The Effects of Seatback Reclined Positions of Occupants in Motor Vehicles Collisions

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Background

• Motor vehicle crashes (MVC) are leading cause of trauma-related death in US each year
• Multiple factors determine outcome: Vehicle type, Delta-V, PDOF, seat belt use and airbag deployment
• Occupant factors such as height and weight also impact outcome
• Seat recline position has not been evaluated
Crash safety testing

- Performed by NHTSA and IIHS
- Test vehicles at different speeds and different body habitus of crash test dummies
- Standard driving seatback position used within 12 degrees of vertical
However..

Many occupants travel with their seats reclined
Study Question:

Does reclining your seat impact your outcome from a motor vehicle crash?
Methods:

- Two components:
  1. Detailed case review using Crash Injury Research Engineering Network (CIREN)
  2. Outcomes analysis using NHTSA sponsored National Automotive Sampling System Crashworthiness Data Set (NASS/CDS)
Phase 1: CIREN Case Reviews

- Front seat occupants
- Case occupants documented in fully reclined seatback position by crash investigations or interviewee
Reclined CIREN cases, n=11

<table>
<thead>
<tr>
<th>Category</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>32.4 (16 – 75) years</td>
</tr>
<tr>
<td>Sex</td>
<td>6 men, 5 women</td>
</tr>
<tr>
<td>Occupant Position</td>
<td>3 drivers, 8 passengers</td>
</tr>
<tr>
<td>Weight</td>
<td>85.3 (57 – 122) kg</td>
</tr>
<tr>
<td>Height</td>
<td>172.1 (150 – 185) cm</td>
</tr>
<tr>
<td>Delta V</td>
<td>47.4 (24 – 68) kmph</td>
</tr>
<tr>
<td>Frontal impact</td>
<td>8</td>
</tr>
</tbody>
</table>
CIREN case summary continued

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Seatbelt used</td>
<td>6 (54.5%)</td>
</tr>
<tr>
<td>Airbag deployed</td>
<td>6 (54.5%)</td>
</tr>
<tr>
<td>ISS</td>
<td>27.8 (2 – 75)</td>
</tr>
<tr>
<td>Mortality</td>
<td>3 (27.3%)</td>
</tr>
</tbody>
</table>
Seatback Fully Reclined

CIREN Case Reviews
Head-on
Full frontal crash
Speed Limit
70mph/112kmph
2003 Compact 4 door sedan
PDOF – 12 o’clock
Delta V = 44kmph/ 27 mph (smash missing run)
Seatback Recline
Case Review 1 – Case Occupant

20’s yr. – Female
Lap/shoulder & Air bag
Fully reclined seatback position and sleeping
Seatback Recline
CIREN Case Review 1 – Contacts

R knee/Leg contact scuff to door panel
Seatback Recline
CIREN Case Review 1 – Injuries

AIS 3
T-Spine

AIS 3
Lower Extremity
Seatback Recline
Case Review 1 – Occupant Kinematics
Seatback Recline
Case Review 1 – Occupant Kinematics
Seatback Recline
CIREN Case Review 2 – Scene
Seatback Recline
CIREN Case Review 2 – Case Vehicle

2003 Compact Sedan 2-door

PDOF - 12 o’clock

Reconstruction
Delta V = 24mph/38kmph
Seatback Recline
Case Review 2 – Case Occupant

Driver
Teenager – Male
Frontal steering column air bag deployment
No manual seat belt use
Seatback full recline
Seatback Recline
Case Review 2 – Occupant Kinematics

Bilateral knee bolster contacts
Deformed Steering Rim
Complete collapse steering column
Seatback Recline
Case Review 2 – Contacts

Steering Rim Deformation
Complete Steering Column Collapse
Seatback Recline
Case Review 2 – Contacts

Shear Capsules
Seatback Recline
Case Review 2 – Contacts

Left knee contact
Scuffed cover, Deformed Bolster
Seatback Recline
Case Review 2 – Contacts

Right knee contact to bolster
Evidence: skin, fabric, hair
Seatback Recline
Case Review 2 – Contacts

Left hand contact with intrusion of windshield reinforced by exterior hood
Seatback Recline
Case Review 2 – Injuries

AIS 2 – Hip
AIS 3 – Lower Extremity

AIS 2 – Hand
AIS 3 – Lower Extremity
Seatback Recline
CIREN Case Review 3 – Scene
Seatback Recline
Case Review 2 – Case Vehicle

2006 Compact - 2HB
12 o’clock PDOF
Delta V = 30 mph / 48 kmph
Seatback Recline
CIREN Case Review 3 – Driver

Elderly – Male
Seatback Upright Position
Manual Lap/Shoulder belt w/ Pretensioner
Air bag Deployments
- Steering Column
- Knee Bolster
Seatback Recline
CIREN Case Review 3 – Driver

Safety belt usage evidence at latch plate and pillar point
Seatback Recline
CIREN Case Review 3 – Driver

Air bag
Deployments
Seatback Recline
Case Review 3 – Driver Injuries

AIS 2 – Chest

AIS 3
L-spine
Seatback Recline
Case Review 3 – Case Occupant

Elderly – Female
Fully reclined seatback
Manual lap/shoulder w/pretensioner
Instrument panel air bag deployment
Seatback Recline
Case Review 3 – Contacts

Left and Right Knee contacts
Seatback Recline
Case Review 3 – Contacts

Left and Right Knee contacts
Seatback Recline
Case Review 3 – Safety Belt

Safety belt latch plate and webbing
Seatback Recline
Case Review 3 – Safety Belt
Seatback Recline
Case Review 3 – Safety belt
Seatback Recline
Case Review 3 – Injuries

AIS 6  C-spine
AIS 6 - Brain
AIS 4 – Chest
AIS 3 – Abdomen
AIS 3 – Pelvis
AIS 3 – Brain
Seatback Recline
Case Review 3 – Occupant Kinematics
Seatback Recline
Case Review 3 – Occupant Kinematics
Mechanisms in fully recline seatback CIREN case reviews

- Patterns of lower extremity injuries
- Associated thoracic trauma in restrained
  - Spine injury from flexion over shoulder belt “clothesline” type
  - Rib fracture patterns
- Positioning of lap belt resulted in upper abdominal injuries
PHASE II — NASS/CDS
Methods:

- Front seat occupants in frontal impact collisions
- Occupant details: Age, gender, height, weight, seatbelt use
- Crash details: Vehicle type, rollovers, ejection, DeltaV, PDOF
- Seat details: seat back and track position
- Outcomes: Mortality, AIS. ISS

- 90,412
- 28,944
- Remaining 61,468
- Missing Data
- 15,935 Upright
- 45,250 Partial Reclined
- 280 Fully Reclined

* No differences in occupant or collision factors
<table>
<thead>
<tr>
<th></th>
<th>Upright</th>
<th>PR</th>
<th>FR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(17.6%)</td>
<td>(50%)</td>
<td>(0.3%)</td>
</tr>
<tr>
<td>Age (yrs)</td>
<td>39.4</td>
<td>35.7</td>
<td>29.6</td>
</tr>
<tr>
<td>Male gender (%)</td>
<td>7775</td>
<td>24705</td>
<td>197</td>
</tr>
<tr>
<td></td>
<td>(48.8%)</td>
<td>(54.7%)</td>
<td>(70.4%)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>170.1</td>
<td>171.4</td>
<td>174</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>75.9</td>
<td>75.8</td>
<td>79</td>
</tr>
<tr>
<td>Vehicle Type</td>
<td>Upright</td>
<td>PR</td>
<td>FR</td>
</tr>
<tr>
<td>------------------</td>
<td>-------------</td>
<td>--------</td>
<td>--------</td>
</tr>
<tr>
<td></td>
<td>(17.6%)</td>
<td>(50%)</td>
<td>(0.3%)</td>
</tr>
<tr>
<td>Passenger car</td>
<td>10490 (65.8)</td>
<td>33539 (74.1)</td>
<td>224 (80)</td>
</tr>
<tr>
<td>SUV</td>
<td>2350 (14.7)</td>
<td>5661 (12.5)</td>
<td>22 (7.9)</td>
</tr>
<tr>
<td>Pickup</td>
<td>1666 (10.4)</td>
<td>3151 (7)</td>
<td>14 (5)</td>
</tr>
</tbody>
</table>
No difference in:

Delta V
PDOF - Direction of Force
Rollovers
Ejections
<table>
<thead>
<tr>
<th>Injury severity score</th>
<th>Upright (UP)</th>
<th>Partial Recline (PR)</th>
<th>Full Recline (FR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (SD)</td>
<td>5.7 (14)</td>
<td>5.5 (13.8)</td>
<td>7.2 (16)</td>
</tr>
<tr>
<td>1 – 8</td>
<td>8717 (54.7)</td>
<td>23807 (52.6)</td>
<td>120 (42.9)</td>
</tr>
<tr>
<td>9 – 25</td>
<td>1832 (11.5)</td>
<td>4799 (10.6)</td>
<td>38 (13.6)</td>
</tr>
<tr>
<td>&gt; 25</td>
<td>879 (5.5)</td>
<td>2604 (5.8)</td>
<td>25 (8.9)</td>
</tr>
</tbody>
</table>
## Outcome: AIS

<table>
<thead>
<tr>
<th>AIS</th>
<th>Upright (UP)</th>
<th>Partial Recline (PR)</th>
<th>Full Recline (FR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>0.41</td>
<td>0.42</td>
<td>0.49</td>
</tr>
<tr>
<td>Thorax</td>
<td>0.48</td>
<td>0.44</td>
<td>0.53</td>
</tr>
<tr>
<td>Abdomen</td>
<td>0.19</td>
<td>0.18</td>
<td>0.22</td>
</tr>
<tr>
<td>Spine</td>
<td>0.27</td>
<td>0.26</td>
<td>0.32</td>
</tr>
<tr>
<td>Lower extremity</td>
<td>0.55</td>
<td>0.51</td>
<td>0.48</td>
</tr>
</tbody>
</table>
Is there a difference in mortality?

![Bar chart showing mortality percentages for different seatback positions (UP, PR, FR).]
Mortality risk – regression analysis

- Difference in mortality persist when adjusted for age, sex, seatbelt use and type of vehicle

<table>
<thead>
<tr>
<th>Mortality Risk</th>
<th>Odds Ratio</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Partial Reclined</td>
<td>1.14</td>
<td>1.02 – 1.22</td>
</tr>
<tr>
<td>Fully Reclined</td>
<td>1.77</td>
<td>1.13 – 2.78</td>
</tr>
</tbody>
</table>
## Mortality stratified by seatbelt use

<table>
<thead>
<tr>
<th>Mortality Risk</th>
<th>Belted</th>
<th>Unbelted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Partial Reclined</td>
<td>1.17 (1.03 – 1.34)</td>
<td>1.13 (0.99 – 1.29)</td>
</tr>
<tr>
<td>Fully Reclined</td>
<td>1.91 (0.77 – 4.75)</td>
<td>1.71 (0.97 – 3.04)</td>
</tr>
</tbody>
</table>

Overall regression model with interaction term to evaluate seatbelt use and recline – i.e. if seatbelt contributes to mechanism of effect. $P = 0.87, 0.93$ i.e. no significant interaction.
Conclusion:

- Fully reclined occupants are predominantly young, male and not wearing a seatbelt
- “Clothesline” type
  - Chest and spinal injuries with the shoulder belt appear to be one mechanism in fully reclined occupants wearing a seatbelt.
- Fully reclined seats are an independent risk factor for death in motor vehicle collisions
- Slightly reclined seats have a small increase in mortality