Restraint Optimization for Obese Occupants

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Motivation

% of Adult U.S. Pop. Obese

2012

35%

2011-2012: 78.6 million U.S. adults obese
(Ogden et al. 2014)

Motivation

More likely to die or get injured in car crash

Rear-seat frontal impact sled tests

BMI 35

Experimental test video
Obese subject

BMI 22

Experimental test video
Non-obese subject
Restraint system optimization for obese occupants
Overview

Field Data Analysis

HBM Evaluation

Injury Metrics

HBM Instrumentation

Sled and Restraint Models

Parameter Selection

Simulation Runs

Meta-model Development

Optimization
FURTHER UNDERSTANDING THE ISSUE

FIELD DATA ANALYSIS
Restrained occupants in frontal crashes

Data
- NASS-CDS
- Frontal crashes (PDOF -30° to 30°)
- Belted occupants only
- Air bag deployed
Restrained occupants in frontal crashes

Data

- NASS-CDS
- Frontal crashes (PDOF -30° to 30°)
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Objectives

- BMI vs Risk of AIS2+ injury to different body regions
- Most common injuries of obese vs non-obese
- Injury mechanism speculation
BMI vs Risk of Injury to Different Body Regions

Risk of AIS2+ Injury (%)

Body Region

All Injuries  Head  Face  Thorax  Abdomen  Spine  UX  LX

Underweight  Normal  Overweight  Obese I  Obese II  Obese III

Significant difference From multivariate regression analysis
### Most common injuries of obese

<table>
<thead>
<tr>
<th>Rank</th>
<th>Description</th>
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<tbody>
<tr>
<td>1&lt;sup&gt;st&lt;/sup&gt; frequent</td>
<td>Talus fracture</td>
</tr>
<tr>
<td>2&lt;sup&gt;nd&lt;/sup&gt;</td>
<td>Tibia NFS; medial malleolus; open/ displaced/ comminuted</td>
</tr>
<tr>
<td>3&lt;sup&gt;rd&lt;/sup&gt;</td>
<td>Metatarsal or tarsal fracture</td>
</tr>
<tr>
<td>4&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Carpus or Metacarpus fracture</td>
</tr>
<tr>
<td>5&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Patella fracture</td>
</tr>
<tr>
<td>6&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Radius Fracture NFS with or without styloid process including Colles</td>
</tr>
<tr>
<td>7&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Knee NFS sprain</td>
</tr>
<tr>
<td>8&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Fibula fracture; any type but NFS as to site; head, neck, shaft</td>
</tr>
<tr>
<td>9&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Rib Cage NFS; 2-3 multiple rib fractures; any location or multiple fractures of single rib; with stable chest or NFS (OIS Grade I, II, III)</td>
</tr>
<tr>
<td>10&lt;sup&gt;th&lt;/sup&gt; frequent</td>
<td>Rib Cage NFS; multiple rib fractures NFS; &gt;3 ribs on one side and no more than 3 ribs on other side, stable chest or NFS</td>
</tr>
</tbody>
</table>

*risk for obese > risk for non-obese*
Injury mechanism speculation

- Large forward motion
  - Higher risk of LX and UX injury
  - Foot/ankle/tibia injuries
- Limited by knee bolsters
  - Knee injuries commonly observed
  - No difference in abdominal injuries
Obese HBM

- Baseline GHBMC morphed
  - External body contour
  - Rib cage and lower extremity skeletons geometry
- 3 BMIs, 2 heights, 2 ages
29 km/h Tests

Pelvis excursion 19 cm

Experimental test video
48 km/h Tests

Submarining

Pelvis excursion 25 cm

Pelvis excursion 40 cm

Experimental test video
Reasons contributing to decreased protection of obese

1- Big body mass → higher belt force required
2- Thick adipose tissue → delayed engagement of lap-belt with pelvis
3- Submarining → penetration into abdomen

Mimicked by HBM

HBM unable to submarine due to large shear stiffness of flesh
Conclusion

- HBM and PMHS behaviors comparable in test with no submarining
- Pelvis motion restrained for driver
- → HBM useful
RESTRAINT MODELS

SIMULATION SET-UP
Restraint models

Sled
Seat belt
  Standard and inflatable
  Buckle and anchor pre-tensioner
Adaptive vent driver air bag
Knee air bag
  Low-mount
  Mid-mount
Under-the-seat air bag
Curtain air bag
Choosing parameters

- Seat belt
  - Buckle vs anchor pre-tensioner
  - Load limiter and pre-tensioner levels
  - Air-belt vs no air-belt
  - Air-belt pressure
- Pressure of different air bags
- Force level of collapsible steering column
Optimization method

Choosing parameters → Domain reduction

Guess a solution

Run simulation

Not good enough

2500 simulations

Good enough

Solution
Optimization method

Choosing parameters ➔ Domain reduction ➔ Latin hypercube sampling

Guess a solution

Estimate the response

Run ~300 simulations

Meta model

Solution

Not good enough

Good enough
Objective Function

- **Functional Capacity Index**
- **Risk of Injury to different body regions**
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