Analysis of Toe-In Gait Modification for Patients with Knee Osteoarthritis

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Introduction: Knee osteoarthritis(OA) is a painful and debilitating condition affecting nearly one in five adults over the age of 45 [1]. Gait modification has been suggested as a non-invasive treatment for medial compartment knee OA to decrease medial loading and alleviate pain [2]. One such form of gait modification is toe-in gait, defined as a decrease in foot progression angle from baseline through internal foot rotation. Toe-in gait has been shown to reduce the net adduction moment and knee pain [2]. By investigating muscle force and joint contact load modifications, toe-in gait may be better understood in terms of targeted training programs for muscle groups and optimal kinematics for minimizing joint loads. We hypothesized that for toe-in gait to reduce knee pain, the joint contact loads must also be reduced.

Materials and Methods: In this case study, we analyzed a patient, representing average kinematics of a larger cohort, with knee OA walking 10 steps on a treadmill both before (Baseline) and after (Post-Training) toe-in gait modification. A patient-specific model was created in OpenSim [3] by scaling a generic model to the size of the patient. Then, inverse kinematics was used at each time step of experimental data to "best match" the model's position to the experiments by varying its joint angles. Next, computed muscle control was used to determine an optimal set of muscle excitations generating forward dynamic simulations consistent with the experiments. To test our hypothesis concerning joint contact load reduction, the bone-on-bone (not net from inverse dynamics) joint reaction forces and moments were computed and compared.

Results and Discussion: Our results support the hypothesis that joint contact loads decrease with toe-in gait (Fig. 1). To achieve this modification, there was a trade-off in muscles forces. Psoas major, rectus femoris, and adductor longus showed the largest relative increases in mean muscle force, while gluteus medius, sartorius and extensor digitorum longus decreased the most. These changes contribute to hip adduction, hip internal rotation, hip flexion, and knee extension causing the foot progression angle to decrease and ultimately a decrease in knee joint contact loads.

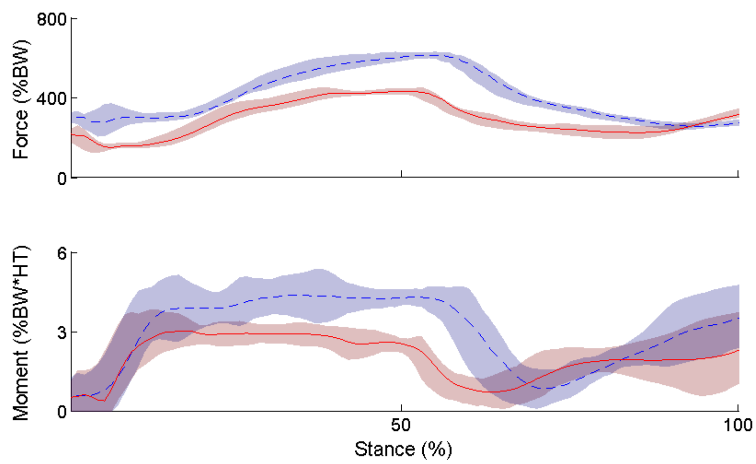

Figure 1. Post-Training (solid, red) toe-in gait resultant joint reaction forces and moments are lower than Baseline (dashed, blue) normal gait.

Conclusions: Patient-specific modeling and simulation offers a powerful tool to investigate muscle force contributions and joint contact loads during gait modification. Our findings suggest that toe-in gait modification is a viable method for reducing knee joint loads and may serve to relieve knee pain due to medial knee OA. Further research is needed to determine optimal whole-body kinematics to minimize joint loads through gait modification.

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References: [1] Shull, PB, et al., *J Orthop Res* **31(7)**:1020-5, 2013. [2] Shull, PB, et al., *J Biomech* **46(1)**:122-8, 2013. [3] Seth, A, et al., *IUTAM* **2(1)**:212-232, 2011.