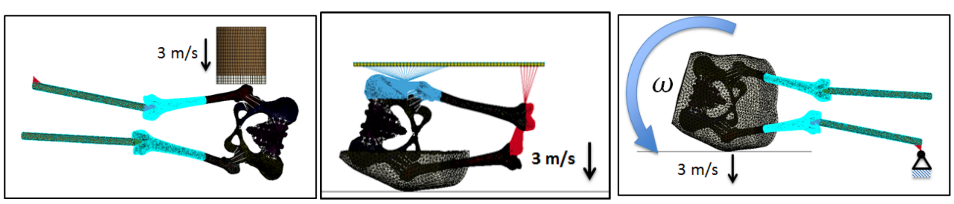
Using explicit Finite Element Models for Designing a Dynamic Cadaveric Sideways Fall Experiment

Ingmar Fleps[1], Jonah Killam[2], Peter A. Cripton[2], Stephen Ferguson[1], Benedikt Helgason[1]

[1]Institute for Biomechanics, ETH Zürich, Switzerland; [2]Orthopaedic and Injury Biomechanics Group, Depts of Mechanical Engineering and Orthopaedics, University of British Columbia, Canada

Abstract

The majority (>90%) of hip fractures are associated with a low height fall. ***.*** *These injuries are often associated with a reduction in mobility and mortality [1]. Methods to estimate the femur load during these falls use spring mass models and velocity from from human volunteers falling on compliant surfaces [2]; and effective mass and stiffness data for the pelvic region based on low falls [3]. However, these models ignore the non-linear structural response of the pelvis[3] and they assume that the body does not rotate after contact with the ground. To address the limitations of these models we are developing Finite Element Models (FEMs) of side-ways falls using cadaveric specimens. The objective of this study was to analyse falls to the side with dynamic FEMs to identify the most biofidelic boundary conditions and the design parameters having the most influence on the outcome of the experiments.*



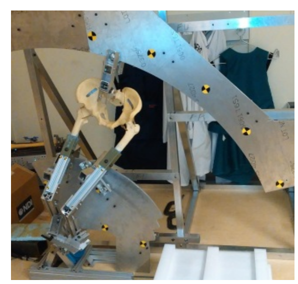


Figure 1 Schematic boundary condition for set-up (I) left, (II) middle and (III) right. Photo on the right shows the experimental set-up.

Methods

Calibrated CT data from a bone database (VSD, https://www.smir.ch/) for a 19 y.o. (170cm, 54kg, T-score = -0.7) female was used. An explicit FE model of the subject's pelvic structure was created and solved using LS-Dyna (Livermore Software Technology Corp.). Heterogeneous, non-linear, strain-rate dependent material bone properties were mapped to the femurs and the pelvis. For the pelvis a linear viscoelastic behaviour was assumed. Soft tissue and the joint cartilage were assigned hyper-elastic properties, and ligaments were assigned linear elastic materials based on literature. The model was then used to simulate experimental *set-ups (figure 1) with; (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 incorporated rotation. The set-ups were adjusted to match kinetic energy corresponding to 38 % body mass impacting at a speed of 3 m/s.*

Results

The peak impact force was found to be 9.4 kN, 7.8 kN and 4.9 kN for models I, II and III, respectively. The corresponding peak force transferred through the femoral neck was found to be 9.4 kN, 6.3 kN and 3.6 kN. With more detailed soft tissue modelling and more motion of the pelvis, the energy absorbed by the soft tissue increased from 15.7 J to 52.0 J and the energy transferred through the femur decreased from 41.3 J to 5.4 J.

Discussion

We consider the pendulum boundary conditions (III), which were derived based on observations made from video recordings of humans falling, to represent the most biofidelic boundary conditions. This is due to a detailed model of soft tissue and the fall motion and an effective pelvic stiffness of 55 N/mm comparable to 51 N/mm for low falls found by other investigators in literature [3]. Important differences with respect to peak impact force and energy absorption were found between model III and models I and II which are easier to setup experimentally. We therefore conclude that a simplification of the boundary condition, beyond our model III, should be avoided.

References

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