Status of the WorldSID injury risk curves

on behalf of ISO/WG6

March, 2012
Outline

• Conclusion of the work included in the TR12350 and in Stapp 2009
• Definition of guidelines to build injury risk curves
• Selection of injury risk curves
  ✓ Based on Akaike (AIC) criterion
  ✓ Based on the quality index
  ✓ Based on engineering judgment
• WorldSID 50th injury risk curves
Conclusion of the work included in the TR12350 and in Stapp 2009

• Injury risk curves constructed:
  ✓ Based on selected PMHS samples
  ✓ For commonly used measurements
  ✓ With commonly used statistical methods
  ✓ Without correction for age and for 45-year-old

• TR12350 updated with a new methodology and the injury risk curves dedicated to the WorldSID 50th percentile
• Publication at Stapp 2009 providing the injury risk curve adjusted to 45-year-old
Injury risk curves as proposed in Stapp 2009

**Shoulder**
- Shoulder injury risk AIS2+ as a function of shoulder force
- Shoulder injury risk AIS2+ as a function of shoulder deflection

**Thorax**
- Thoracic skeletal injury risk AIS3+ as a function of rib deflection
- Thoracic skeletal injury risk AIS4+ as a function of rib deflection

**Abdomen**
- Abdomen injury risk AIS2+ as a function of abdomen rib deflection
- Abdomen injury risk AIS3+ as a function of abdomen rib VC

**Pelvis**
- Pelvis injury risk AIS2+ as a function of pubic force
- Pelvis injury risk AIS3+ as a function of pelvis acceleration

- Pelvis injury risk AIS2+ as a function of pelvis acceleration
- Pelvis injury risk AIS3+ as a function of pelvis acceleration
Definition of guidelines to build injury risk curves

- ISO/WG6 agreed on guidelines to build injury risk curves
- These guidelines include several steps
- Among those:
  - ✔ The use of the survival analysis
  - ✔ The release of the injury risk curves associated to a quality index based on the width of the confidence intervals
  - ✔ The recommendation of an injury risk curve per body region, injury type and injury level
Selection of injury risk curves

• Based on the Akaike (AIC) criterion
  ✓ Based on maximum likelihood but weighted by the number of variables
  ✓ Only possible comparing two injury risk curves built with identical samples
## Selection of the injury risk curves

<table>
<thead>
<tr>
<th>Shoulder</th>
<th>Thorax</th>
<th>Abdomen</th>
<th>Pelvis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Shoulder injury risk AIS2+ as a function of shoulder force</strong></td>
<td><strong>Thoracic skeletal injury risk AIS3+ as a function of rib deflection</strong></td>
<td><strong>Abdomen injury risk AIS2+ as a function of abdomen rib deflection</strong></td>
<td><strong>Pelvis injury risk AIS2+ as a function of pubic force</strong></td>
</tr>
<tr>
<td><strong>Shoulder injury risk AIS2+ as a function of shoulder deflection</strong></td>
<td><strong>Thoracic skeletal injury risk AIS4+ as a function of rib deflection</strong></td>
<td><strong>Abdomen injury risk AIS3+ as a function of abdomen rib deflection</strong></td>
<td><strong>Pelvis injury risk AIS3+ as a function of pubic force</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Thoracic skeletal injury risk AIS3+ as a function of rib VC</strong></td>
<td><strong>Abdomen injury risk AIS2+ as a function of abdomen rib VC</strong></td>
<td><strong>Pelvis injury risk AIS2+ as a function of pelvis acceleration</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Thoracic skeletal injury risk AIS4+ as a function of rib VC</strong></td>
<td></td>
<td><strong>Pelvis injury risk AIS3+ as a function of pelvis acceleration</strong></td>
</tr>
</tbody>
</table>

Based on AIC
Selection of injury risk curves

- Based on the quality index
- Based on width of the confidence intervals
- Curves with unacceptable quality classes are not recommended

Relative CI size = \frac{upper \ bound \ of \ the \ CI - lower \ bound \ of \ the \ CI}{value \ of \ dummy \ measurement \ at \ this \ risk}

Quality classes:
- unacceptable
- marginal
- fair
- good
Selection of the injury risk curves

**Shoulder**
- Shoulder injury risk AIS2+ as a function of shoulder force
- Shoulder injury risk AIS2+ as a function of shoulder deflection

**Thorax**
- Thoracic skeletal injury risk AIS3+ as a function of rib deflection
- Thoracic skeletal injury risk AIS4+ as a function of rib deflection
- Thoracic skeletal injury risk AIS3+ as a function of rib VC
- Thoracic skeletal injury risk AIS4+ as a function of rib VC

**Abdomen**
- Abdomen injury risk AIS2+ as a function of abdomen rib deflection
- Abdomen injury risk AIS2+ as a function of abdomen rib VC
- Abdomen injury risk AIS3+ as a function of abdomen rib deflection
- Abdomen injury risk AIS3+ as a function of abdomen rib VC
- Abdomen injury risk AIS2+ as a function of lower spine acceleration
- Abdomen injury risk AIS3+ as a function of lower spine acceleration

**Pelvis**
- Pelvis injury risk AIS2+ as a function of pubic force
- Pelvis injury risk AIS3+ as a function of pubic force
- Pelvis injury risk AIS2+ as a function of pelvis acceleration
- Pelvis injury risk AIS3+ as a function of pelvis acceleration

Based on AIC
Based on quality classes
Selection of injury risk curves

- Based on engineering judgment
  - **SHOULDER**: The test sample used for the construction of the IRC as a function of the shoulder deflection includes only impactor tests, while the sample for the construction of the IRC as a function of the shoulder force includes both impactor and sled tests
    - Recommendation of the IRC as a function of the shoulder force
  
  - **ABDOMEN**: The quality index is better for the curve as a function of the abdomen rib deflection than for the one as a function of the abdomen rib VC
    - Recommendation of the IRC as a function of the maximum abdomen rib deflection

- **PELVIS**: Most of the injuries observed in the PMHS tests used to build the injury risk curves are related to ilio-ischio rami and pubic symphysis
  - Recommendation of the dummy measurement which is the more closely related to these injuries: pubic force
### Selection of the injury risk curves

#### Shoulder
- Shoulder injury risk AIS2+ as a function of shoulder force
- Shoulder injury risk AIS2+ as a function of shoulder deflection

#### Thorax
- Thoracic skeletal injury risk AIS3+ as a function of rib deflection
- Thoracic skeletal injury risk AIS3+ as a function of rib VC
- Thoracic skeletal injury risk AIS4+ as a function of rib deflection
- Thoracic skeletal injury risk AIS4+ as a function of rib VC

#### Abdomen
- Abdomen injury risk AIS2+ as a function of abdomen rib deflection
- Abdomen injury risk AIS2+ as a function of abdomen rib VC
- Abdomen injury risk AIS3+ as a function of abdomen rib deflection
- Abdomen injury risk AIS3+ as a function of abdomen rib VC

#### Pelvis
- Pelvis injury risk AIS2+ as a function of pubic force
- Pelvis injury risk AIS2+ as a function of pelvis acceleration
- Pelvis injury risk AIS3+ as a function of pubic force
- Pelvis injury risk AIS3+ as a function of pelvis acceleration
- Pelvis injury risk AIS3+ as a function of pelvis acceleration

Based on AIC
Based on quality classes
Based on engineering judgment
WorldSID 50th injury risk curves

- at 45 yo (target age of the occupant to protect)
- and at the median age of the PMHS used to build the curve (age closer to those of the PMHS → more information available → confidence in the curves is more important)
WorldSID 50th injury risk curves

- Shoulder injury risk AIS2+

<table>
<thead>
<tr>
<th>Maximum shoulder Y force (N)</th>
<th>5% AIS2+</th>
<th>quality index at 5% AIS2+</th>
<th>25% AIS2+</th>
<th>quality index at 25% AIS2+</th>
<th>50% AIS2+</th>
<th>quality index at 50% AIS2+</th>
</tr>
</thead>
<tbody>
<tr>
<td>45 year old</td>
<td>1799</td>
<td>fair</td>
<td>2270</td>
<td>fair</td>
<td>2556</td>
<td>fair</td>
</tr>
<tr>
<td>67 year old</td>
<td>1594</td>
<td>good</td>
<td>2011</td>
<td>good</td>
<td>2265</td>
<td>good</td>
</tr>
</tbody>
</table>

Note: no AIS3 case and above

![Graph showing shoulder risk AIS2+ for 45 and 67 year olds]
WorldSID 50th injury risk curves

Thoracic skeletal injury risk AIS3+

<table>
<thead>
<tr>
<th>Maximum thorax and abdomen rib deflection (mm)*</th>
<th>5% AIS3+</th>
<th>quality index at 5% AIS3+</th>
<th>25% AIS3+</th>
<th>quality index at 25% AIS3+</th>
<th>50% AIS3+</th>
<th>quality index at 50% AIS3+</th>
</tr>
</thead>
<tbody>
<tr>
<td>45 year old</td>
<td>41.4</td>
<td>fair</td>
<td>51.2</td>
<td>fair</td>
<td>58.1</td>
<td>good</td>
</tr>
<tr>
<td>67 year old</td>
<td>29.3</td>
<td>fair</td>
<td>36.3</td>
<td>good</td>
<td>41.2</td>
<td>good</td>
</tr>
</tbody>
</table>

* Measured by 1D IR-TRACC
WorldSID 50th injury risk curves

- Abdomen injury risk AIS2+

<table>
<thead>
<tr>
<th>Maximum abdomen rib deflection (mm) *</th>
<th>5% AIS2+</th>
<th>quality index at 5% AIS2+</th>
<th>25% AIS2+</th>
<th>quality index at 25% AIS2+</th>
<th>50% AIS2+</th>
<th>quality index at 50% AIS2+</th>
</tr>
</thead>
<tbody>
<tr>
<td>45 year old</td>
<td>58.9</td>
<td>fair</td>
<td>72.0</td>
<td>fair</td>
<td>79.8</td>
<td>fair</td>
</tr>
<tr>
<td>67 year old</td>
<td>37.1</td>
<td>fair</td>
<td>45.3</td>
<td>good</td>
<td>50.2</td>
<td>good</td>
</tr>
</tbody>
</table>

Note:
only 1 AIS3 case
And no AIS4 or above

* Measured by 1D IR-TRACC
WorldSID 50th injury risk curves

- Skeletal thoracic injury risk is determined as a function of the maximum of the thoracic and abdomen rib deflection.

- Abdomen injury risk is determined as a function of the maximum abdomen rib deflection.

- Given the injury thresholds presented in the two previous slides, if the skeletal injury risk is below a given level, the abdomen risk will also be below this level of risk.
WorldSID 50th injury risk curves

Pelvis injury risk AIS2+

<table>
<thead>
<tr>
<th>Maximum pubic force (N)</th>
<th>5% AIS2+</th>
<th>quality index at 5% AIS2+</th>
<th>25% AIS2+</th>
<th>quality index at 25% AIS2+</th>
<th>50% AIS2+</th>
<th>quality index at 50% AIS2+</th>
</tr>
</thead>
<tbody>
<tr>
<td>45 year old</td>
<td>1818</td>
<td>fair</td>
<td>2645</td>
<td>marginal</td>
<td>3202</td>
<td>marginal</td>
</tr>
<tr>
<td>67 year old</td>
<td>1340</td>
<td>fair</td>
<td>1950</td>
<td>good</td>
<td>2361</td>
<td>good</td>
</tr>
</tbody>
</table>

Pelvis risk AIS2+ vs WorldSID 50th maximum pubic force (N)
WorldSID 50th injury risk curves

Pelvis injury risk AIS3+

<table>
<thead>
<tr>
<th>Maximum pubic force (N)</th>
<th>5% AIS3+</th>
<th>quality index at 5% AIS3+</th>
<th>25% AIS3+</th>
<th>quality index at 5% AIS3+</th>
<th>50% AIS3+</th>
<th>quality index at 5% AIS3+</th>
</tr>
</thead>
<tbody>
<tr>
<td>45 year old</td>
<td>2214</td>
<td>marginal</td>
<td>2922</td>
<td>marginal</td>
<td>3365</td>
<td>marginal</td>
</tr>
<tr>
<td>67 year old</td>
<td>1714</td>
<td>good</td>
<td>2262</td>
<td>good</td>
<td>2605</td>
<td>good</td>
</tr>
</tbody>
</table>

Pelvis risk AIS3+

WorldSID 50th maximum pubic force (N)
WorldSID 50th injury risk curves

- Agreement within ISO/WG6
- TR12350 to be updated early 2012
  ✓ Vote by the ISO/SC12 by the end of 2012