INTRODUCTION:
We introduce the concept of total knee arthroplasty (TKA) fingerprinting as a tool to characterize and graphically convey the sensitivity of a TKA design to surgical variability in implant component position and patient-related anatomic factors. Identifying sensitive directions preoperatively which would cause undesirable effects may decrease the need for revision surgery by informing surgical decisions and planning. To provide an example of TKA fingerprinting, we estimated and compared the contact forces in a single TKA simulating joint line elevation during a loaded deep squat. The purpose of this study is not to analyze the behavior of this specific TKA design but rather to illustrate a tool that could be used to show, in general, how surgical errors or anatomical factors can alter patello-femoral (PF) and tibio-femoral (TF) contact forces relative to its reference configuration.

METHODS:
An anatomic knee model consisting of CT-derived bone models and ligament insertion/origin locations was developed from one human cadaveric leg specimen. A single TKA design was considered in this study: conventional fixed bearing, posterior stabilized design: Genesis II PS (Smith&Nephew, Inc). Each total knee replacement was virtually implanted in several configurations: (a) normal joint line position (b) 2 mm joint line elevation (c) 5 mm joint line elevation (d) 5 mm joint line elevation with femoral component size reduction. A deep squat of 120°, was simulated with a constant hip load of 45 lbs (~200 N) using LifeMOD/KneeSim 2007.0.5 (LifeModeler, Inc., San Clemente, California), a validated, dynamic, musculoskeletal modeling system. Lateral and medial collateral ligaments were modeled as single and double bundle linear elastic elements with viscous damping, respectively. The maximum patello-femoral, tibio-femoral, and forces were recorded during each simulation.

RESULTS:
PF contact force decreased by 6.7 % and 18.7 % with joint line elevations of 2 mm and 5 mm respectively (Figure 2). Medial and lateral TF contact forces increased from 6.0 % and 8.1 % to 18.6 % and 27.6 % respectively. Subsequent resizing of the femoral component restored knee contact forces to within 6 % of their reference values. Earlier onset of tendofemoral wrapping was observed with increasing joint line elevation.

DISCUSSION:
The results of computational parameter variation studies may be difficult to understand due to the large quantities of data that are generally produced. Graphical visualization techniques allow rapid understanding of information that may be too complex to present in tabular format to be condensed.

Recent numerical studies have explored the effect of joint line elevation during simulated stair and gait activities using a previous musculoskeletal model that did not include tendofemoral contact. Joint line elevation in this previous study caused patellofemoral joint contact forces to increase 60% during stair climbing and 30% during walking at 10 mm of elevation. These results suggest that joint line elevation results in higher patellofemoral contact forces during walking and stair climbing when tendofemoral wrapping is not included in the musculoskeletal model. However, these results may not be indicative of contact forces during squating, where the tendofemoral contact at higher angles of knee flexion may alleviate the loading between the patellofemoral joint. Our results demonstrate a decrease in maximum PF contact force by approximately 20% at 5 mm of elevation.

SIGNIFICANCE:
Understanding the effect of component positioning on the biomechanical kinematics behavior of the knee is fundamental to understanding the implication of malalignment on implant behavior and on TKAs life expectancy.

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