EFFECT OF ACTIVE MUSCLES ON KNEE LIGAMENT FORCES DURING IMPACT

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INTRODUCTION

Lower extremity is the second most injured body region in car-pedestrian collisions. To develop safer car fronts, injury mechanism must be known. Volunteer experiments, for obvious ethical reasons, can not be performed in higher injury severity range, whereas, other alternatives, such as, PMHS and instrumented ATD's do not account for live muscle actions. However, it is expected that muscle forces at joints maintain a posture and affect the post impact kinematics and stresses. Injury prediction for pedestrians becomes even more difficult due to their variety of pre-impact postures which are directly controlled by the muscle forces. Finite element modeling has facilitated the study of effect of muscle actions on knee injuries at low speed (20 Kmph) lateral impact.

METHODS

40 muscles are modeled on a validated lower extremity FE model [1]. The FE model includes cortical and spongy part of bones, passive muscles, skin and four knee ligaments (ACL, PCL, MCL, LCL).

Muscles are modeled using 1-D bar elements between insertion points taken form previous cadaver dissection studies. Hill muscle model is implemented to capture live muscle activation effects such as voluntary and involuntary reflexes. Parameters such as muscle optimum length, maximum contraction / elongation velocity, maximum muscle force, penation angle, reflex time constant and initial value of activation levels are used to define Hill muscle cards in PAM-CRASH™.

The impact forces in the modified lower extremity FE model with minimal muscle forces (activation level of 0.005), are compared with experimental [2] as well as results of simulations without muscles [1] (Fig 1). This establishes the correctness of muscle definition in our model.

This validated model is then used to study the effect of muscle contraction on knee injuries of an unaware pedestrian in standing posture at low speed lateral impact. Appropriate muscle activation levels, required to maintain standing posture, are assigned for the pre-impact stage. Reflexes are activated to account for involuntary muscle contraction during impact event. Simulations are performed for just-below-knee and ankle impact, with and without muscles.

RESULTS

A comparison of ligament forces with and without muscle activation (Fig 2) reveals significantly lower ligament forces when muscles are activated (with the exception of the ACL in the ankle impact). In the ankle impact muscle reinforced interlocking between the tibia and femur causes larger ACL forces. This is not entirely unexpected. These results reinforce the hypothesis that muscles significantly affect the knee joint in impact loading. Their effect in other postures is now being investigated.

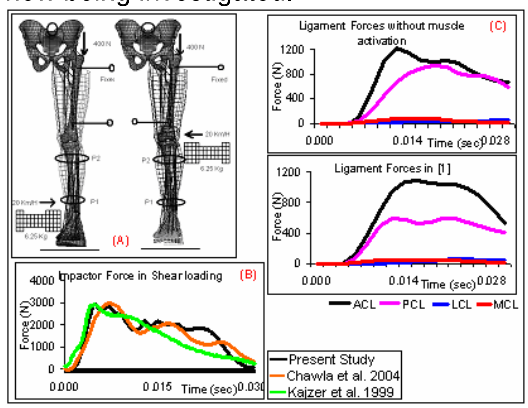

Fig 1: FE model Validation (A) Simulation set up for bending (left) and shear (right) load (B) Comparison of impact force in shear loading (C) Comparison of ligament force between present model (above) and [1] (below) in shear loading

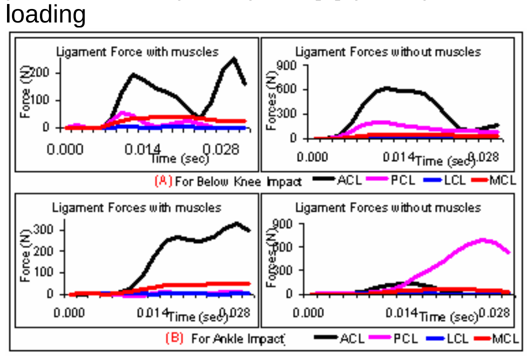

Fig 2: Ligament forces for knee impact in a standing posture with and without muscles (A1, A2) Below-knee impact (B1, B2) Ankle impact

REFERENCES

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2. Kajzer, J., Ishikawa H., Matsui Y., Schroeder G., Bosch U. (1999) Shearing and Bending Effects at the Knee Joint at Low Speed Lateral Loading, SAE Paper 1999-01-0712.