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 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.

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.

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. 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.

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 femoral condyles at the knee. The vectors below it then show the varying forces applied throughout gait for both normal and abnormal gait.

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.

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