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USING MUSCULOSKELETAL SIMULATIONS TO AID IN KNEE BRACE DEVELOPMENT

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Summary

Knee braces have been proposed to prevent anterior cruciate ligament (ACL) injury, and musculoskeletal (MS) models can be used to assess the effect of such braces on joint mechanics. Therefore, the aim of this study was to use MS simulations to estimate the effect of an *in silico* ACL injury prevention brace. Motion capture and force plate data recorded of one subject, performing movements with high ACL injury risk were used to drive a lower-limb inverse dynamic model with, and without, the equivalent loads of a virtual brace that applied a posterior force and internal axial moment to the shank. A second MS model using the force-dependent kinematics method was used to estimate the effect of the brace on ligament loading, secondary joint kinematics, and contact forces. The results suggest that MS simulations are a powerful tool to assess and design knee braces.

Introduction

A significant increased risk of developing knee osteoarthritis is related to anterior cruciate ligament (ACL) injuries, either from trauma occurred during the injury or from changes in knee kinematics [1]. Knee braces that help stabilize the knee have been proposed as a method to reduce incidence of ACL injuries [2]. Nonetheless, the effect of such braces on knee joint loads is difficult to measure. However, musculoskeletal (MS) models are used by the scientific community to study internal joint mechanics and accordingly MS simulations represent an opportunity to estimate the effect of external devices on knee mechanics. Therefore, the aim of this study was to assess the effect of a ACL injury prevention brace concept on ACL loading through musculoskeletal simulations.

Methods

One subject (25 year old male, m: 87 kg, h: 1.84 m) was recorded with Qualisys motion system (Qualisys, Sweden) and a force platform (AMTI Corp., USA). The subject performed three different movements, where he ran at a self-selected speed and made a 45º change in direction, a side-step, and a pivot over his right leg with an abrupt decrease in velocity.

The motion capture was used to drive an inverse dynamic model in the Anybody Modeling System (AMS) (Anybody Techology, Denmark). The model had implemented the Twente Lower Extremity Model (TLEM) 2.0 with a revolute knee joint. The effect of a virtual knee brace to prevent ACL injuries was simulated by applying an anterior force and an internal moment to the shank relative to the knee flexion angle, and opposite in the thigh. Thereafter, specific outputs from the inverse dynamic analysis, with and without the brace, were used to drive a 6 degrees of freedom (DOF) knee model.

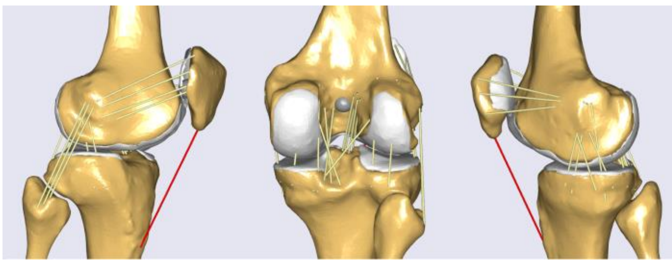

Figure 1: From left to right: lateral, posterior and medial views of the force-dependent kinematics knee.

This second model consisted of a non-subject-specific femur, tibia, patella, tibiofemoral and patellofemoral articular cartilage, and ligaments (Fig. 1). The knee revolute joint was here substituted by a 6 DOF tibiofemoral joint and analysed using the force-dependent kinematics (FDK) method [3]. The previously estimated knee flexion angle and loads at thigh and patella were used to drive the FDK knee, while the tibia was grounded.

Results and Discussion

Estimated effects of the brace on ACL loading are shown in Figure 2 during two different trials. A mean decrease of 18% ACL loading was found. Significant changes in ligament loading were also found for the posterior cruciate ligament (30% increase) and lateral collateral ligament (47% decrease). Predicted secondary joint kinematics and contact forces were also affected by the brace. The individual effects of each load or its implication on muscle activations were not studied.

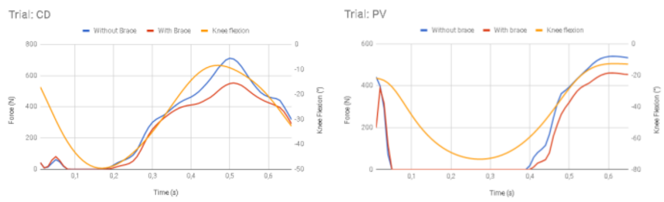

Figure 2: Brace effect on ACL loading during a change in direction (left) and a pivot turn (right).

Conclusions

Our simulations suggest that ACL loading can be reduced applying a functional brace and that musculoskeletal models are a powerful tool in the design and study of braces that affect joint mechanics.

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