Medial and Lateral Articular Loading Strategies in Knee Osteoarthritis
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Purpose: In knee OA, high knee adduction moments (KAM) and high muscle co-contraction strategies are presumed to contribute to higher joint contact forces possibly leading to rapid cartilage damage. The data from the instrumented knee studies have been invaluable in terms of providing actual loading values for healthy people and for the validation of various musculoskeletal models but are limited for estimations of articular loading for pathological conditions like knee OA. A number of mathematical models have been used in the past for estimating muscle forces and joint contact loads but none of them use subject-specific muscle activation patterns. We use an EMG driven forward dynamics musculoskeletal model that uses individual EMG patterns to estimate muscle forces and joint loads. The model takes into account the length-tension relationship, force-velocity relationship, pennation angles and the type of contraction (concentric vs eccentric), as well as kinetics in sagittal and frontal planes. Currently, there are no reports on loading values and patterns for people with knee OA. The aim of this paper is to analyze loading patterns in people with knee OA and also discuss the relationship of other mechanical and clinical factors that might have an impact on the loading strategies in this population.

Methods: Kinematic, kinetic and EMG data were obtained during regular walking at self-selected speed from 7 subjects with medial knee OA (Age Mean ± SD: 64.4 ± 10.8; BMI Mean ± SD: 31.4 ± 4.3) and 7 healthy (C) controls (Age Mean ± SD: 50.2 ± 7.8; BMI Mean ± SD: 28.1 ± 4.8). All subjects signed an informed consent prior to testing and the protocol was approved by the University of Delaware IRB.

EMG was collected from the Medial and Lateral Quadriceps, Rectus Femoris, Medial and Lateral Hamstrings and Medial and Lateral Gastrocnemii. The model uses a hybrid approach where EMG patterns during stance are used to estimate individual muscle forces and moments in the sagittal plane using a forward dynamics approach and the net sagittal moment from forward dynamics is optimized against the net sagittal moment from inverse dynamics obtained from motion analysis. The parameters optimized pertain to the EMG-force relationship. All parameters are scaled to each subject’s anthropometric dimensions. One walking trial is optimized and the parameters obtained are used to predict muscle forces and moments from 5 more walking trials. The predicted data are presented here. The muscle forces thus calculated are used to balance the moment in the frontal plane to obtain joint loading values. The loading is calculated separately for the medial and lateral compartment and normalized to body weight (BW). Peak values during first and second halves of stance are also calculated for each subject. The relative medial and lateral loading in terms of percentage of total loading was calculated to analyze medial vs lateral loading strategies in each group.

Quadriceps strength (normalized to BMI- MVIC/BMI) and Central Activation Ratio (CAR) were measured at an angle of 90° using the Burst Superposition technique. Functional parameters were obtained using the Knee Osteoarthritis and injury Outcome Score (KOOS) and Stair climbing test (SCT in seconds). Long cassette x-rays were used to measure mechanical axis (MA in degrees) and weight bearing line (WBL as a ratio) and stress x-rays were used to measure joint space narrowing (JSN in mm) and lateral laxity in mm (LL). Joint space narrowing (JSN) was measured from the weight bearing ant PA radiographic views which were used to grade the severity of knee OA using the KL scale.

Results: In this preliminary data, the OA group was not weaker or inhibited (Table 1). They walked slower and performed worse on the SCT. Medial JS was considerably less for the OA group (Table 2). In terms of percentage of total loading, the medial loading for controls was maintained at 60-70% whereas OA increased it from 60% to almost 100% in late stance. Lateral loading was maintained at 30-40% for C whereas the OA unloaded from 30% to almost 0 in late stance.

Discussion: OA group was more disabled, malaligned but not weaker compared to controls which indicates that quadriceps strength might not be the only factor related to disability and loading. As expected, all subject had greater medial contact force during walking. Our peak loading values for Controls are slightly higher than those found from the instrumented knee studies but that could be due to the higher walking speed. Controls maintained a similar balance of medial and lateral loading throughout stance whereas the OA group showed unloading of lateral compartment. This could be due to the static and dynamic malalignment present in the OA group but its more likely a failure of the neuromuscular strategies. The strategies appear to work in early stance where the loads are highest but not during late stance.

Contrary to our hypothesis, the loading in OA was not higher than C which can be accounted for by the much slower walking velocity seen for the OA group. The results highlight the need for this musculoskeletal model since kinetic data cannot be used to infer loading strategies. High frontal plane moment in OA indicates higher loading but it does not demonstrate the differences in medial vs lateral loading and does not take into account the compression due to muscular co-contraction.

These are the first reports of articular loading in people with knee osteoarthritis. The sustained peak loading over repetitive cycles during everyday walking could lead to more rapid medial cartilage damage over time. We are analyzing data from 30 more subjects with knee OA and healthy controls while also collecting more data as a part of an ongoing study. These results are the highlight the need to expand the current research to include measures to reduce loading during mid and late stance, along with the early loading phase, thereby possibly slowing the progression of the disease.

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