THORAX FP7 Workshop
WP2 Biomechanics
Task 2.3 Injury mechanisms &
Task 2.5 PMHS Testing

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Thorax biomechanics: open issues

• How the loading sustained by a human thorax leads to injury?
  1. How the 3D deformation of the ribcage is linked to injury?

  2. What are the parameters governing these injury mechanisms?
     ▪ External parameters: Loading conditions, restraint systems, ...
     ▪ Internal parameters: Geometry, material properties, ...

(Kent et al., Stapp 2005)
Thorax biomechanics: open issues

• Internal parameters:
  1. The overall geometry of the rib cage (structural characterization)

Thorax geometry ≠ shape

Thorax geometry ≠ rib orientation
Thorax biomechanics: open issues

- Internal parameters:
  1. The overall geometry of the rib cage (structural characterization)
  2. The role of the joints (functional characterization)

Costo vertebral joint

[Kapandji, 1994]
Thorax biomechanics: open issues

- External parameters:
  1. What is the influence of restraint systems?
  2. What is the influence of loading conditions?

The same “chest deflection” can be obtained for different loading conditions but with different rib deformation and rotation.

→ Can result in different injuries

[Image: Kent et al, Stapp 2005]
Methods

- **INRETS Experiments: test matrix on rib cage**
  - 4 isolated ribcages @ 4 different loading velocities each (16 tests) with dynamic loading
    - Non injurious tests
    - Description of 3D deformation of the ribcage
  
  - 3 (or 4) isolated ribcages @ 2 different impact velocities each (6 or 8 tests) with an impactor
    - Non injurious and injurious tests on same rib cage
    - Description of 3D deformation of the ribcage
    - Analyze of rib fracture mechanism

- 1 (or more) isolated ribcages @ same impact velocities with an impactor with and without intercostal muscle
  - Non injurious tests
  - Description of 3D deformation of the ribcage
Methods

- INRETS Experiments: test matrix on full thorax

- 3 (or 4) full thorax @ 2 different impact velocities each (6 or 8 tests) with an impactor
  - Non injurious and injurious tests on same thorax
  - Description of 3D deformation of the ribcage
  - Analyze of the influence of inner organs
  - Thorax will be pressurized and vascularized
  - Lungs and aorta pressure will be measured
• **3D Motion analysis**

- Motion of the ribs were obtained through the motion of 3 triplets of reflective markers
- Using 4 High speed cameras (2000 fps)
- and an algorithm of reconstruction (Direct Linear Transformation)
- Markers were filmed at least by 2 cameras
How the 3D deformation of the ribcage is linked to injury?

- Describe the relationship between this 3D deformation ("local displacement") and rib fracture

**Objectives**

**Methods**

**Experiments**

**Simulation**

**Experiments**

**Upper ribs**

- a) antero-posterior deflection of the rib in its plane;
- b) flexion perpendicular to the rib plane;
- c) torsion around the mean fiber;
- d) solid body rotation of the rib allow by the costo-vertebral joint;
- e) transverse deformation of the rib.

**Lower ribs**

- Loading direction
How the 3D deformation of the ribcage is linked to injury?

- Describe the relationship between the rib rotation (w.r.t spine/vertebra) and rib fracture
- Costo-vertebral joints characterization
How the 3D deformation of the ribcage is linked to injury?

What we learn from first test:

- A **costal level dependency** on the response of the rib cage that can be explained by the structure (geometry) of the rib cage.

- An **inter individual variation** that can not be explained only by geometrical differences between the subject.

- Local (at rib level) deformation of rib cage are subject dependent: important subject variability linked to:
  - **Morphometric parameters**
  - **Material properties** (bone, cartilage, muscle, ..)
  - **Functional parameters** (joint characteristics)
How the 3D deformation of the ribcage is linked to injury?

- Assessment of the influence of these different parameters

⇒ Will be done with the performance of simulations of tests with FE model and parametric study.
HUMOS2 FE model with personalization methods

- The model used is a modified and improved version of the European FE human model HUMOS2, developed on PamCrash® ("Aprosys" version)
- Personalization method is based on RBF

- It is not just a Scaling, it is more like a "morphing"
HUMOS2 FE model with personalization methods
Examples of personalized mesh
On going activities

- **Tests on PMHS and simulation are performed in parallel**

- **Methodology:**
  - Validated the FE model by duplicating non injurious tests (Vezin and Berthet Stapp 2009) and some UVA tests.
  
  - Simulated injurious tests when available
  
  - Performed simulation with personalized models to analyze the:
    - Influence of geometry variability
    - Influence of material properties variability
    - Influence of loading conditions
Final remarks

- Strain is good predictor for rib fractures (see LAB’s work in thorax project)

- Strain probably difficult to be measured on dummy

- Aim of simulation/experiment coupled study is to find a more global parameter (≠ from chest deflection), based on the 3D deformation of single rib or rib cage that:
  - Is related/linked to strain
  - Can predict rib fracture
  - Can be measured “easily” with a dummy
Acknowledgments

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