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

Ingmar Fleps[1], Jonah Killiam[2], Peter A. Cripton[2], Stephen J. Ferguson[1], Benedikt Helgason[1]
[1]**Institute for Biomechanics, ETH Zurich**
[2]Orthopaedic and Injury Biomechanics Group, Departments of Mechanical Engineering and Orthopaedics, University of British Columbia, Canada

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.(170cm, 54kg, 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.

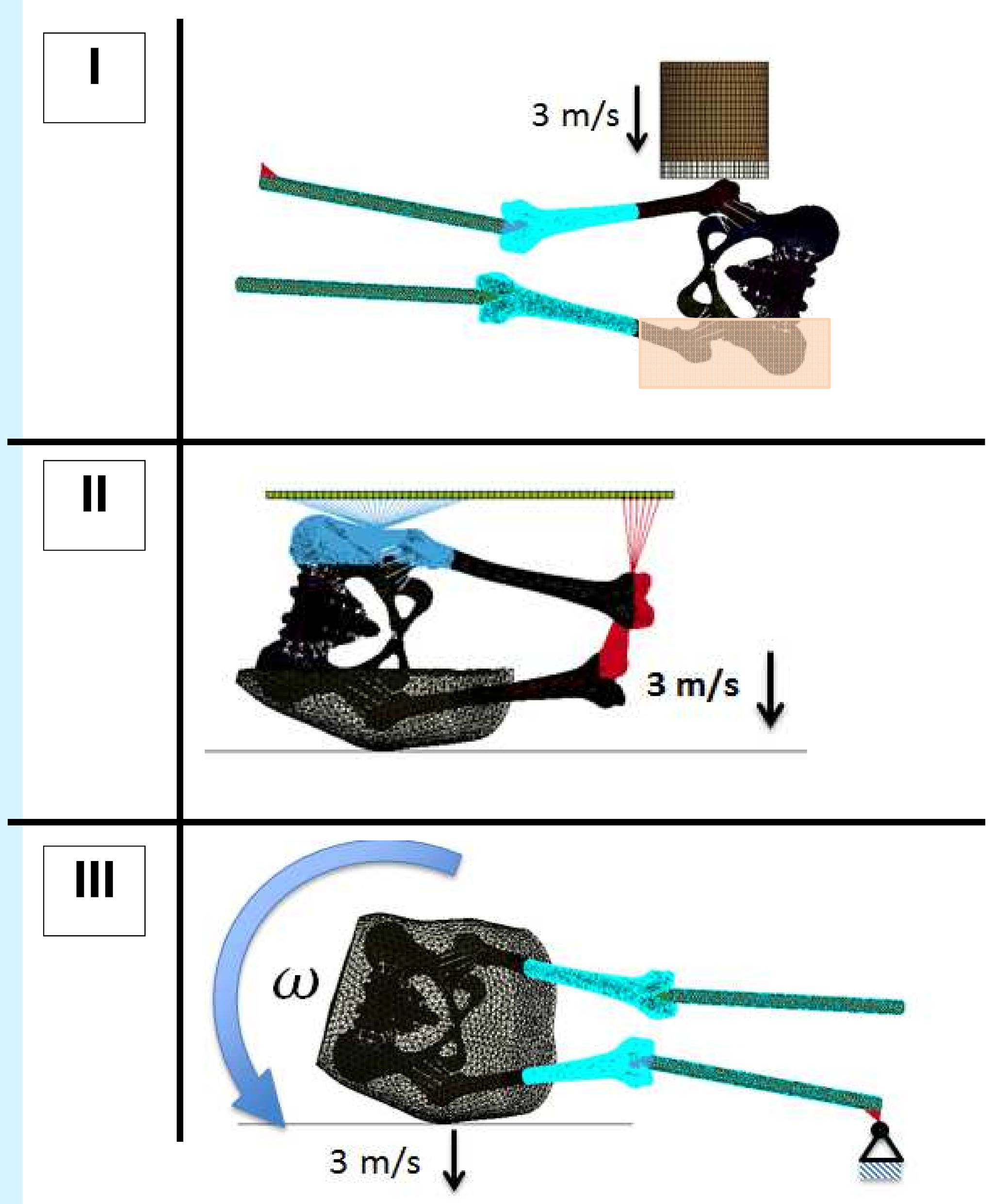

Fig. 1 Schematic boundary condition for Setup (I) left, (II) middle and (III) right.

RESULTS

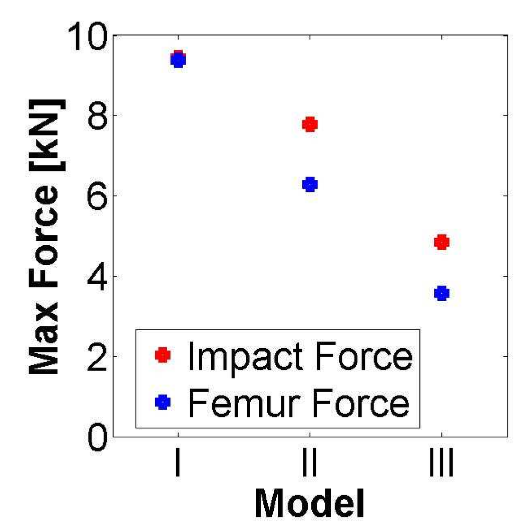

Fig. 2 Force experienced by the impact surface (impact force) and force transferred from the femur to the acetabulum (femur force) for Setup I-III

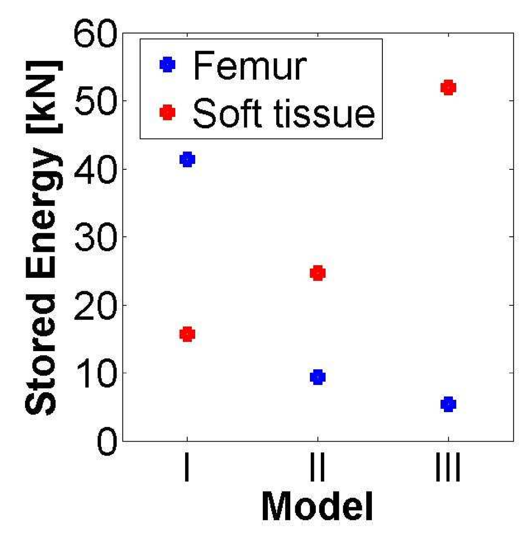

Fig. 3 Energy stored in the femur and the soft tissue for Setup I-III

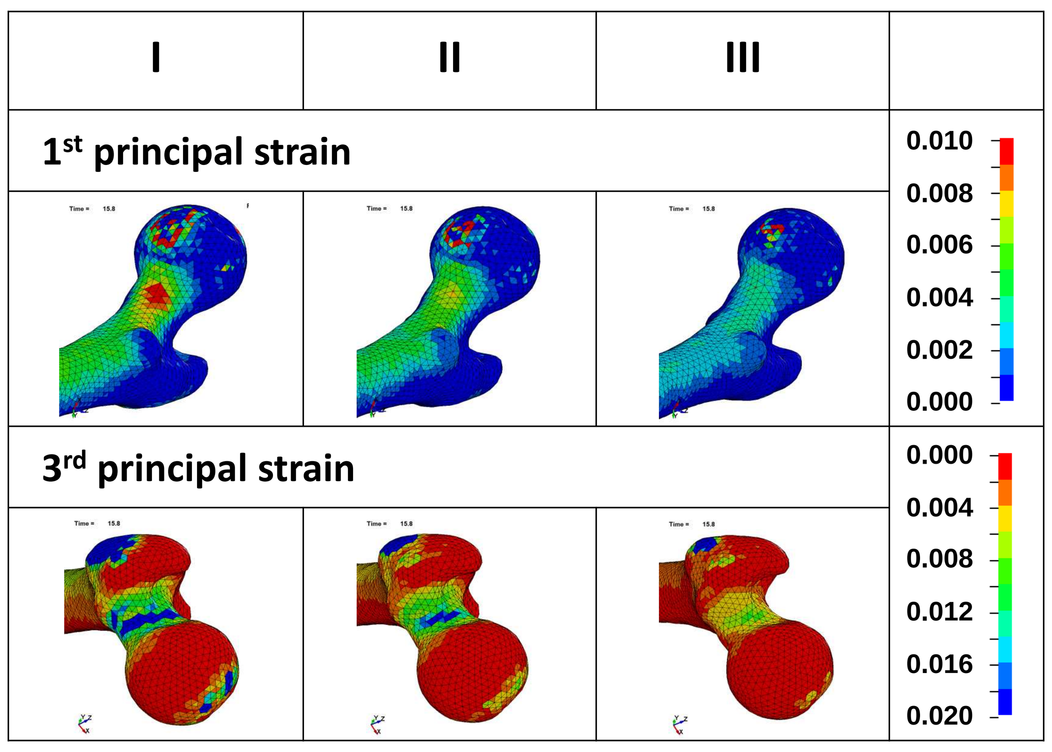

Fig. 4 Strain pattern for Setup I-III, showing that the femur is more likely to fail for Setup I and II than for Setup III.

- 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 a possible fracture for Setup 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.

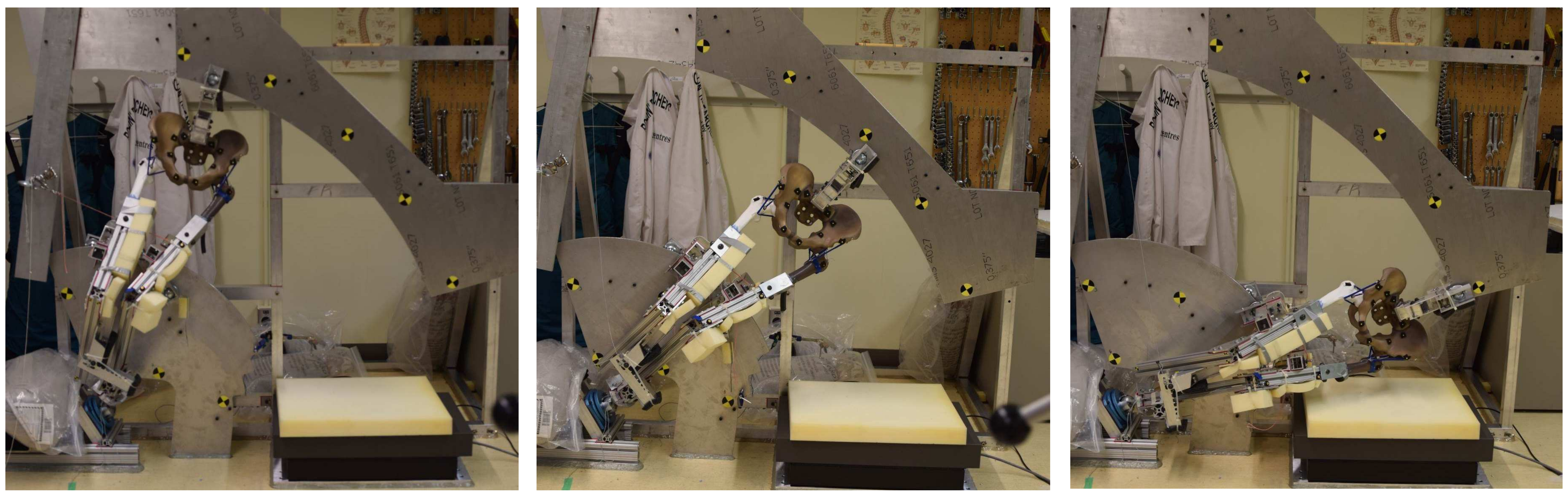

Fig. 2 Preliminary experimental setup descending from left to right.

References

[1] Haleem et al, Injury, 39: 1157-1163, 2008
[2] v. d. Kroonenberg et al, J Biomech Eng, 117(3): 309-318, 1995
[3] Laing et al, J Biomech Eng, 43:1898-1904, 2010

Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich