Muscle Contribution During Varus Knee Gait

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I. Introduction

Knee adduction is often associated with osteoarthritis. In a knee with varus deformity some of the contact load is shifted to the medial compartment of the knee. This transfer of the load-bearing axis makes normal gait painful and difficult. Despite the fact that osteoarthritis is common among elderly patients, there are currently few clinical interventions to slow the progression of osteoarthritis. One of the most common treatments is a high tibial osteotomy (HTO). This surgical procedure a wedge is removed or added to the tibia to change from a varus stance to slightly valgus. [1]

Noninvasive treatment options which have been explored are modifications to gait. The modifications which have proven to effectively shift the load-bearing axis from the medial compartment towards the center of the knee are: toeing out, walking at a slower pace, decreasing stride length, increasing medial-lateral trunk sway, and using lateral heel wedges. Although each of these have had a desired effect on shifting the load-bearing axis, the extent to which each modification needs to performed to achieve a small shift in load creates an abnormal looking gait, and they do not have consistent results between patients. [2], [4], [13], [14]

In order to create better treatment plans, which can be personalized to each individual patient, it is important to know how different muscles contribute to knee adduction for multiple degrees of varus alignment. This study seeks to look at how several lower extremity muscles contribute to adduction. Based on this knowledge it may prove more beneficial to strengthen particular muscles in place of or in addition to modifying gait.

II. Methods

The model contained 10 segments, with 25 degrees of freedom, and 54 muscles. The pelvis was also a single rigid body, with 6 DOF. The head, arms, and torso (HAT) are also represented as a single rigid body, and articulated with the pelvis with 3DOF. Each hip was a 3 DOF ball and socket joint. The knees each had 2 DOF, flexion and varus. The varus degree of freedom was locked during gait simulation, so the knee operated as a single DOF hinge joint. The foot was comprised of two segments the hind foot and the toes. The hind foot used a 2 DOF universal joint, and the toes were a 1DOF hinge joint. Details relating to the axes and centers of rotation of the joints are given in Anderson [3].

The simulation used gait data for patients with normal knees. To maintain the varus knee angle, the varus DOF in the knee was locked in place throughout the process. Inverse dynamics was used to determine the moments at each joint. Then static optimization was used to determine the activations and forces produced by the muscles. A 6 Hz low pass filter was used in both the inverse dynamics and static optimization processes. This process was repeated with the knee varus DOF locked at 0°, 5°, and 10°.

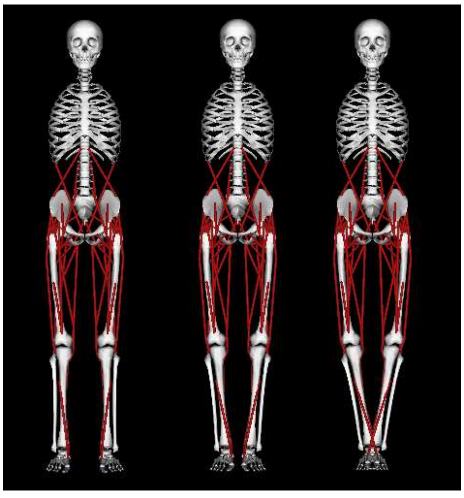

Fig.1. Model with knee varus degree of freedom at 0°,5°, and 10° (from left to right).

III.	Results

As the model is not patient specific, symmetry was assumed between the right and left side. Therefore only half a gait cycle was needed. Data was computed for just before right heel strike to just before right heel strike, and only for the right side.

It was found that in general the forces and activation levels for hip flexor muscles were decreased, and those for hip extensor muscles were increase. The knee flexor muscles overall had decrease forces and activations, while knee extensors were increased. The resultant was a straighter leg during the swing phase of gait. This may be due to the fact that a varus knee deformity shortens the length of the leg. Thus, the varus leg would not need to flex as much as a normal leg to clear the floor and avoid a dragging effect.

The most significant decrease in hip and knee flexion can be seen in the Figure 2, in the gracilis. For a normal knee the gracilis is activated between 40% and 68% throughout the gait cycle. While in both the 5˚and 10˚ varus knee results, gracilis activation never exceeds 20%. This causes a difference in force of around 100N along the entire gait cycle.

It was also found the plantar flexors increased the forces they produced. This may be in order to try to lengthen the leg slightly to match the motion of a normal knee gait.

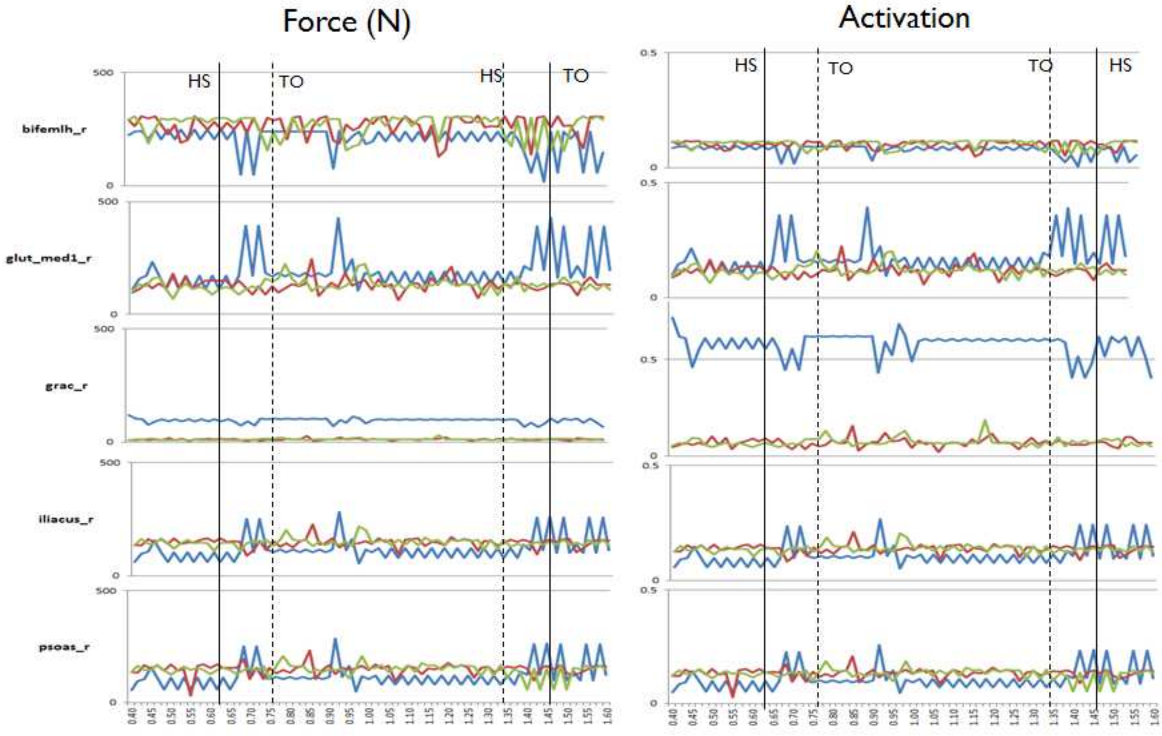

Figure 2. Muscle force and activation for some muscles.

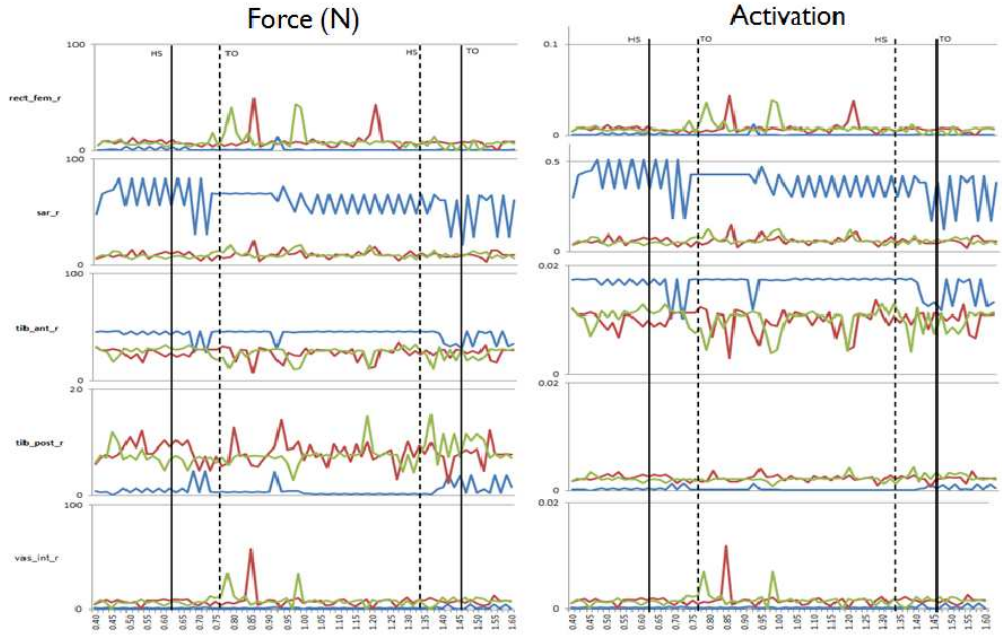

Figure 3. Muscle force and activation for some more muscles.

IV. Discussion

It is important to be able to predict movement, because it allows for further investigation of how the structure and function of a model affect the movement. Predicted changes in the model could then be used to recommend treatments for a patient with higher success rates. However, a model is only useful in improving treatments if its predictions are accurate. In this simulation the gait data used was that of a normal patient. There was no experimental gait data from patients with varus knee deformity to compare to the model's predictions. If the models prediction could be confirmed close to actual gait of patients with a varus knee deformity, it could be a powerful tool in prescribing treatments.

The model used has been used to predict vertical jump [3], and normal gait optimization [5]. Each of the activities allowed for the model to be modified improving its accuracy. One issue that may cause inaccuracies for this use of the model is at 10° the medial portions of the tibia and femur overlapped. Since this is anatomically impossible it may cause errors in the predicted results.

Referecnces

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