Evaluation of seat performance criteria for rear-end impact testing: BioRID II and insurance data

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Background

- Traditional approach
- Whiplash Associated Disorders

Phase 1
Phase 2
Phase 3

a) b) c) d)
Objective and Principle method

- Suggest seat performance criteria to be used in rear-end impact seat tests with BioRID II

Correlation coefficient

$R^2 = \text{measure of the strength of the relationship}$

Measurements from sled tests with BioRID II
Methods: Data used

Insurance data

- Folksam, Sweden
  - 1998 - 2012
  - Only drivers
  - Only rear +/-30 degrees
  - Only neck and spine injuries
- Risks used:
  - Symptoms for more than one month in case of initial symptoms
  - Permanent medical impairment in case of initial symptoms

BioRID II seat test data

- Euro NCAP medium pulse rear-end impact test data
  - Thatcham, 2004 and 2012
- BioRID II build level E or G
- H-point tool:
  - TechnoSports, Inc.
  - Automotive Accessories, Ltd.
## Methods: Grouping insurance data

<table>
<thead>
<tr>
<th>Group names</th>
<th>No. cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ford with STD</td>
<td>382</td>
</tr>
<tr>
<td>Hyundai with STD</td>
<td>195</td>
</tr>
<tr>
<td>Mercedes with STD</td>
<td>191</td>
</tr>
<tr>
<td>Opel with STD</td>
<td>500</td>
</tr>
<tr>
<td>Peugeot with STD</td>
<td>397</td>
</tr>
<tr>
<td>Saab with STD older</td>
<td>504</td>
</tr>
<tr>
<td>Saab with STD newer</td>
<td>150</td>
</tr>
<tr>
<td>Saab with SAHR</td>
<td>354</td>
</tr>
<tr>
<td>Toyota with STD</td>
<td>579</td>
</tr>
<tr>
<td>Toyota with WIL</td>
<td>1136</td>
</tr>
<tr>
<td>Volvo with STD old</td>
<td>1057</td>
</tr>
<tr>
<td>Volvo with STD</td>
<td>676</td>
</tr>
<tr>
<td>Volvo with WHIPS</td>
<td>305</td>
</tr>
<tr>
<td>VW group with STD small</td>
<td>163</td>
</tr>
<tr>
<td>VW group with STD medium</td>
<td>440</td>
</tr>
<tr>
<td>VW group with STD large</td>
<td>683</td>
</tr>
<tr>
<td>VW group with RHR</td>
<td>181</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Insurance data for group Toyota with WIL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auris</td>
</tr>
<tr>
<td>Avensis</td>
</tr>
<tr>
<td>Avensis Verso</td>
</tr>
<tr>
<td>Camry</td>
</tr>
<tr>
<td>Corolla</td>
</tr>
<tr>
<td>Corolla Verso</td>
</tr>
<tr>
<td>Corolla Verso</td>
</tr>
<tr>
<td>Prius</td>
</tr>
<tr>
<td>Prius</td>
</tr>
<tr>
<td>RAV4</td>
</tr>
<tr>
<td>RAV4</td>
</tr>
<tr>
<td>Yaris and Yaris Verso</td>
</tr>
<tr>
<td>Yaris</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BioRID tests for group Toyota with WIL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
</tr>
<tr>
<td>Production year</td>
</tr>
<tr>
<td>Test year</td>
</tr>
<tr>
<td>Test facility</td>
</tr>
<tr>
<td>BioRID II version</td>
</tr>
</tbody>
</table>
Methods: Compensation for classification of injury

![Diagram showing the risk of symptoms >1 month (%) over different accident years from 1999 to 2009. The risk decreases from 25% in 1999 to 10% in 2009, with a significant drop in 2005.](image-url)
Methods: Studied parameters

- Maximum Neck Injury Criteria (NIC)
- Maximum Neck Force Criteria (N_{km})
- Maximum Lower Neck Loads Criteria (LNL)
- Maximum Head x- and z-acceleration
- Maximum C4 x- and z-acceleration
- Maximum T1 x- and z-acceleration
- Maximum T8 x- and z-acceleration
- Maximum L1 x- and z-acceleration
- Maximum Pelvis x- and z-acceleration
- Maximum and minimum Upper Neck Loads (F_x, F_z and M_y, before head contact stop)
- Maximum and minimum Lower Neck Loads (F_x, F_z and M_y, before head contact stop)
- Maximum Occipital condyle rel. T1 x- and z-displacement in the T1 frame (OC-x and OC-z)
- Maximum Head rel. T1 angular displacement
- Head Contact Time (HCT)
- Maximum Head Rebound Velocity (HRV)
Results: Neck Injury Criteria versus permanent medical impairment

![Graph showing the relationship between NIC (m²/s²) and Risk for various car brands and models.](attachment:image.png)
Results: Occipital Condyles rel. T1 x-disp. versus permanent medical impairment
Results: Head Contact Time versus permanent medical impairment
# Results: Correlation $R^2$ values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Permanent medical impairment</th>
<th>Symptoms &lt; 1 month</th>
</tr>
</thead>
<tbody>
<tr>
<td>NIC</td>
<td>0.59</td>
<td>0.72</td>
</tr>
<tr>
<td>OC rel. T1 x-displacement (retraction)</td>
<td>0.42</td>
<td>0.39</td>
</tr>
<tr>
<td>L1 x-acceleration</td>
<td>0.42</td>
<td>0.32</td>
</tr>
<tr>
<td>Pelvis z-acceleration</td>
<td>0.40</td>
<td>0.19</td>
</tr>
<tr>
<td>L1 z-acceleration</td>
<td>0.37</td>
<td>0.14</td>
</tr>
<tr>
<td>Head rel. T1 y-rot. (extension)</td>
<td>0.35</td>
<td>0.53</td>
</tr>
<tr>
<td>$N_{km}$</td>
<td>0.33</td>
<td>0.38</td>
</tr>
<tr>
<td>T8 x-acceleration</td>
<td>0.28</td>
<td>0.29</td>
</tr>
<tr>
<td>T8 z-acceleration</td>
<td>0.22</td>
<td>0.07</td>
</tr>
<tr>
<td>U. N. $F_x$ (head r.w.)</td>
<td>0.19</td>
<td>0.23</td>
</tr>
<tr>
<td>L. N. $F_x$ (head f.w.)</td>
<td>0.17</td>
<td>0.22</td>
</tr>
<tr>
<td>L. N. $M_y$ (negative)</td>
<td>0.16</td>
<td>0.20</td>
</tr>
<tr>
<td>T1 x-acceleration</td>
<td>0.15</td>
<td>0.40</td>
</tr>
</tbody>
</table>
**Discussion 1: Effect of outliers**

- $R^2 = 0.40$ for 17 datasets
- $R^2 = 0.60$ for 16 datasets
- $R^2 = 0.73$ for 15 datasets

The graph shows the relationship between the risk of symptoms >1 month and T1 x-acceleration (g) for various car models and models divided into older, newer, and standard (STD) categories.
Discussion 2: Injury risk measures

Risk of long term symptoms and impairments given the occupant had initial symptoms following a rear-end impact

Risk of long term symptoms and impairments given the occupant were in a rear-end impact
Discussion 3: Dummy tests

• Since the BioRID tests were carried out:
  – Test procedures modernized
  – Dummy calibration routines changed
  – Dummy build level updated
• Single sled pulse was used
  – Evaluate injury predictability of the complete sled test method
Conclusions

• NIC, L1-acceleration and Occipital condyles relative T1 x-displacement correlate with long term injury risk:
  — NIC 25 m²/s²
  — L1 x-acceleration 120 m/s²
  — Occipital Condyle x-displacement 22 mm

• Neck extension and T1 x-acceleration may be candidates but appear to be sensitive to set model inclusion

• These findings are in partial agreement with other studies on this

• Additional parameters may predict PMI and long term symptoms
End!

Many thanks to Thatcham and Autoliv for providing BioRID seat test data!