VTТИ Center for Injury Biomechanics

PARTNERS
Virginia-Maryland College of Veterinary Medicine
Institute for Critical Technology and Applied Science
Virginia Tech-Carilion Research Institute
Virginia Bioinformatics Institute
Virginia College of Osteopathic Medicine
Wake Forest University
Biomechanics and Injury Prevention

- **Mechanism (multiple scales):**
  - Mechanical response,
  - Injury response.

- **Tolerance:**
  - Injury metric/function to be evaluated (HIC, ADFS),
  - Injury Assessment Reference Values (IARVs).

- **Mitigation:**
  - Tools for design/evaluation of environments and equipment,
    - Physical and numerical models.

- **Treatment:**
  - Understanding mechanism can lead to improved diagnosis,
  - Can provide foundation for new treatment regimes.
## CIB Research Areas

<table>
<thead>
<tr>
<th>Body Region</th>
<th>Application</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head/Brain</td>
<td>FMVSS 208</td>
<td>Blast</td>
</tr>
<tr>
<td>Eye/face</td>
<td>Airbag/Particle</td>
<td>IED/Shrapnel</td>
</tr>
<tr>
<td>Neck</td>
<td>Nij</td>
<td>Head Mass</td>
</tr>
<tr>
<td>Thorax</td>
<td>Belt Loading</td>
<td>Restraints</td>
</tr>
<tr>
<td>Upper limb</td>
<td>Airbag Loading</td>
<td>Airbags</td>
</tr>
<tr>
<td>Pregnant</td>
<td>Restraints</td>
<td>Work/time</td>
</tr>
<tr>
<td>Pelvis</td>
<td>Side Impact</td>
<td>Vehicle</td>
</tr>
<tr>
<td>Lower limb</td>
<td>Knee Bolster</td>
<td>Paratrooper</td>
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</tbody>
</table>
CIB Activities

1. Empirical Biomechanics
   - Impact and injury response characterization
     - Transportation
     - Recreation
     - Military
   - Multiscale, multimodal, multirate investigation
   - Mechanism determination
   - Material property description
   - Tolerance quantification
   - Injury risk formulation
   - Surrogate implementation
   - Protective system evaluation
   - Mitigation strategy realization

2. Computational Biomechanics
   (Dr. Costin Untaroiu)
   - Rigid body modeling
   - Finite element modeling

3. Test Subjects
   - Cadavers (PMHS)
   - Animals (rats, pigs)
   - Dummies (ATDs)
   - Human volunteers
CIB Personnel and Funding

1. Personnel
   - Seven Principal Investigators
   - Four staff
   - Four post-doctoral fellows
   - Twenty-six graduate students

2. Funding
   - Historically maintain > $30m open research

3. Historical Funding Sources
   - Department of Defense
   - National Highway Traffic Safety Administration
   - Centers for Disease Control
   - NIH
   - NSF
   - NASA
   - OEM Automobile Manufacturers
   - Tier-One Suppliers
Crash Sled and Impact Laboratory

- 1.4 MN
- 475,000 N-m
- 90 kph and 93 g (20 g/ms)
- 57 kph and 37 g
- 2500-kg payload
- High-frequency (500 Hz)
- 2-m driving stroke
High-Speed Biplane X-Ray

A high-frequency Dual-axis x-ray generator
80 kW: 150 kV or 1,000 mA

Accurate to within 0.1 mm in 0.05 cubic meter
Tissue Testing

Biaxial Tissue Testing
Military Applications
Accident Investigation, Simulation, Statistics

- EDR Maximum Longitudinal Average Acceleration (G)
- Probability of Serious (MAIS 3+) Driver Injury

50 ms Criteria

10 ms Criteria
Kelly Hall Building (Biomedical Laboratories)

Mini-sled

Vicon Motion Capture System
- 18 MX-T20 cameras (2 megapixel)
- Max Resolution = 1600 x 1280
- Max Sampling = 2000 fps
Computational Biomechanics (current/recent projects)

1. Development and validation of occupant/pedestrian human FE Models (e.g. GHBMC, THUMS, etc.)

2. Testing and material identification of biological tissues (e.g. liver, spleen, ribs etc.)

3. Statistical shape analysis of human organs

4. Development and validation of ATD FE models (e.g. THOR - automotive, WIAMAN –military)

5. Adaptive restraint systems
GHBMC occupant FE Model

GHBMC Pelvis and Lower Extremity Finite Element

- **Geometry**
  - Reconstructed geometry of 50th male volunteer
  - Additional data from literature for defining the cortical bone shells with thin thickness (e.g. in pelvis and epiphysis regions) and foot/hip ligaments

- **Meshing**
  - Almost 625k elements and 322k nodes included in 285 distinct components (parts)
  - More than 73% solid elements (93% hexa)
  - All elements fulfill GHBMC mesh quality criteria (Jacobian solid/shell>0.3/0.4; Tet collapse>0.2, etc.)
  - Model stable with 0.3/0.6 µs time steps (0.4/6% mass scaling)

- **FE Model Validation**
  - 19 Component / sub-system validations
  - 4 Robustness/Stability simulations

- **Biomechanical Database**
  - Develop a biomechanical database which includes all validation data (loading curves, test setups etc.) corresponding to component validations
  - Develop test data corridors

* This database obtained from published references/databases can be used in developments of further GHBMC FE models (e.g. 5th female)


Dr. Jaeho Shin
Neng Yue
Development and validation of THOR-k FE Model

Development of head neck

Frontal loading

Vertical loading

Jacob Putnam
( NASA, former VT MSc student)
ATD vs. Human under vertical loading

Photogrammetric Imaging
* 18 Markers
* Localized to chair

THOR
THUMS

% Force Distributed Through Model

T=0 ms
T=75 ms
T=150 ms

- Lumbar Spine - L1: 35%, 12%, 7%
- Lower Neck - T1: 34%, 13%, 6%
- Upper Neck - C1: 8%, 14%, 10%
Material modeling of abdominal organs

Dr. Yuan-Chiao Lu
(Uniformed Services University of the Health Sciences, former VT PhD student)
GHBMC adult pedestrian FE Models

US (2012) 4,743 pedestrians killed & 76,000 pedestrians injured (NHTSA 2014)
GHBMC adult pedestrian FE Models

Component validation

Vehicle-to-pedestrian validation

Abdomen FE validation (Viano’s abdomen tests)
Time = 0

Pelvis FE validation (Viano’s pelvis tests)
Time = 0

Car to 5th Female Pedestrian Collision (FE Simulation)
Time = 8

Knee Pedestrian Validation (Rose’s tests)
Time = 8

Car to 50th percentile Male Pedestrian Collision (FE simulation)
Time = 8

Wansoo Pak (VT PhD student)
(wspak@vt.edu)
GHBMC child pedestrian FE Models

Component validation

Vehicle-to-pedestrian validation

Yunzhu Meng (VT MSc student) (mengyz@vt.edu)
Development and validation WIAMAN leg FE model

Validation of WIAMAN FE Model

WIAMAN better biofidelity than HIII!

Wade Baker – VT MSc student (wadeb6@vt.edu)
Statistical Shape Analysis & Mesh Morphing

(Yates et al. 2016)
Identifying TBI thresholds using animal and human FE models

Göttingen mini-pigs
Identifying TBI thresholds using animal and human FE models

- Animal testing
- Animal finite element (FE) model
- Simulate Injury
- Develop specific transfer function
- Human FE model
- PMHS testing
Identifying TBI thresholds using animal and human FE models

Results – Horizontal Displacement (mm) Time (s) Histories

(Yates et al. 2016)
Identifying TBI thresholds using animal and human FE models

- Simulations can be run applying similar loadcases to human models
  - Allows investigation of scaling methods
  - Better scaling can be developed

(Yates et al. 2016)
