Biomechanical Responses and Injury Assessment of PMHS in Rear-facing Seating Configurations
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Motivation

Non-standard seating configurations for highly automated vehicles (HAV) are likely to be present

- Studies using computational models [Kitagawa et al., 2017; Jin et al., 2018; Katagiri et al., 2018]
- ATD and FE HBM
  - evaluated and validated only in low speed rear impacts
  - require biomechanical data generated in the desired severity
  - need more biomechanical data in high speed rear impacts with different recline angle
Objective

To investigate biomechanical responses and injury of Post Mortem Human Surrogates (PMHS) in rear-facing seating configuration (high speed rear impacts)
METHODS
Sled Buck Concept

Generate meaningful ATD/HBM targets for use in evaluating future/unknown seat designs

- Currently, no consensus on future AV seat

**Design criteria:**

1) **Repeatable:** rigid support to prevent seat motion
2) **Simulate future AV seat:** current production seat with ABTS
3) **Adjustable:** allow for different recline angles/HR position
4) **Measure reaction loads:** add instrumentation
5) **Various crash directions:** 15° increment
Sled Buck Description

Head restraint is separated from seatback and adjustable in position.
Seat back and head restraint are fixed by a supporting frame.
Sled Buck Description

2017 Honda Odyssey
2nd row seat with ABTS
Sled Buck Description

Load cells at head restraint (1), seat back (6), and seat anchors (4) to measure reaction loads.
Sled Buck Description

Top view

Various crash direction
# PMHS Information

<table>
<thead>
<tr>
<th></th>
<th>PMHS01</th>
<th>50th male</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>Age</td>
<td>57</td>
<td>45</td>
</tr>
<tr>
<td>Cause of Death</td>
<td>COPD</td>
<td>N/A</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>167</td>
<td>175</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>63.0</td>
<td>78.2</td>
</tr>
<tr>
<td>Head mass (kg)</td>
<td>3.8</td>
<td>4.5</td>
</tr>
<tr>
<td>Seated Height (cm)</td>
<td>90.0</td>
<td>90.7</td>
</tr>
<tr>
<td>Chest Depth (cm)</td>
<td>20.7</td>
<td>22.9</td>
</tr>
<tr>
<td>Chest Breadth (cm)</td>
<td>30.3</td>
<td>33.0</td>
</tr>
</tbody>
</table>
PMHS Instrumentation

<table>
<thead>
<tr>
<th></th>
<th>PMHS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td><img src="image1.png" alt="Image" /></td>
</tr>
<tr>
<td>Chest</td>
<td><img src="image2.png" alt="Image" /></td>
</tr>
<tr>
<td>C2/4/6</td>
<td><img src="image3.png" alt="Image" /></td>
</tr>
<tr>
<td>T1</td>
<td><img src="image4.png" alt="Image" /></td>
</tr>
<tr>
<td>T4</td>
<td><img src="image5.png" alt="Image" /></td>
</tr>
<tr>
<td>T8</td>
<td><img src="image6.png" alt="Image" /></td>
</tr>
<tr>
<td>T12</td>
<td><img src="image7.png" alt="Image" /></td>
</tr>
<tr>
<td>S1</td>
<td><img src="image8.png" alt="Image" /></td>
</tr>
<tr>
<td>Pelvis</td>
<td><img src="image9.png" alt="Image" /></td>
</tr>
<tr>
<td>Femur</td>
<td><img src="image10.png" alt="Image" /></td>
</tr>
<tr>
<td>Tibia</td>
<td><img src="image11.png" alt="Image" /></td>
</tr>
</tbody>
</table>

Kang et al., 2011 & 2015; Yoganandan et al., 2006
PMHS Instrumentation

<table>
<thead>
<tr>
<th>PMHS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>6aω</td>
</tr>
<tr>
<td>Chest</td>
<td></td>
</tr>
</tbody>
</table>

- **C2/4/6**
- **T1**
- **T4**
- **T8**
- **T12**
- **S1**
- **Pelvis**
- **Femur**
- **Tibia**

- **Mid-sternum**
PMHS Instrumentation

<table>
<thead>
<tr>
<th>PMHS</th>
<th>C2/4/6</th>
<th>T1</th>
<th>T4</th>
<th>T8</th>
<th>T12</th>
<th>S1</th>
<th>Pelvis</th>
<th>Femur</th>
<th>Tibia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chest</td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<td></td>
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</tbody>
</table>

Anterior: rib 3-9
Posterior: rib 3-10
PMHS Instrumentation

- **Strain Gauges**
  - Chestband
  - C2, C4, C6
  - T4, T8, T12, S1, Pelvis

- **Chestband**
PMHS Instrumentation

<table>
<thead>
<tr>
<th>PMHS</th>
<th>Head</th>
<th>Chestband</th>
<th>Strain Gauges</th>
<th>3aω</th>
</tr>
</thead>
<tbody>
<tr>
<td>C2/4/6</td>
<td>T1</td>
<td>T4</td>
<td>T8</td>
<td>T12</td>
</tr>
<tr>
<td>S1</td>
<td>Pelvis</td>
<td>Femur</td>
<td>Tibia</td>
<td></td>
</tr>
</tbody>
</table>

- 6aω
- Chestband
- Strain Gauges
- 3aω
## PMHS Positioning

![PMHS Positioning Image]

<table>
<thead>
<tr>
<th>Measurement</th>
<th>UMTRI Target(^1)</th>
<th>PMHS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head Angle</td>
<td>22.3 ± 2º</td>
<td>22.0º</td>
</tr>
<tr>
<td>Pelvic Angle</td>
<td>21.1 ± 5º</td>
<td>25.0º</td>
</tr>
<tr>
<td>Thigh Angle</td>
<td>11.1 ± 2º</td>
<td>10.0º</td>
</tr>
<tr>
<td>Leg Angle</td>
<td>45.9 ± 2º</td>
<td>46.0º</td>
</tr>
<tr>
<td>Hip-to-Eye Angle</td>
<td>31.6 ± 5º</td>
<td>26.0º</td>
</tr>
<tr>
<td>Back set</td>
<td>0 mm</td>
<td>0 mm</td>
</tr>
<tr>
<td>Top set</td>
<td>---</td>
<td>46 mm</td>
</tr>
<tr>
<td>Hip X</td>
<td>+55 ± 10 mm</td>
<td>+60.4 mm</td>
</tr>
<tr>
<td>Hip Z</td>
<td>-375 ± 10 mm</td>
<td>-366 mm</td>
</tr>
</tbody>
</table>

\(^1\)Reed M, Ebert S. “Effects of Recline on Passenger Posture and Belt Fit” UMTRI Report 2018-2
Sled Pulse

37.6 g 56.6 kph
RESULTS

PRELIMINARY RESULTS
Offboard HS Video
Onboard HS Video
Kinematics

Initial horizontal rearward motion, followed by significant vertical motion; shoulder continued rearward while head, pelvis, and knees rebounded)
Injuries

Cervical spine (640284.1)
• C3/C4 and C4/C5 moderate laxity

Scapula (750952.2)
• Left side – comminuted, medial border and superior angle

Ribs (≥3 rib fx; 450203.3)
• R3: fracture through cutaneous cortex only
• L3: fracture through both cortices
• L6: fracture at CCJ, through cutaneous cortex only
• L7: fracture at CCJ, through cutaneous cortex only
Seat Reactions: Seat Back Fx

Top load cells

Middle load cells

Bottom load cells

Left
Right

FX
Seat Reactions: Seat Back Fx

Top load cells

Middle load cells

Bottom load cells

Left scapula interaction

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Chest Deformation vs. Time
Chest Deflection

Anterior max

17.9mm (15.3%) @ 44.7ms

‡ Rib fractures

Posterior max
Rib (L3) Fracture
Summary

• Designed and built a repeatable, realistic as possible, adjustable setup that measures seat reaction loads
• Able to match PMHS to UMTRI positioning target
• Conducted one PMHS test
  - Scapula and rib fractures were found (minor C spine injury)
  - Integrated belt system prevented PMHS ejection but may affect injury response in high speed rear impacts
• Future Work: More PMHS tests (25/45 deg reclined, 24/56 kph)
  - Develop response targets
  - Matched pair ATD tests to evaluate biofidelity
  - Create injury risk functions
Acknowledgements

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  - Amanda Agnew and Rakshit Ramachandra
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  - Hyun Jung Kwon and Duey Thomas
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New HR Attachment
Seat Reactions: Head Restraint Fx