate and collateral ligaments [2]. The template was scaled according to the anatomical dimensions measured from each participant's MRI. The computed gait data from each subject was used to drive the FE models in Abaqus. Cartilage and meniscus were modeled as fibril-reinforced poroviscoelastic (FRPVE) material [4]. A linear age-dependent function was implemented to estimate cartilage degeneration based on excessive and accumulated tensile stresses linked to collagen damage.

Cartilage degeneration volumes were predicted from 10 "years" (computational iterations) before baseline assuming that BMI was constant. The fully patient-specific predictions were compared to predictions where either gait data or knee geometry implemented represented the group average ("generic" approach) in which loading inputs were scaled according to body mas. Kellgren-Lawrence (KL) grades at baseline were utilized to evaluate the numerical predictions for each subject. Predictive accuracy was verified using receiving operating characteristics (ROC) and area under curve (AUC).

Results

Numerical predictions showed a better correlation in the medial compartment than lateral for both KL grades. Interestingly, predictions based on patient-specific geometry combined with generic knee gait showed a similar ability to predict cartilage degeneration grades as full patient-specific FE models. When attempting to separate predictions of KL0-KL1 vs. KL3-KL4, an adequate outcome was obtained for full patient-specific models (AUC = 0.71, $p < 0.01$) and for patient-specific geometry with generic gait data (AUC = 0.68, $p < 0.01$), but not for generic geometry and patient-specific gait data (AUC = 0.48, $p = 0.73$).

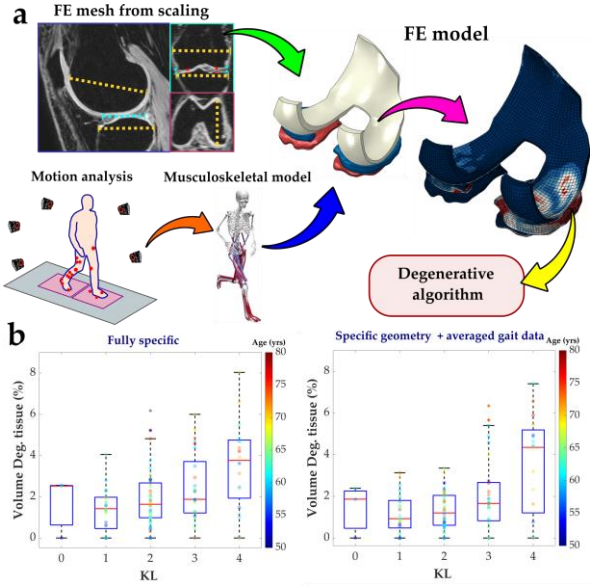

Figure 1: a) Workflow of the study. b) Predicted cartilage degenerated volumes in the medial compartment for each KL group using different levels of specificity.

Discussion

Based on this study, our modeling approach was able to adequately categorize obese adults into normal and advanced OA groups. Results also suggest that patient-specific geometry has more impact than patient-specific gait data on the prediction of cartilage degeneration. This suggests that generic knee kinematics might be enough in prognostic tools to evaluate the risk of onset and OA progression.

References

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