Injury Risk Curves for WorldSID
Considerations for Shoulder, Thorax, Abdomen, & Pelvis

November 5, 2009
Overview

- **History & Background**
  - Side impact dummy IARVs
  - ISO WorldSID 50th work

- **Construction of an Injury Plot**
  - Dummy vs. PMHS in same exposure, normalization

- **Statistical Methods**
  - Description of five approaches used by ISO

- **Additional Considerations**
  - An objective methodology for IRC selection?
  - Open Questions?
  - Opportunities for collaboration?
History
Side Impact Dummy Summary

- ES-2re & SID-IIs
  - Binary Logistic Regression (Kuppa 2006)
- WorldSID 50<sup>th</sup>
  - Five methods (Petitjean/ISO 2009)
    - Need consensus
- WorldSID 5<sup>th</sup>
  - Scaled from 50<sup>th</sup> (APROSY 2009)
    - Probit
WorldSID Background

- Petitjean, ISO 2009
- Re-analyzed all available PMHS side impact tests
- Developed selection criteria for PMHS test data
- Collected WorldSID data to match PMHS test data
- Developed multiple risk curves for body regions – shoulder, thorax, abdomen, pelvis
Injury Data

Steps

1. Pair PMHS injury outcome with dummy measure in same exposure level
2. Normalize stimulus levels for each specimen based upon age & PMHS size
3. Assign injury = 1, no injury = 0 (for each stimulus level)
4. Develop continuous injury risk curves to quantify the relationship between stimulus and injury probability
Injury Data

Example

Dummy stimulus = 25 resulted in no injury to PMHS

Dummy stimulus = 50 resulted in injury to PMHS
Populate the dataset for a series of tests (for each exposure, we have a PMHS injury-dummy measure pair)
Injury Data

Example

Normalize points by age, PMHS size, etc.
Apply some risk function that best relates stimulus to risk.
Statistical Methods
Developing a continuous risk function from injury data

- Logistic Regression
- Certainty
- Mertz-Weber (Median Rank)
- Survival
  - Censoring
  - **Weibull** & Lognormal most commonly used
- Consistent Threshold Estimate
Historically most common method
- This approach uses the relationship between continuous stimuli and categorical injury/no injury information to calculate an odds ratio, which is the risk value at each stimulus.
- Parametric (distribution is assumed)
O’Brien (Biometrics 1978)

- This method is often called the “reliability” method to measure cycles to failure in engineering applications or time to death in biological processes. Stimulus levels and corresponding censor type (failure or no failure) are assigned and a Weibull distribution is fit to it using the parameter estimates for shape and scale.

Petitjean ISO 2009
Mertz & Weber (SAE 826048)

- This method assigns a rank order value to each specimen based on stimulus level. Using the lowest stimulus level having an injury and the highest stimulus level without an injury, the dataset is truncated and the mean and standard deviation are calculated. These values are then used to define the best normal distribution to describe injury risk.

Petitjean ISO 2009
Mertz et al (SAE 960099)

- For a given set of data points, only specimens where the injury outcome is **certain** are included in the development of the risk curve. In other words, only left-censored (failure occurred) and right-censored (no failure occurred) data is included in the calculation.

- **Non-parametric** (distribution not assumed)
Nusholtz & Mosier (SAE 1999-01-0714)

- Like the Certainty method, this nonparametric method does not assume that the injury risk curve follows a particular type of distribution. A monotonically increasing curve is generated using a maximum likelihood approach with the doubly censored data.

Petitjean ISO 2009
Which to choose?

- For some measurements, it doesn’t matter which because the curves are consistent with one another at the selected risk level for compliance.
- For other measurements, it is necessary to choose a method:
  - For 50% shoulder injury risk: 45 mm (certainty) – 62 mm (CTE)
  - For 20% shoulder injury risk: ~42 mm (all curves)

Petitjean ISO 2009
Items for Discussion

- Seek consensus for objective selection of IRC
- Methodological questions
  - Non-parametric vs. parametric?
  - Is censored data important?
  - Is a consistent approach required across all body regions?
- How should the 5th small adult WorldSID injury risk be handled?
  - Scale first, then compare IRC?
  - Re-do analysis with 5th-sized tests?
## Evaluation Summary

<table>
<thead>
<tr>
<th>Metric</th>
<th>WorldSID 50&lt;sup&gt;th&lt;/sup&gt; (adjusted to 45YO, range of all methods)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25%</td>
</tr>
<tr>
<td>Shoulder Deflection AIS 2+ (mm)</td>
<td>54.3 – 63.7</td>
</tr>
<tr>
<td>Shoulder Force AIS 2+ (N)</td>
<td>2138 - 2400</td>
</tr>
<tr>
<td>Thorax Deflection AIS 3+ (mm)</td>
<td>48.5 – 57.9</td>
</tr>
<tr>
<td>Thorax Deflection AIS 4+ (mm)</td>
<td>56.5 – 71.3</td>
</tr>
<tr>
<td>Thorax VC AIS 3+ (m/s)</td>
<td>0.55 – 0.78</td>
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<tr>
<td>Thorax VC AIS 4+ (m/s)</td>
<td>1.39 – 1.70</td>
</tr>
<tr>
<td>Abdomen Deflection AIS 3+ (mm)</td>
<td>70.3 – 84.3</td>
</tr>
<tr>
<td>Abdomen VC AIS 3+ (m/s)</td>
<td>1.06 – 1.41</td>
</tr>
<tr>
<td>Lower Spine Acceleration AIS 3+ (m/s²)</td>
<td>643 - 689</td>
</tr>
<tr>
<td>Pelvis Force AIS 3+ (N)</td>
<td>2334 - 2914</td>
</tr>
<tr>
<td>Pelvis Acceleration AIS 3+ (m/s²)</td>
<td>707 - 1034</td>
</tr>
</tbody>
</table>

Analytical effort needed to assess all injury risk analysis methods and select the most appropriate method for establishing injury thresholds.
Thank you
Data Censoring

For most biomechanical data, the minimum level of stimulus needed for injury has not been determined by the test; therefore the data is censored.

If test does not produce injury, that data point is considered right censored
  – Failure threshold is above the stimulus value used by experimenter

If test does produce injury, that data point is considered left censored
  – Failure threshold is below the stimulus value used by experimenter

Most test series are therefore doubly censored; both right and left censored data is obtained
Evaluation of Risk Functions
Which statistical method is most appropriate?

Methods
- Nakahira et al (IRCOBI 2000)
- Wang et al (SAE 2003)
- Di Domenico & Nusholtz (SAE 2003)
- Kent & Funk (SAE 2004)