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Determining Knee Loading for Abnormal Gait

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BACKGROUND

Understanding the loads in a joint for different types of gait is essential to analyze and understand the implications of abnormal forms of gait. The calculation of knee loads from the hip would be useful in understanding what is happening in the knee throughout gait. More specifically, these loads would be helpful when performing a deeper analysis such as a finite element model.

OBJECTIVES

The objective of this study was to take known experimental loads found at the hip and to calculate the corresponding loading at the knee. In addition to finding the loads at the knee for normal gait, the loads would then be augmented in a way as to simulate bowlegged gait. After the loads were calculated, we were to plot the loads graphically so that the trends through gait could be more readily visualized.

DEFINITIONS

- **Normal Gait:** The walking pattern of a person who goes through the gait cycle without any known pathological variations of gait.
- **Abnormal Gait:** The walking pattern of a person who has at least one pathological variation of gait.
- **Bowlegged Gait:** The specific pathological variation of gait where the knees are positioned more laterally. This causes the person to have an outward bend in his or her legs.
- **Varus:** A type of bowlegged gait in which the outward bend of the leg is caused by an angle in the frontal plane of the body.
- **External Rotation of the Femur:** A type of bowlegged gait caused by the rotation of the femur in the outward direction which causes the leg to move laterally in the forward positions of gait.
- **Mechanical Axis of the Femur:** The axis which goes from the center of femoral head to the center of the knee.

Figure 1: *The mechanical axis of the knee and the variation of the mechanical axis that is defined as varus.*

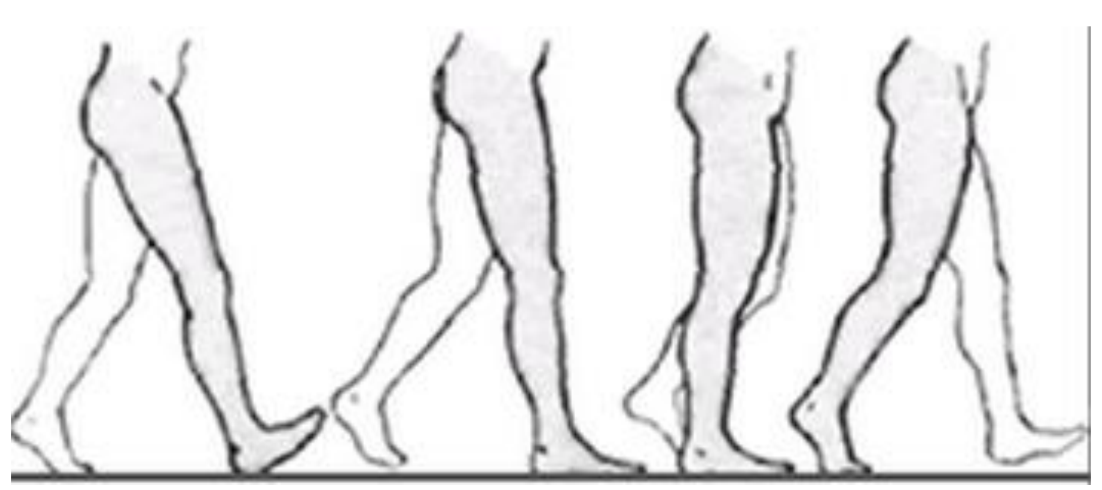

Figure 1: *The typical movement of a single leg through half of gait. This only represents a single leg through the stance phase of gait and does not show the swing phase.*

Rotation of Hip Loads

The premise of the ability to augment the loads at the hip for normal gait was based upon the assumption that the magnitude and location of the loads from the hip would be the same for each type of gait. With this assumption, we continued that we could then simulate the loads for each type of abnormal gait (varus and external rotation of the femur) by rotating the vector of the load on the femoral head. Changing different angles of the vector about the femoral head would be able to simulate different forms of gait.

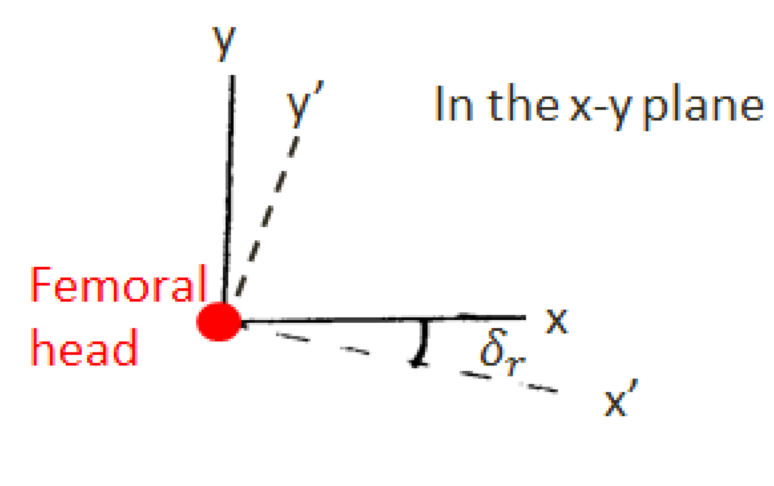

Figure 3: *The angle defined as the angle of rotation for the calculation of loads at the knee.*

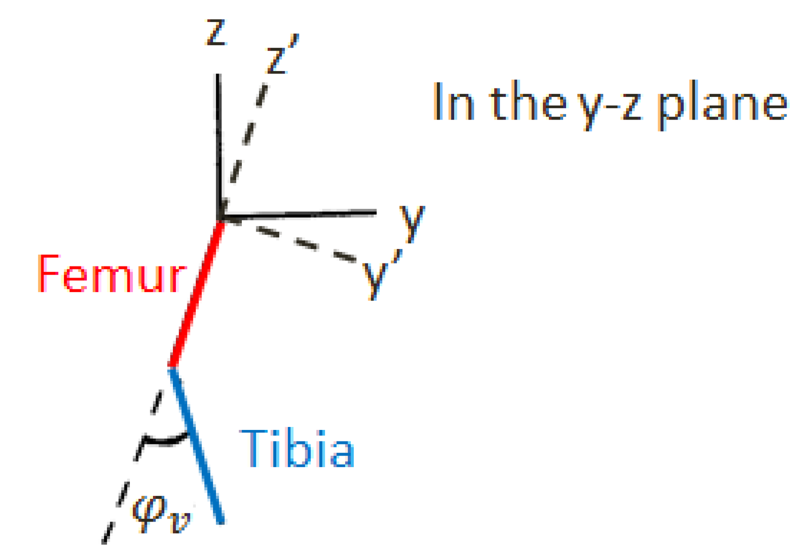

Figure 4: *The angle defined as the varus of the knee used for calculation of the loads at the knee..*

The above angles are the particular angles which defined the two abnormal gaits of interest. The varus angle rotates more laterally about the femoral head. This represents the movement of the knee in a lateral direction as the location of the load in relation to the pelvic bone doesn't move. The same goes with the angle representing the external rotation of the femur, as the angle of the load rotates, it simulates the movement of the femur with relation to the fixed location of the load in the pelvis.

Static Model

In order to calculate the loads at the knee, static equilibrium was assumed and equilibrium equations were then used. This was done after the loads were rotated. The loads that were rotated were retrieved from *Realistic Loads for Testing Hip Implants* by Bergman et al., (2010). The loads retrieved from the article gave a matrix of information which gave the loads for the gait throughout the gait cycle.

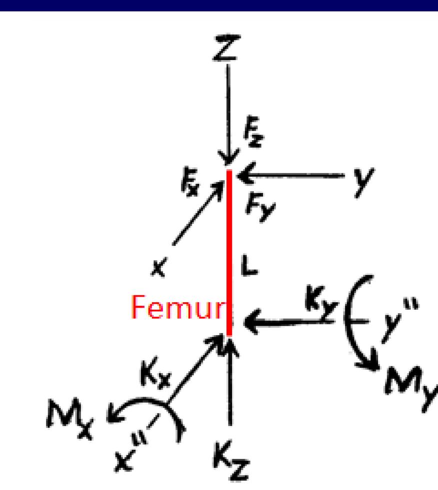

Figure 5: *The Free Body Diagram of the femur.*

Therefore, the loads were calculated at the knee throughout all of gait. The loads for two critical positions of gait were then given: the maximum force and the maximum moment. These maximum forces and moments were calculated using the static model mentioned above.

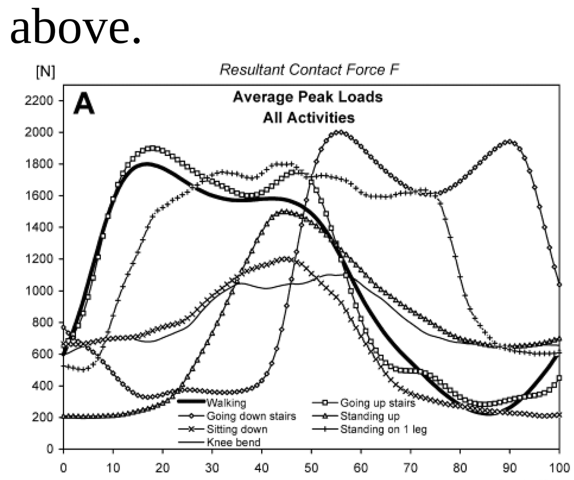

Figure 6: *The loads at the hip for different types of gait given by Bergman et al. (2010).*

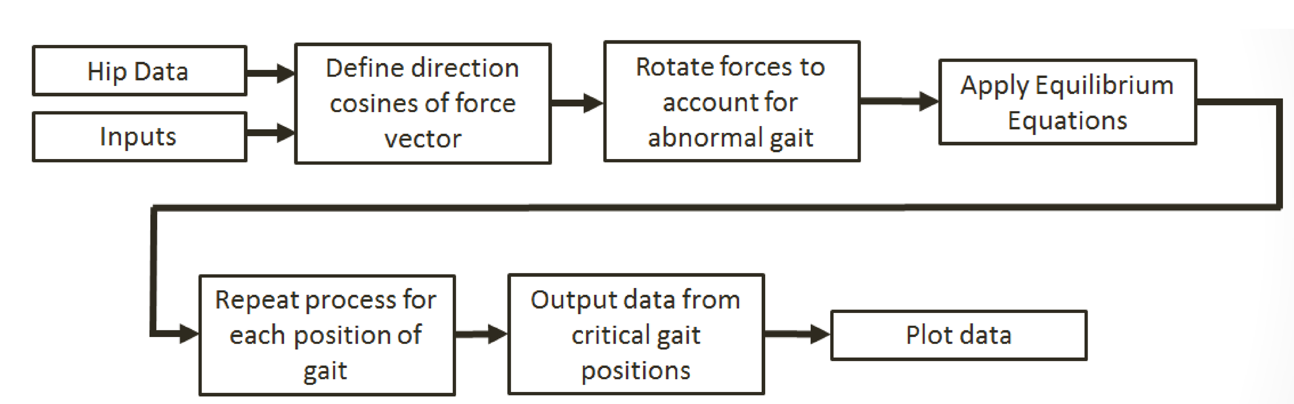

Figure 7: *The flow chart that visually demonstrates the way the information is processed in the static equilibrium model. In other words, this is the way the code programmed goes about solving the model.*

Plotting the Loads

We then needed a visual in order to assist in the interpretation of the loads at the knee throughout the entire gait cycle. The first figure shown uses a contour to replicate the rough shape of the femoral condyles at the knee. The vectors below it then show the varying forces applied throughout gait for both normal and abnormal gait.

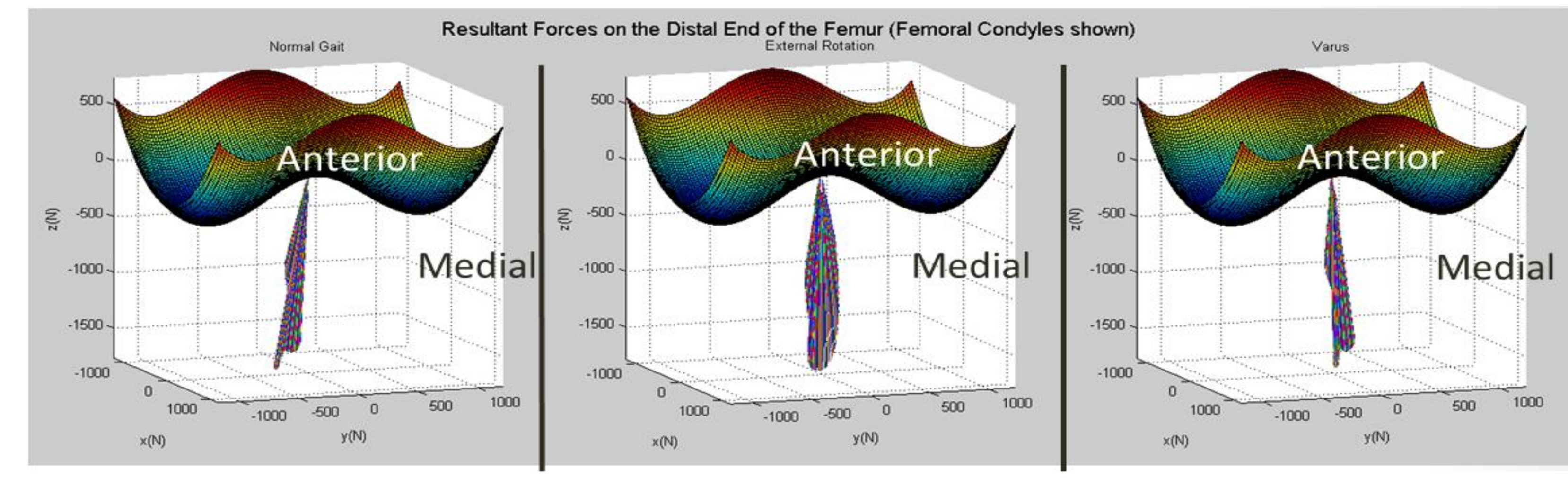

Figure 8: *The resultant forces acting on the center of the knee with the femoral condyles shown.*

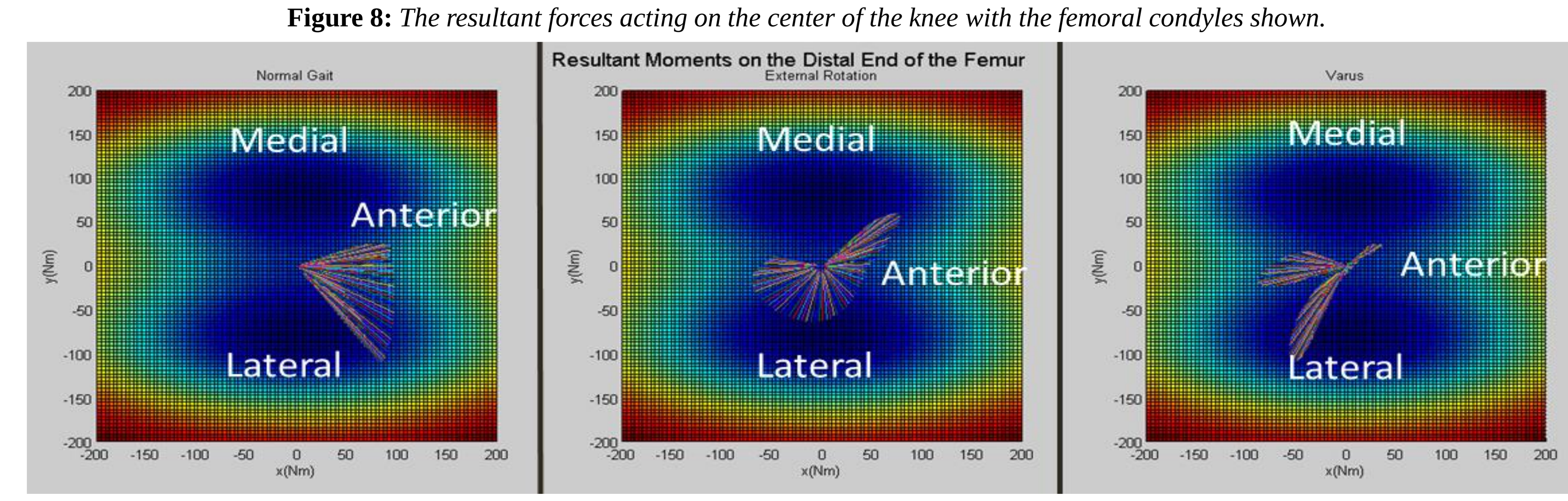

Figure 9: *The resultant moments acting on the knees with the countours showing the shape of the femoral condyles looking from above.*

The second figure plots the reaction moments at the knee. It is shown in a two dimensional figure because there are no moments in the z-direction. This is because the model went along the mechanical axis. The color gradient showed us the femoral condyles as looking from above the femur.

Visual Representation of the Loads

In addition to the plotting of the loads, the loads for the critical positions of gait were shown as applied to the distal end of the femur. This model was along the mechanical axis which meant that the loads were applied to the center of the knee. The loads are shown in the figure below.

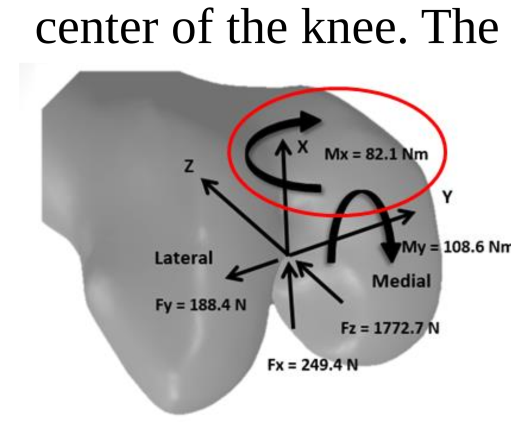

Figure 10: *The resultant loading at the knee along the mechanical axis for normal gait.*

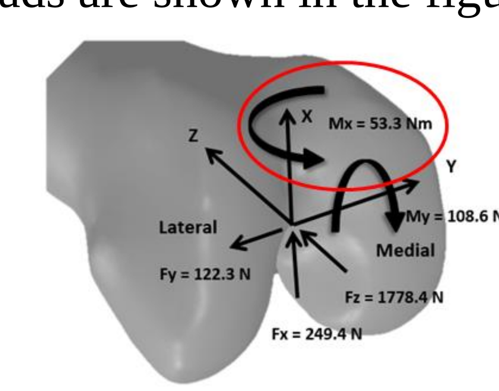

Figure 11: *The resultant loading at the knee along the mechanical axis for a gait with varus.*

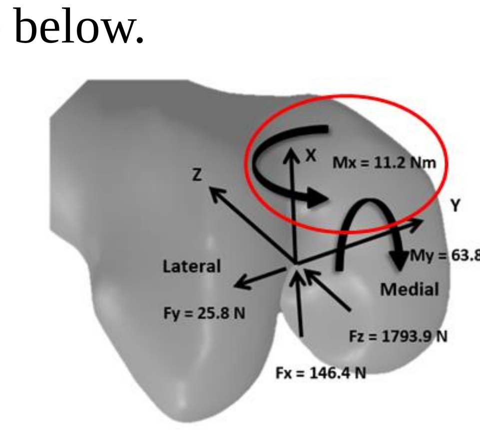

Figure 12: *The resultant loading at the knee along the mechanical axis for an external rotation of the femur gait.*

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