Weight Bearing Patellofemoral and Femorotibial Contact Mechanics for Overground Gait

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INTRODUCTION: Overground gait is the single most common activity of daily living in which humans participate, with the average person taking roughly 2,000,000 or more steps annually. Experimental evaluations of gait can be difficult, particularly in subjects with total knee arthroplasty (TKA). Gait labs, although valuable, fail to capture what occurs inside of the knee. Many previous fluoroscopic studies have incorporated treadmills to capture multiple steps, but it is documented that treadmill gait is largely different than overground gait [1]. Similarly, attempts to collect overground gait using fluoroscopy can be limited due to a lack of space for performing multiple steps. Finally, although fluoroscopic or telemetric studies have provided femorotibial insight, less insight is available with respect to patellofemoral mechanics. Theoretical mathematical modeling can provide a solution to some of these problems by allowing for accurate in vivo inputs and greater understandings of the detailed femorotibial and patellofemoral mechanics. The objective of this study is therefore to use forward solution mathematical modeling to analyze both femorotibial and patellofemoral mechanics during the stance phase of gait.

METHODS: A previously validated, 3D forward solution model of the knee was used to evaluate femorotibial and patellofemoral mechanics for a single subject implanted with an Attune® CR TKA construct with Medialized Dome patella (DePuy Synthes) performing a level gait activity. The model uses a contact detection algorithm, which also allows for predictions of contact area, to evaluate the contact between articulating surfaces, and a muscle-controlled algorithm to drive the different activities. Specific parameters of interest include both femorotibial and patellofemoral contact forces, contact area, and contact stress.

RESULTS SECTION: In line with previously reported data, the femorotibial joint experienced a maximum contact force of 2.2 xBW with the presence of the standard "M-curve" pattern. The patellofemoral joint experienced substantially less contact force than the femorotibial joint during the entire stance phase, with a maximum of 0.3 xBW (Figure 1). Throughout stance phase of the gait, the femorotibial joint experienced a consistent contact area with a maximum of approximately 463 mm^2, compared to the patellofemoral joint experiencing 138 mm^2 or less (Figure 2), likely due to the patellofemoral articulation between the patellar button and proximal aspect of the femoral trochlear groove. Accordingly, the femorotibial joint experienced a higher contact stress than the patellofemoral joint (Figure 3).

DISCUSSION: The femorotibial results from this study appear to correlate well with previously available telemetric data, serving as an initial correlation towards the accuracy of this gait model [2]. The results presented here demonstrate initial capabilities of a forward solution model to predict contact areas and stresses of both the patellofemoral joint as well as the femorotibial joint for common activities of daily living. Furthermore, the addition of this activity to a previously validated model serves as a large milestone towards TKA evaluations, as gait is an activity that is significantly more common than previously analyzed high flexion activities such as squatting, stair descent, rising from a chair, etc. Furthermore, gait models can overcome previous experimental limitations associated with analyzing this activity. Although the contact mechanics during gait show less overall stress and more overall stability than other activities, intelligently using these modeling techniques to investigate component designs, alignments, and safe zones can provide deeper long-term insight into contact mechanics and fatigue loading of high frequency activities.

SIGNIFICANCE/CLINICAL RELEVANCE: Controlled investigations using mathematical modeling can provide powerful clinical insight into the effects of component misalignment, design changes, surgical technique, and more. Having the capability to analyze a common activity such as gait can provide further insight into contact mechanics of high frequency activities where implant failures may be due to repetition and fatigue as opposed to significant impulse loading.

REFERENCES

[1] Lee SJ and Hidler J. "Biomechanics of overground vs. treadmill walking in healthy individuals." J Appl Physiol. 2008 Mar;104(3):747-55.
[2] Bergmann G, et al. "Standardized loads acting in knee implants." PLoS One. 2014 Jan 23;9(1):e86035.

FIGURES:

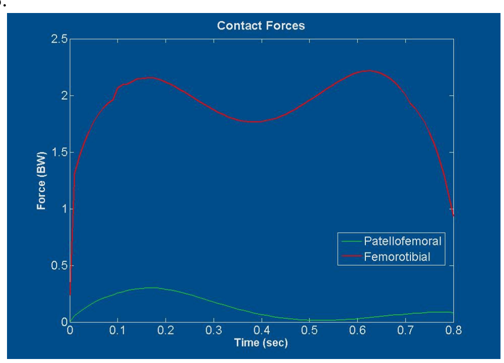

Figure 1: Femorotibial and Patellofemoral Contact Forces.

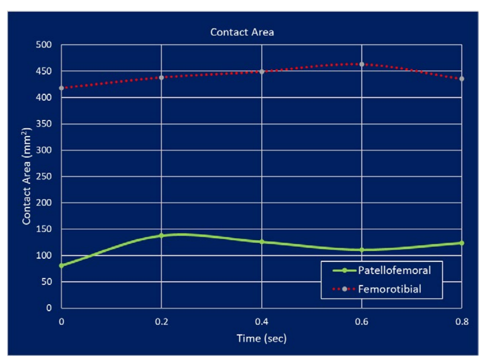

Figure 2: Femorotibial and Patellofemoral Contact Area

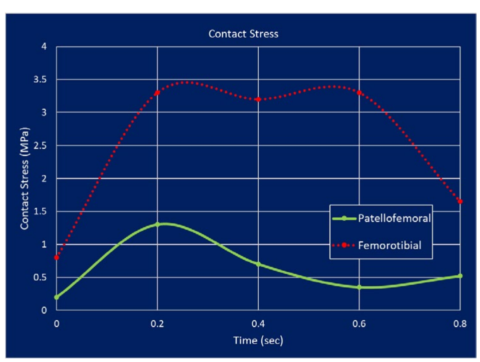

Figure 3: Femorotibial and Patellofemoral Contact Stress.