Using Explicit Finite Element Models for Designing a Dynamic Cadaveric Sideways Fall Experiment

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INTRODUCTION

The majority (>90%) of hip fractures are thought to be a result of low height falls. These injuries are often associated with a reduction in mobility and increase in mortality. Methods to estimate the femur load during these falls are so far limited to spring mass models. These models use velocities from human volunteers falling on compliant surfaces, and effective mass and linear stiffness data for the pelvic region based on low-height falls. To address the limitations of these models we are developing biofidelic dynamic finite element models (FEMs) of sideways falls and validating these models using cadaveric specimens.

MATERIALS & METHODS

- Calibrated CT data for a 19 y.o. female was used (170 cm, 54 kg, T-score = -0.7, VSD, https://www.smir.ch/)
- Material properties were assigned based on CT scans and literature
- Models were solved with explicit FE LS-Dyna (Livermore Software Technology Corp.)
- Three experimental designs (Figure 1) were compared:
  (I) a stationary pelvis impacted in a drop tower with a padded falling mass;
  (II) a pelvis dropped in a drop tower and covered with soft tissue;
  (III) a pelvis covered with soft tissue and subjected to a pendulum drop which incorporates rotation.
- An initial kinetic energy corresponded to 38% body mass impacting at a speed of 3 m/s was applied.

RESULTS

- Impact and femur forces decrease from Setup I-III.
- The ratio between impact and femur force increased when replacing rigid mass with soft tissue.
- The strain pattern suggest a likely fracture for Setup I and II and an unlikely fracture for Setup III.

DISCUSSION

We consider the pendulum boundary conditions (III) to represent the most biofidelic boundary conditions:
- Detailed model of soft tissue and fall motion derived from video recordings of human falling
- Effective pelvic stiffness of 55 N/mm comparable to 51 N/mm for low height falls found in literature [3].
- Important differences with respect to peak impact force and energy absorption were found between Setup III and Setup I and II.

CONCLUSION

Three basic boundary condition designs were evaluated for the load experienced by the femur.
- Simplification of the boundary condition, beyond Setup III, should be avoided
- A pendulum set up with soft tissue was chosen for the design of a biofidelic hip impactor.

REFERENCES