A Validated Hip Finite Element Model for Simulating Pedestrian Accidents

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BACKGROUND

Pedestrians represent one of the most vulnerable road users and comprise about 23 % of the road crash related fatalities in the world. Therefore, pedestrian protection during Car-to-Pedestrian Collisions (CPC) accidents has generated increased attention with proposed regulations which involve subsystem tests. Finite element (FE) models of pedestrians are used in CPC simulations to investigate pedestrian injury responses. FE models are limited by how extensively validated they are. Two of the popular pedestrian models are the THUMS and GHBMC models. These models are well validated but neither model has reported validation data for hip joint loading.

OBJECTIVE

The goal of this study was to validate a hip joint in various loading scenarios and determine its effect on vehicle-pedestrian interactions in a CPC simulation.

METHODS

The GHBMC 50th percentile simplified male pedestrian (M50-PS) [1] was acquired and virtually dissected to isolate the hip joint.

The hip joint was loaded in four calibration tests.

1. Femoral head ligament quasi-static tension [2]
2. Hip joint quasi-static adduction [3]
3. Hip joint quasi-static abduction [3]
4. Hip joint quasi-static extension [3]

Hip properties, such as hip capsule thickness and femoral head ligament stiffness, were calibrated to match Post-Mortem Human Surrogate (PMHS) test data.

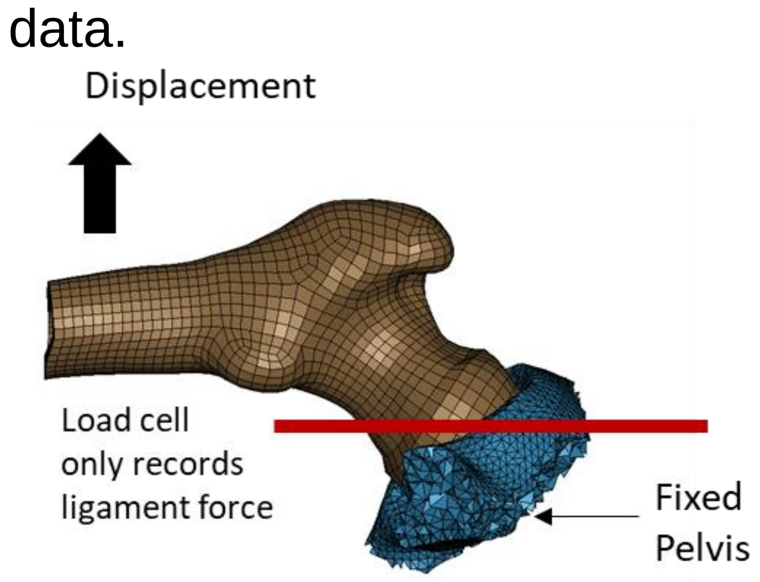

Figure 1: Femoral head ligament calibration setup

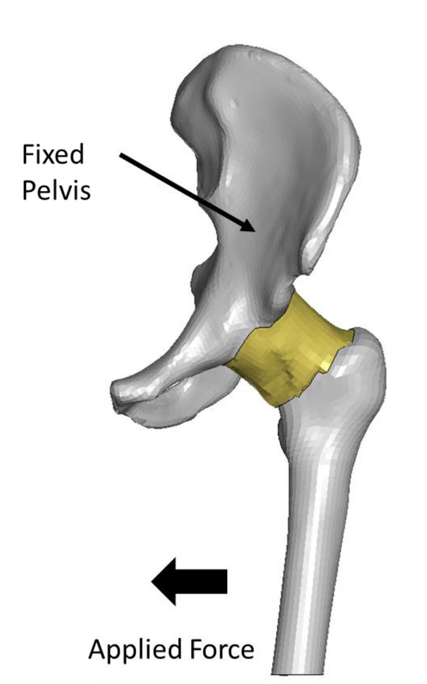

Figure 2: Hip adduction calibration setup

METHODS

The calibrated hip properties were input into the M50-PS model[1], creating an original and a calibrated model. Both pedestrian models underwent a CPC impact scenarios with validated simplified generic vehicle bucks representing a sedan traveling at 40 km/h [4]. The posture of the M50-PS model was set to mid-stance with the legs apart walking towards the vehicle centerline then the rearward leg was impacted first by the vehicle, based on the PMHS test setup. Kinematic trajectories of the body parts were recorded relative to the vehicle and kinematics between the pedestrian and vehicle were recorded and compared to scaled PMHS data. The beginning and the end of the outputs were defined at the time of initial right leg-bumper contact and the initial time of the head-hood contact, respectively.

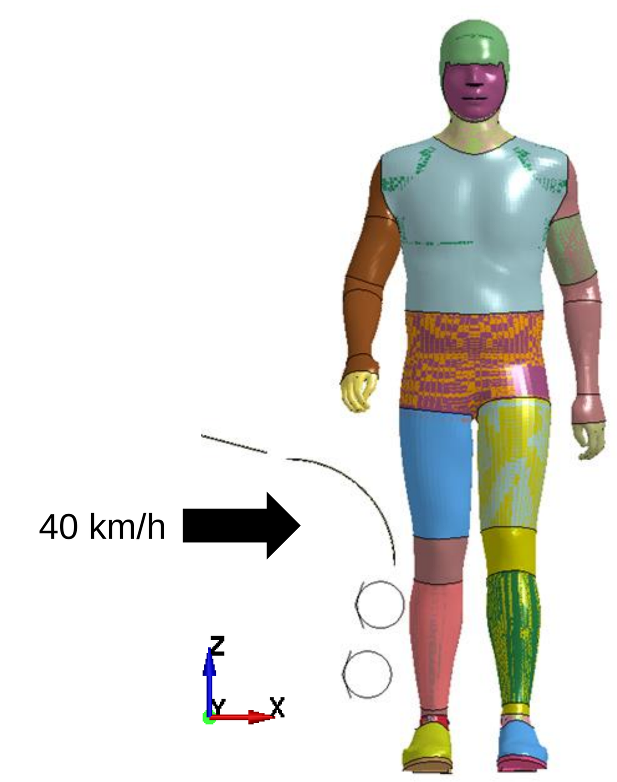

Figure 3: CPC scenario setup with generic sedan buck

RESULTS

Upon calibrating the femoral head ligament stiffness property, the ligament model reported force-displacement data within one standard deviation of PMHS data (Figure 4). Upon calibrating hip capsule thickness, all three hip joint rotation tests (abduction, adduction, and extension) reported values within one standard deviation of PMHS data (Figure 5).

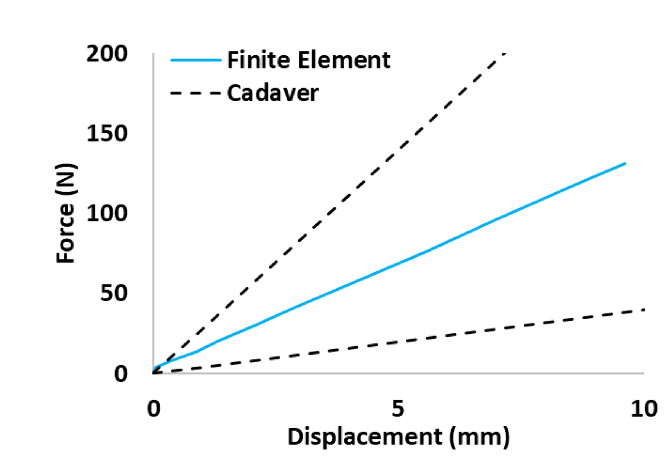

Figure 4: Femoral head ligament calibration results

The calibrated M50-PS, and original models reported similar kinematic outcomes, both falling within the range of PMHS data for the majority of responses (Figure 6). The greatest discrepancies were noted in the T12, Superior Sacral, and Inferior Sacral trajectories, but differences were small.

Forces between the vehicle and pedestrian did not vary greatly between the two pedestrian models either.

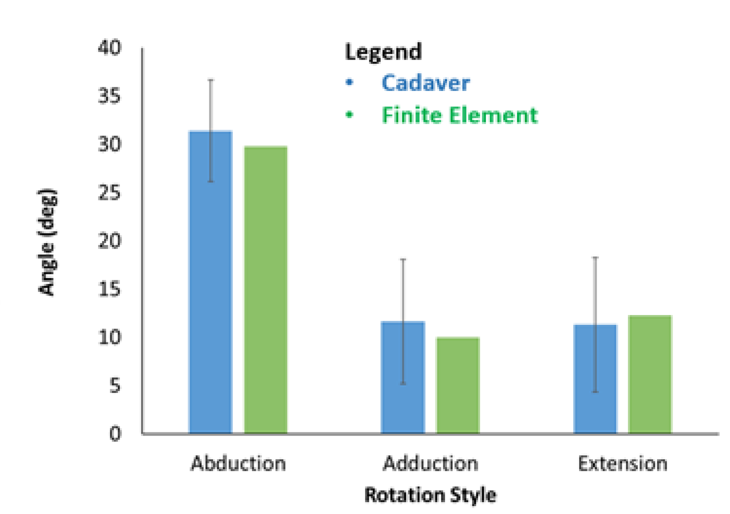

Figure 5: Hip rotation calibration results

RESULTS

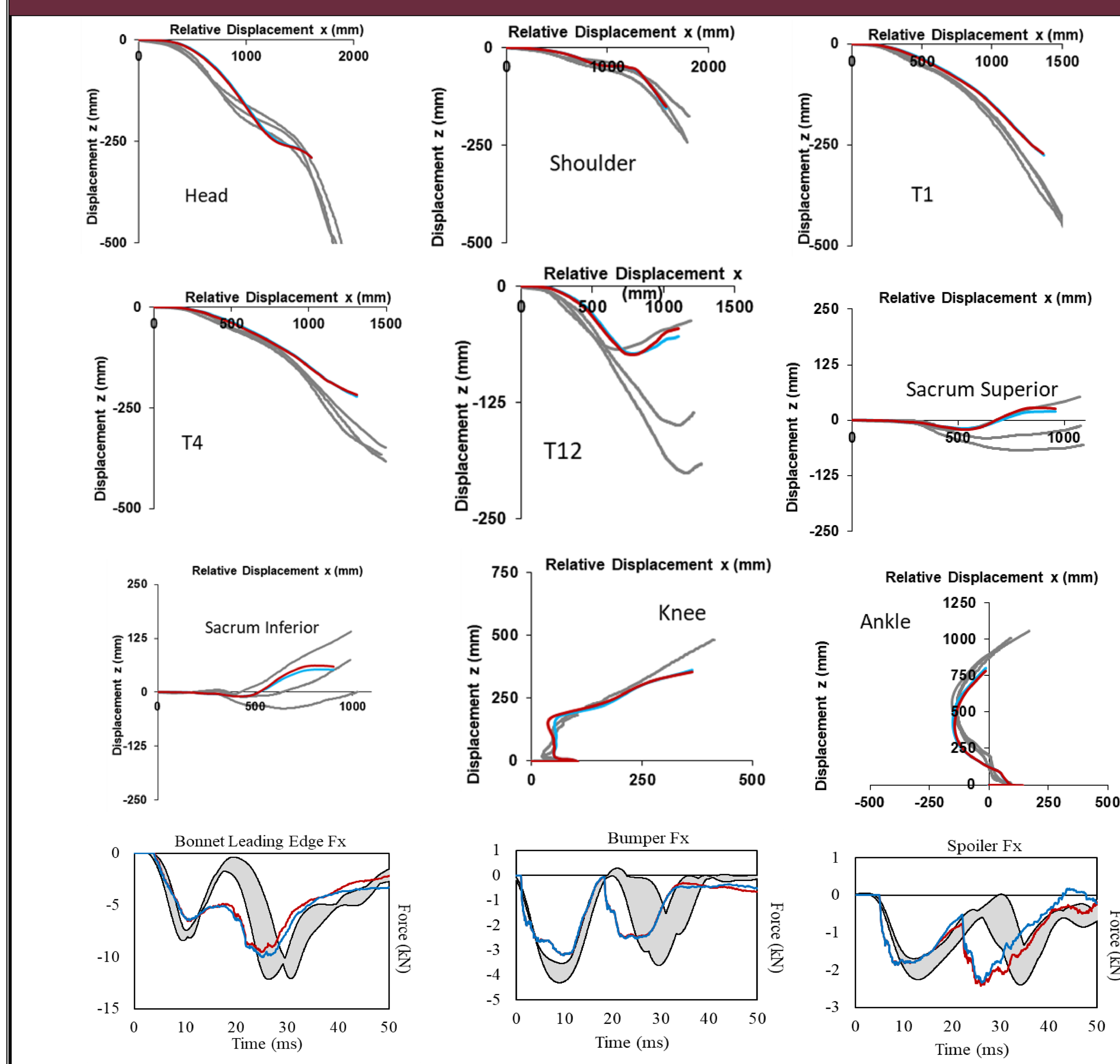

Figure 6: Pedestrian Kinematic and kinetic PMHS trajectories (**grey**), M50-PS model calibrated, (**red**) and original (**blue**) hip properties

CONCLUSIONS

Hip stiffness played little role in CPC kinematic and kinetic outcomes. This lack of biomechanical difference suggest that the hip doesn't play a large role in resists CPC loading. This may be because the initial impact point is below the knee, causing the knee joint to absorb most of the impact. Future work should examine CPC with higher profile vehicles.

REFERENCES

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ACKNOWLEDGEMENT

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