The Benefits of Booster Seats - Sled Tests and CIREN Case Examples

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Objectives

• Increase knowledge benefits of booster seats in child passenger safety
• Understand injury risks associated with premature graduation from booster seats
• Use simulation models to further quantify injury patterns with different restraint systems
Kids are different!

- Age, Weight, & Physiological Differences
- Restraint Type
- Position
- Restraint Direction
- Other Variables
Other Variables

Position
- Rear
  - Left
  - Center
  - Right
- Front

Restraint Type
- 3-Point
- 2-Point
- CSS
  - High-back
  - Shield
  - Low-back

Contact Points
- CSS
- Front Seat Back
- Non-contact

Restraint Type
- Infant Seat
- Convert
- Booster
- Tray
- T-shield
- 5-point
- Rear-facing
- Forward-facing
- 3-pt
- 5-pt
Booster Seats

- Height of 4’9” – appropriate for vehicle belt only
- Booster seats recommended for children 4-10 years old
- Stature (seated height) more important than age, weight

High Back Booster  Low Back Booster  Shield Booster

Not recommended
Reasons for Booster Seats

Improve fit of vehicle belt

- Lap belt (prevent submarining)

Courtesy of BRC
Reasons for Booster Seats

Improve fit of vehicle belt

- Shoulder belt – across chest and shoulder
Reasons for Booster Seats

Practical concerns

• Prevent slouching due to leg length
• Degrades fit for both lap and shoulder belt

Knees at edge of seat
Practical concerns

- Uncomfortable shoulder belt position
- Leads to misuse of shoulder belt
- Behind back, Under arm
Chance Fracture
Sled Tests

Quantifying the injury patterns
Sled Tests

- Similar to FMVSS 213
  - 48 km/h (30 mph) impact speed
  - 3rd row bench seat, Windstar minivan
  - Hybrid III 6 year old dummy
- 4 Sled Tests
  - High Back Booster Seat
  - Low Back Booster Seat
  - Shoulder belt behind back
  - Shoulder belt under arm
Sled Tests

High Back Booster Seat

Low Back Booster Seat
Sled Tests

Shoulder Belt Behind Back

Shoulder Belt Under Arm
Sled Test

- Measured forces during crash simulation
  - Head Excursion
  - Lap Belt Force
  - Shoulder Belt Force
  - Flexion of Lumbar Spine
  - Lumbar Tension
## Sled Tests - Injury Measures

<table>
<thead>
<tr>
<th>Head Excursion (cm)</th>
<th>HBB</th>
<th>LBB</th>
<th>Shoulder Behind Back</th>
<th>Shoulder Under Arm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>64.3</td>
<td>58.5</td>
<td>91.6</td>
<td>73.1</td>
</tr>
</tbody>
</table>
### Sled Tests – Injury Measures

<table>
<thead>
<tr>
<th></th>
<th>HBB</th>
<th>LBB</th>
<th>Shoulder Behind Back</th>
<th>Shoulder Under Arm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lap Belt Force (N)</td>
<td>3180</td>
<td>3011</td>
<td>4078</td>
<td>2611</td>
</tr>
<tr>
<td>Shoulder Belt Force (N)</td>
<td>5080</td>
<td>5340</td>
<td>-</td>
<td>4000</td>
</tr>
</tbody>
</table>
## Sled Tests - Injury Measures

<table>
<thead>
<tr>
<th></th>
<th>HBB</th>
<th>LBB</th>
<th>Shoulder Behind Back</th>
<th>Shoulder Under Arm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lumbar Flex Moment (N m)</td>
<td>24</td>
<td>20</td>
<td>73</td>
<td>41</td>
</tr>
<tr>
<td>Lumbar Tension (N)</td>
<td>1437</td>
<td>2114</td>
<td>5303</td>
<td>4704</td>
</tr>
</tbody>
</table>
Applying simulations data to real pediatric crashes
### CIREN: Case Studies

<table>
<thead>
<tr>
<th></th>
<th>Case 1</th>
<th>Case 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Patient</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>4 yrs old</td>
<td>5 yrs old</td>
</tr>
<tr>
<td>Weight</td>
<td>37 lbs</td>
<td>60 lbs</td>
</tr>
<tr>
<td>Height</td>
<td>36 in</td>
<td>45 in</td>
</tr>
<tr>
<td><strong>Restraint</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type</td>
<td>3-point belt</td>
<td>3-point belt</td>
</tr>
<tr>
<td></td>
<td>shoulder belt behind back</td>
<td>shoulder belt under arm</td>
</tr>
<tr>
<td>Position</td>
<td>middle row/ middle seat</td>
<td>right rear</td>
</tr>
<tr>
<td><strong>Crash</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PDOF</td>
<td>+340</td>
<td>+350</td>
</tr>
<tr>
<td>Crush</td>
<td>21 cm (8.3 in)</td>
<td>55 cm (21 in)</td>
</tr>
<tr>
<td>Delta V</td>
<td>22 km/ hr (13.6 mph)</td>
<td>43 km/ hr ( 27 mph)</td>
</tr>
<tr>
<td>Impact</td>
<td>Frontal</td>
<td>Frontal</td>
</tr>
</tbody>
</table>
CIREN Cases 1: Case Vehicle

Seating Position

Frontal View of Case Vehicle
1993 Mercury Villager
CIREN Cases 2: Case Vehicle

Seating Position

- Max Crush - 55 cm (21 in)

Frontal View of Case Vehicle
1993 Jeep Cherokee
Case 2: External Injuries

Distended Stomach
Summary:
Role of Sled Test

• Compare among restraint systems forces in crash simulation
• Shoulder Belt Misuse Scenarios vs Booster
  • Head excursions increase
  • Lap belt forces similar
    • High shoulder belt forces on abdomen
  • Higher flexion moment and tension on lumbar spine
    • potential for Chance Fractures
Summary:
Role of Booster Seats

• Benefits of Booster Seats
  – Creates comfortable shoulder belt position
  – Alleviates misuse of shoulder belt
    • Placing behind back
    • Placing under arm
  – Creates more comfortable seating position to prevent slouching
    • Submarining
Thank You