WS-1-5

Injury Risk Curves for WorldSID

Considerations for Shoulder, Thorax, Abdomen, & Pelvis

November 5, 2009

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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 50th
  - – Five methods (Petitjean/ISO 2009)
    - Need consensus
- WorldSID 5th
  - – Scaled from 50th (APROSYS 2009)
    - Probit

WorldSID Background

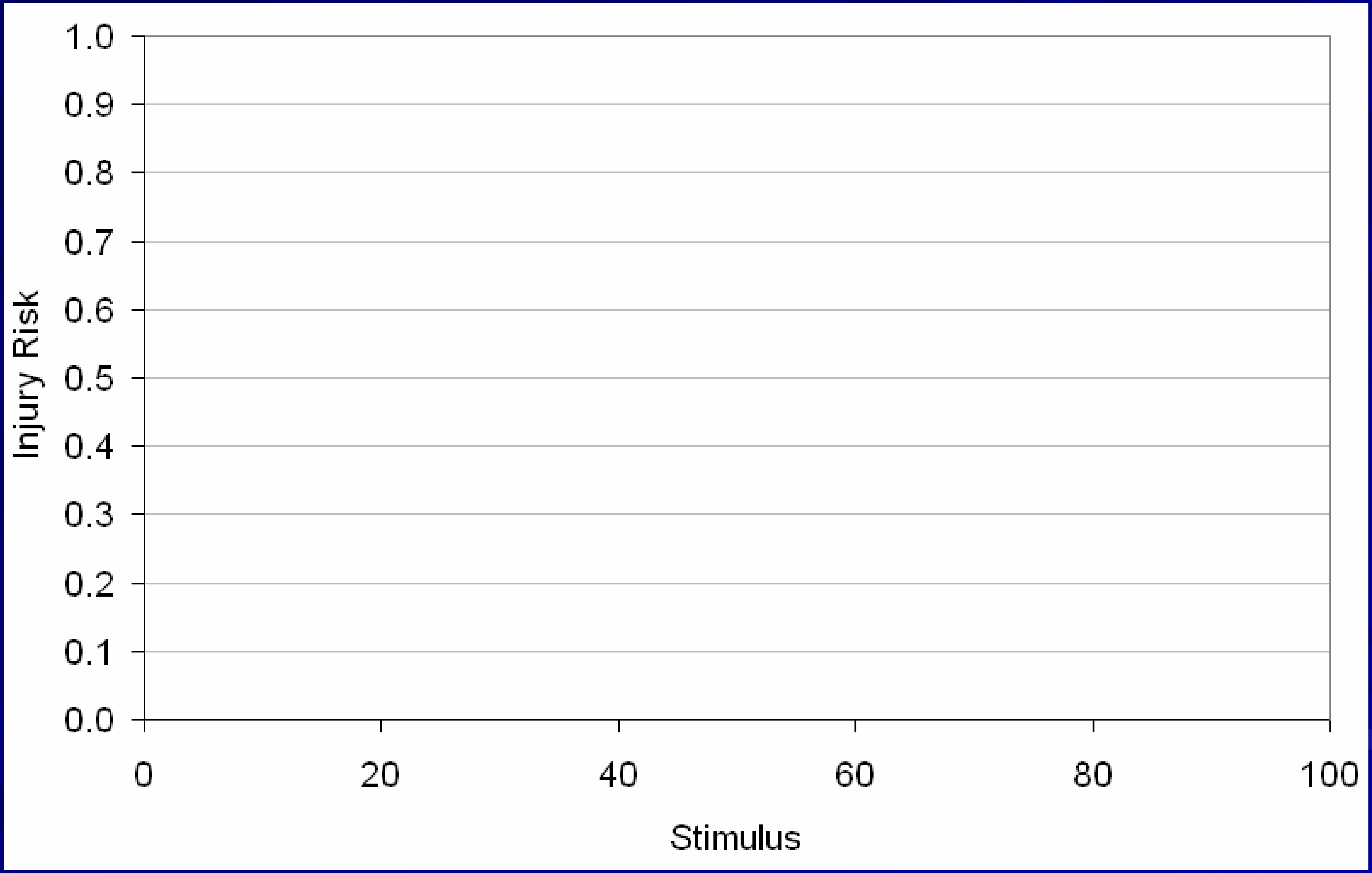
- Petitjean, ISO 2009
- Re-analyzed all available PMHS side impact tests
- Developed selection criteria for PMHS test data
- Collected WorldSID data to match PMHS test data
- Developed multiple risk curves for body regions – shoulder, thorax, abdomen, pelvis

Injury Data
Steps

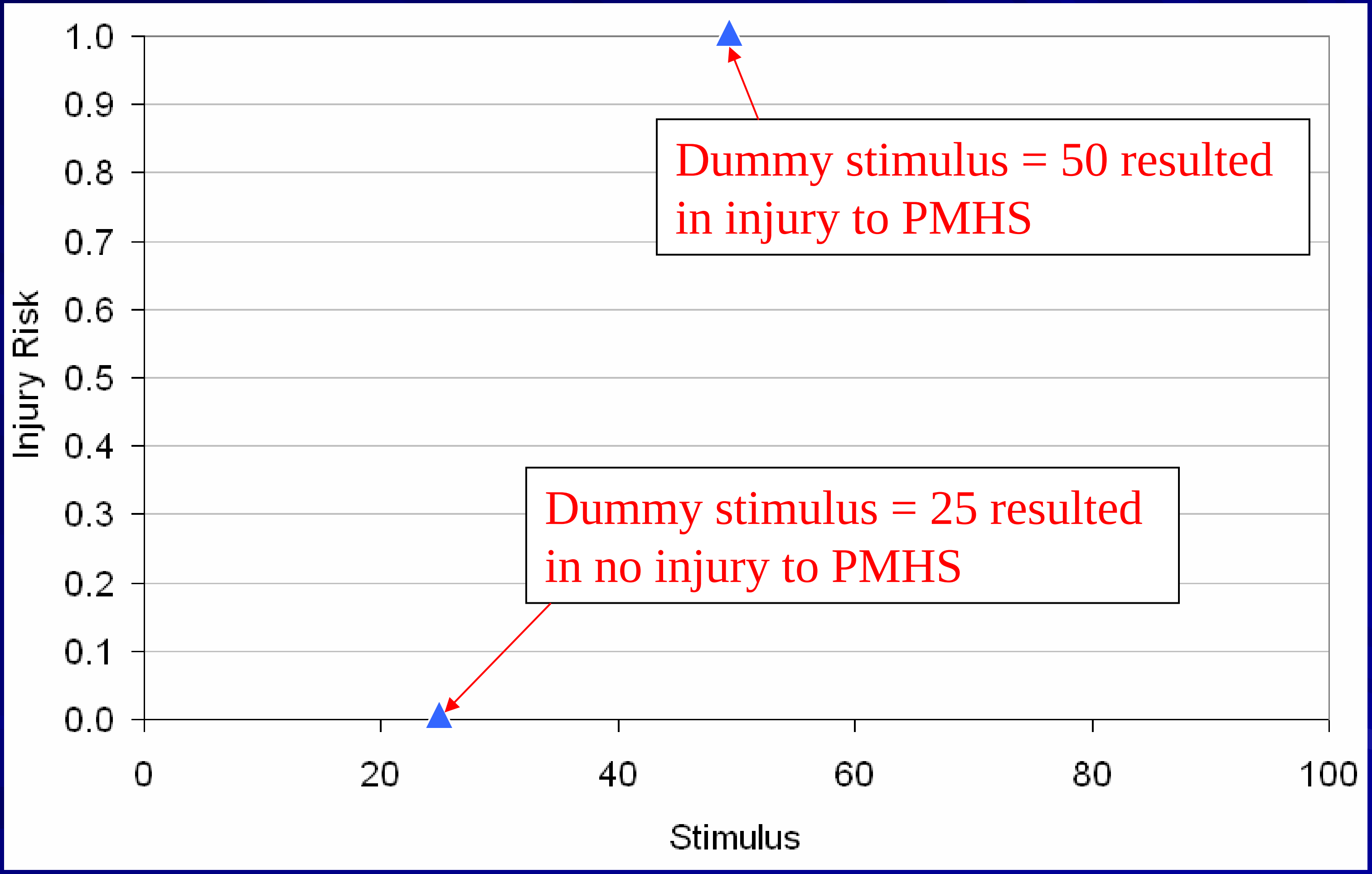
1. Pair PMHS injury outcome with dummy measure in same exposure level
2. Normalize stimulus levels for each specimen based upon age & PMHS size
3. Assign injury = 1, no injury = 0 (for each stimulus level)
4. Develop continuous injury risk curves to quantify the relationship between stimulus and injury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

Injury Data

Example

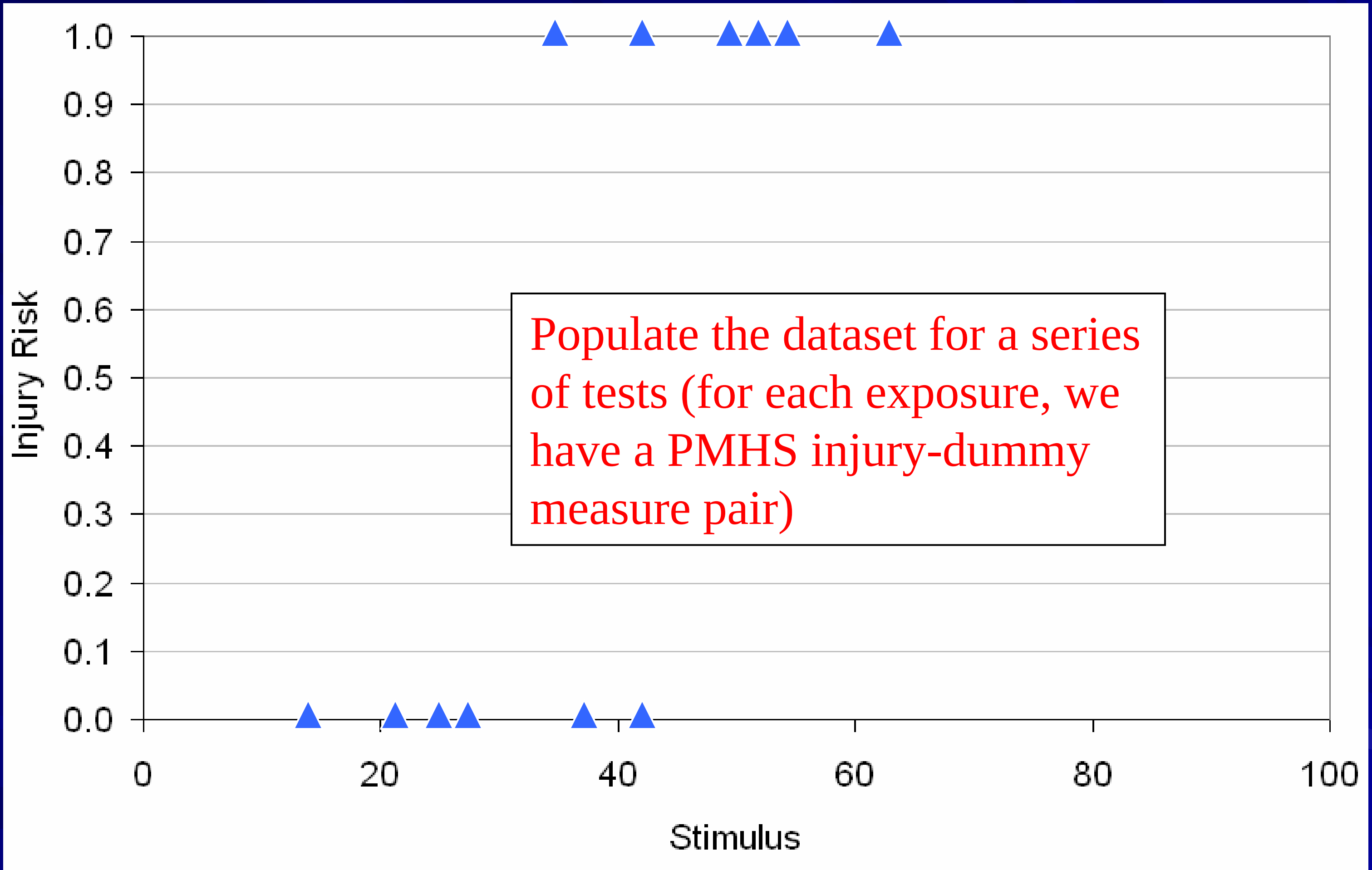


Injury Data
Example



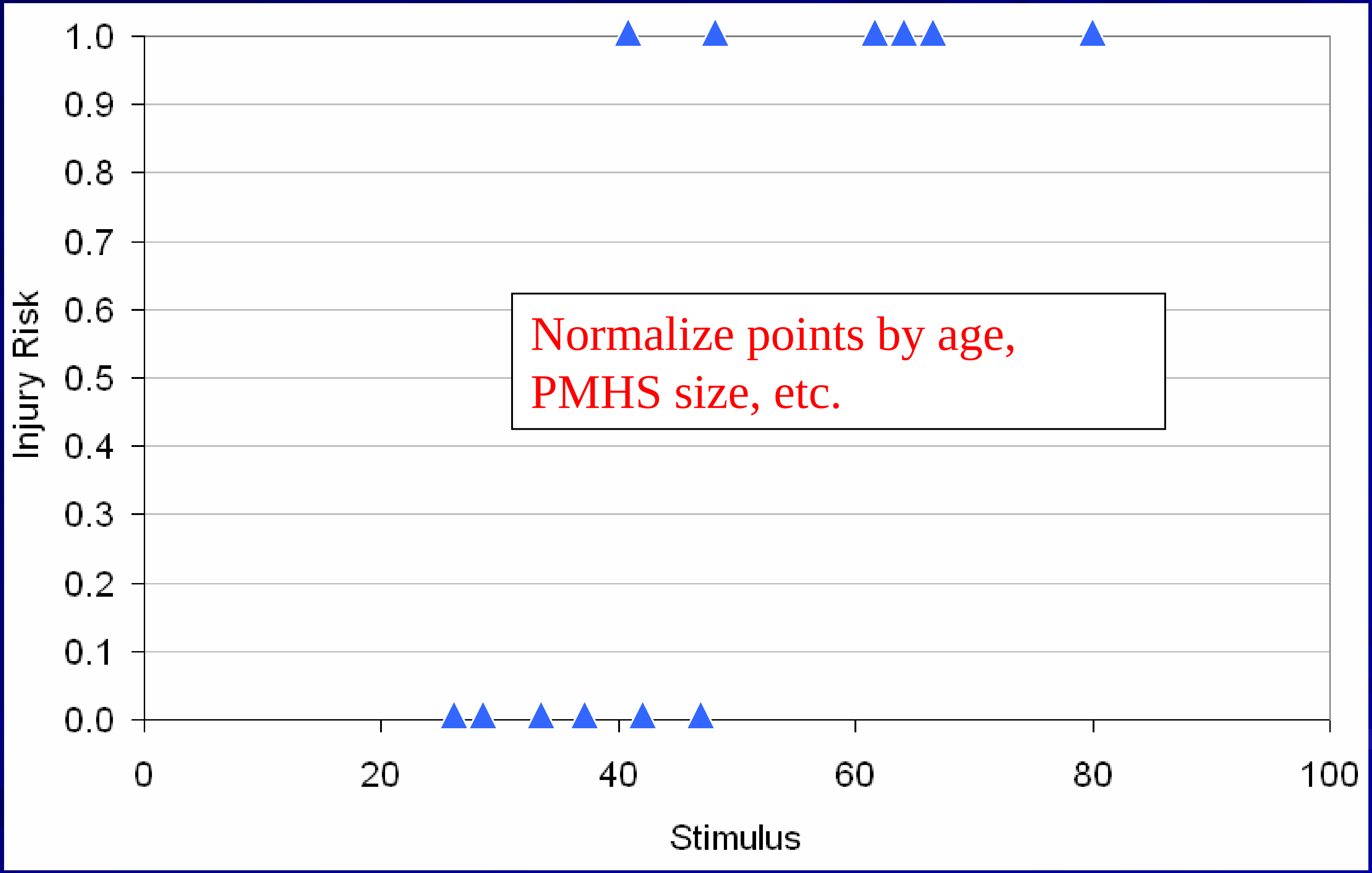
Injury Data

Example



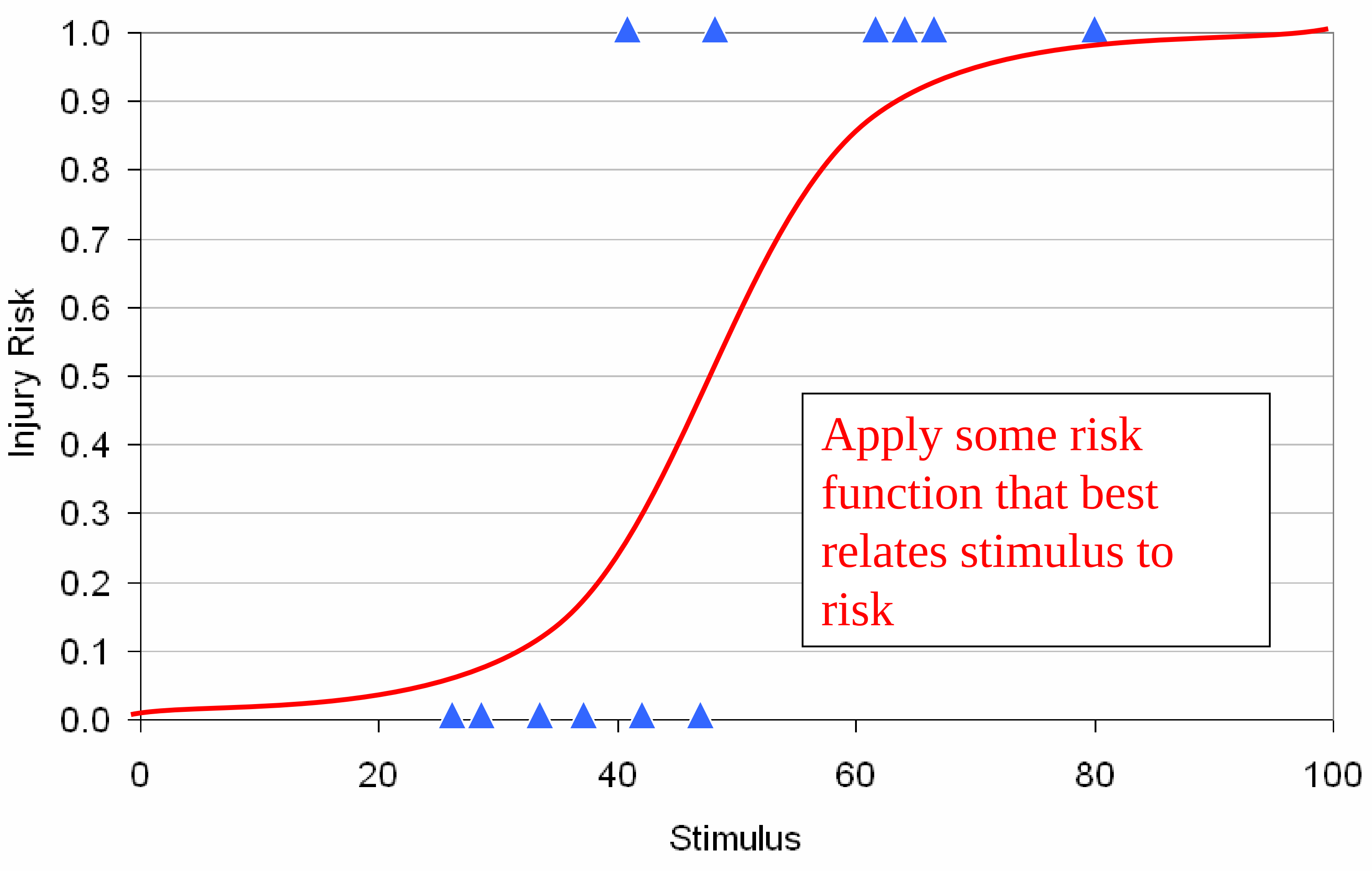
Injury Data

Example



Injury Data

Example



Statistical Methods

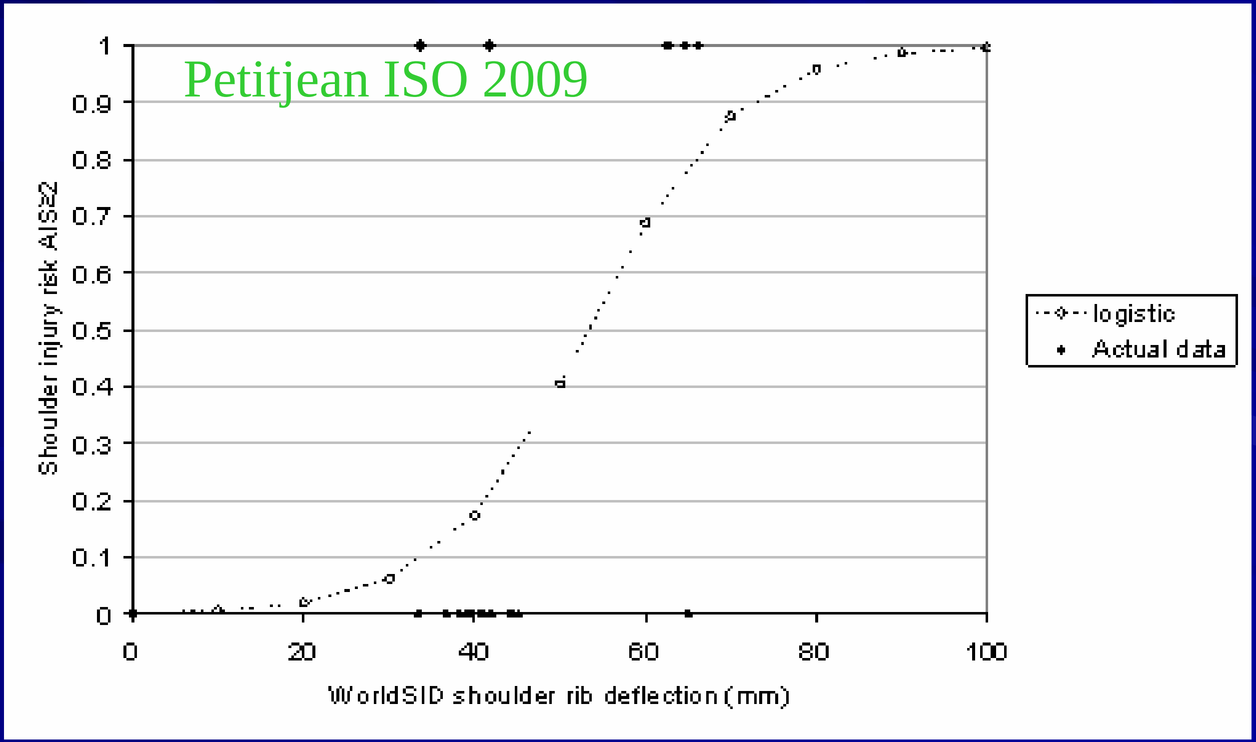
Developing a continuous risk function from injury data

- Logistic Regression
- Certainty
- Mertz-Weber (Median Rank)
- Survival
  - Censoring
  - Weibull & Lognormal most commonly used
- Consistent Threshold Estimate

Statistical Methods

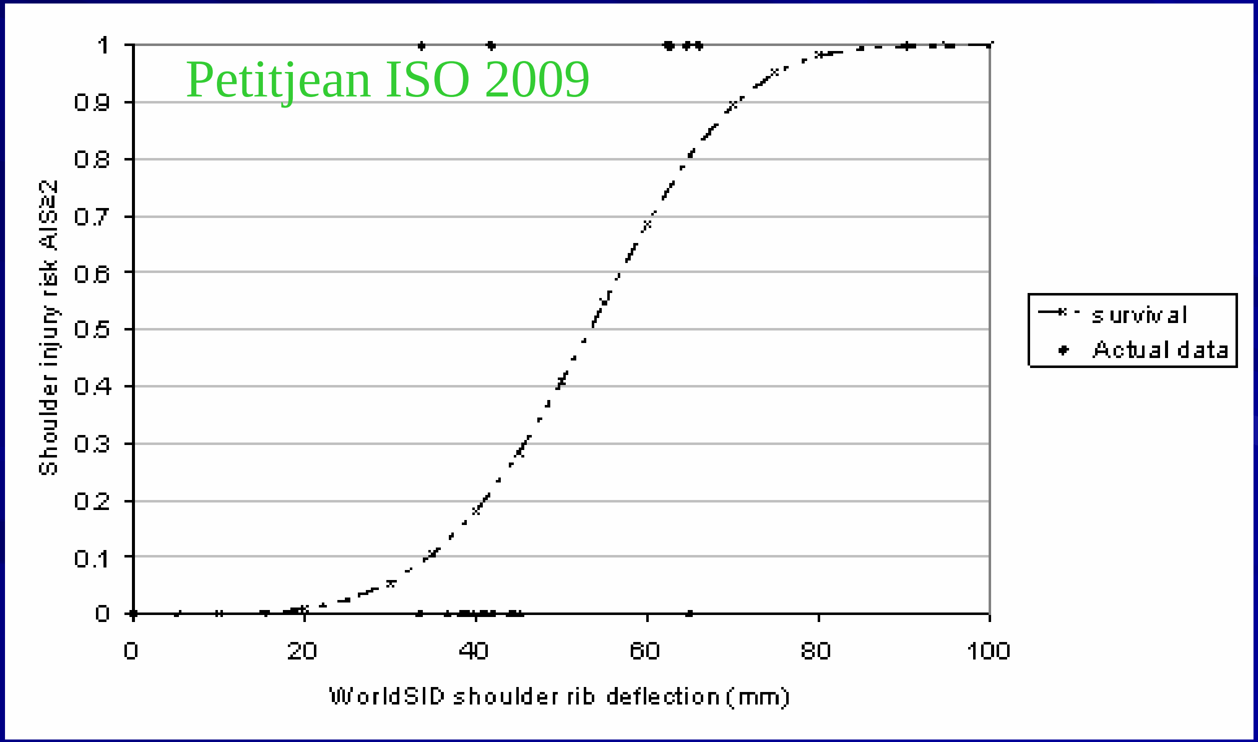
Binary Logistic Regression

- 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)



Statistical Methods
Survival - Weibull

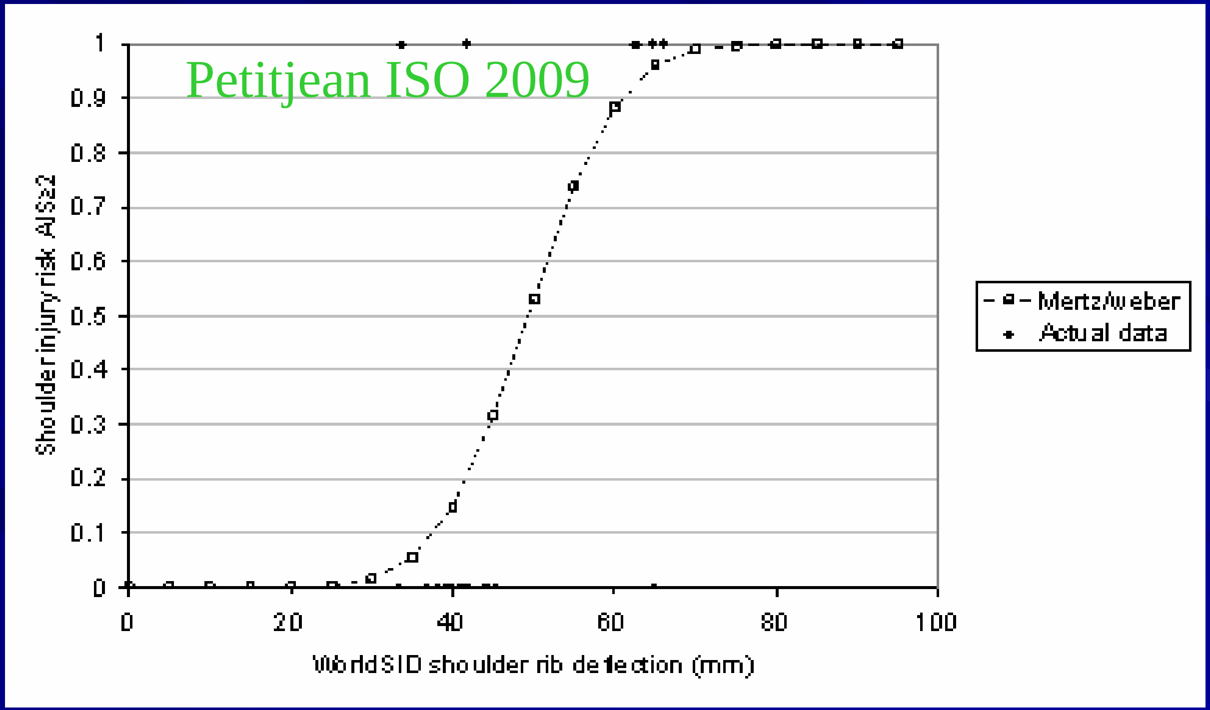
- O'Brien (*Biometrics* 1978)
  - This method is often called the "reliability" method to measure cycles to failure in engineering applications or time to death in biological processes. Stimulus levels and corresponding censor type (failure or no failure) are assigned and a ***Weibull distribution*** is fit to it using the parameter estimates for shape and scale.



Statistical Methods

Mertz-Weber (Median Rank)

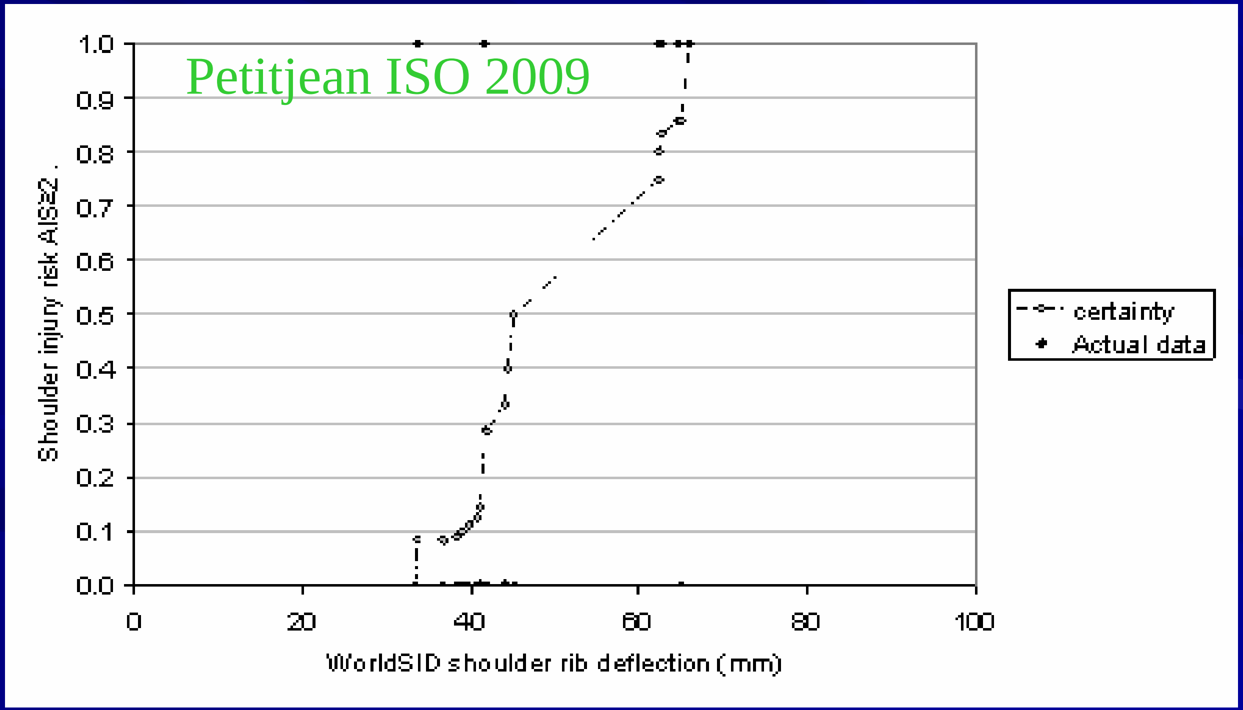
- Mertz & Weber (SAE 826048)
  - This method assigns a rank order value to each specimen based on stimulus level. Using the lowest stimulus level having an injury and the highest stimulus level without an injury, the dataset is truncated and the mean and standard deviation are calculated. These values are then used to define the best ***normal distribution*** to describe injury risk.



Statistical Methods

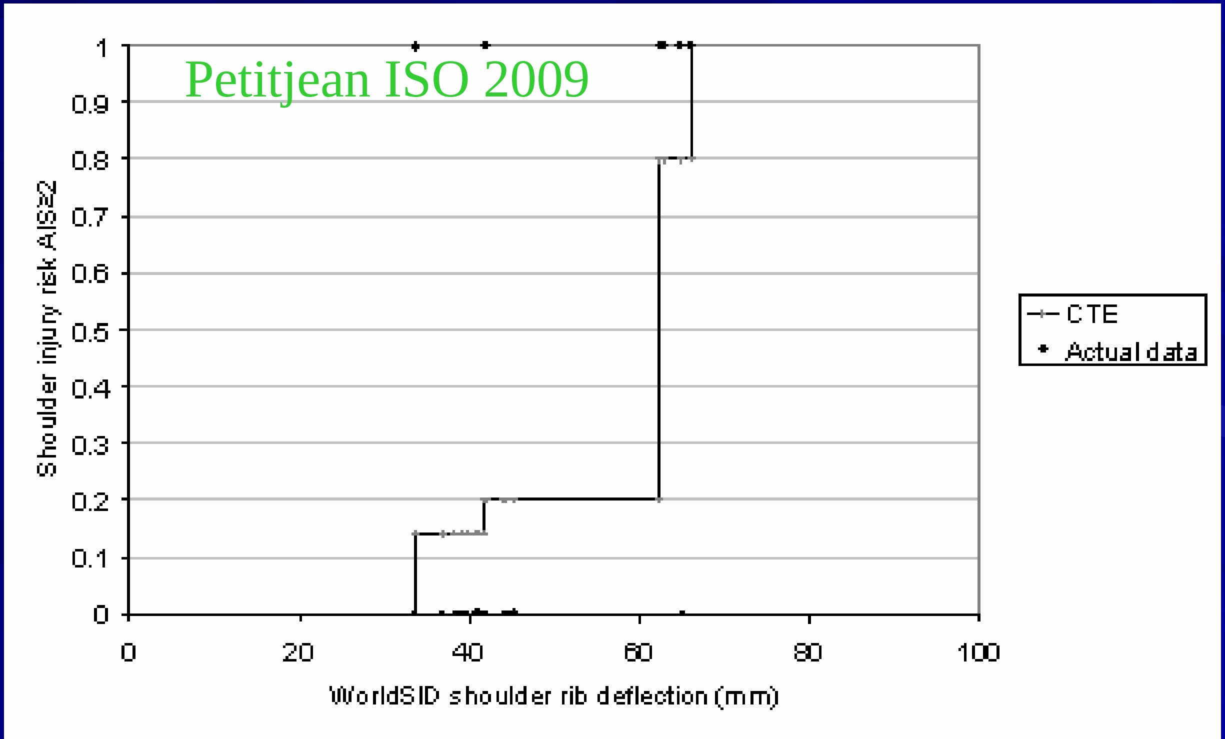
Certainty

- 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)



Statistical Methods
Consistent Threshold Estimate

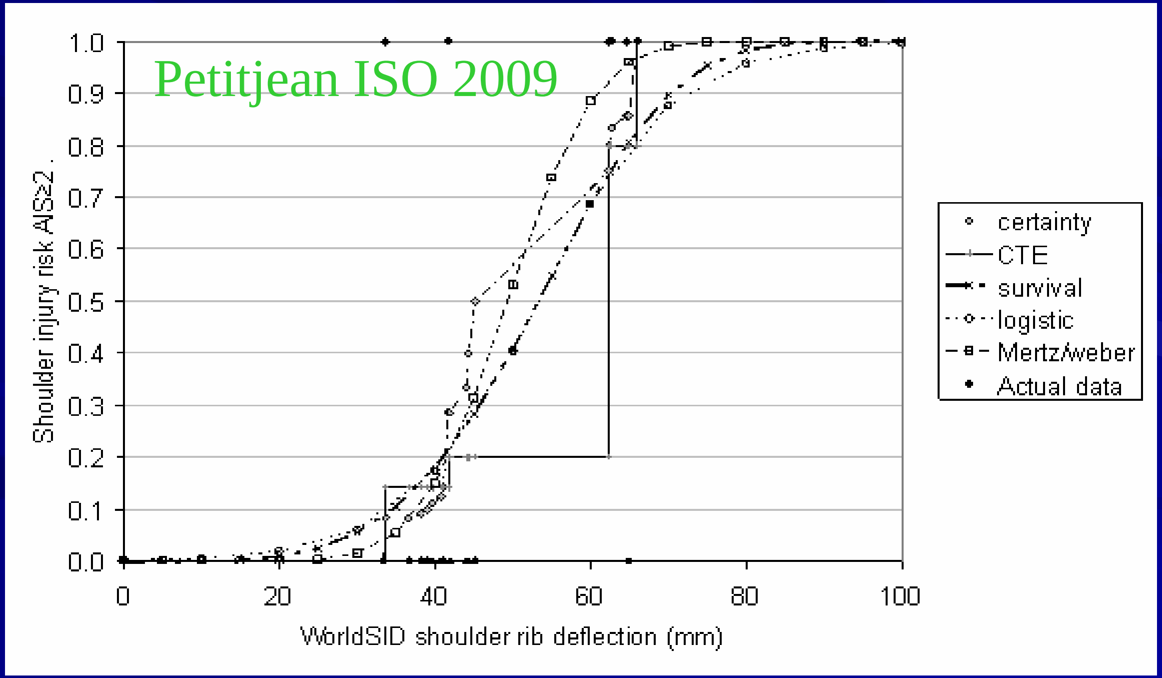
- Nusholtz & Mosier (SAE 1999-01-0714)
  - Like the Certainty method, this nonparametric method does not assume that the injury risk curve follows a particular type of distribution. A monotonically increasing curve is generated using a ***maximum likelihood*** approach with the ***doubly censored*** data.



Statistical Methods

Summary

- 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)



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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

	WorldSID 50th (adjusted to 45YO, range of all methods)	
	25%	50%
Shoulder Deflection AIS 2+ (mm)	54.3 – 63.7	59.2 – 74.9
Shoulder Force AIS 2+ (N)	2138 - 2400	2303 - 2561
Thorax Deflection AIS 3+ (mm)	48.5 – 57.9	51.1 – 62.4
Thorax Deflection AIS 4+ (mm)	56.5 – 71.3	60.6 – 76.8
Thorax VC AIS 3+ (m/s)	0.55 – 0.78	0.80 – 0.92
Thorax VC AIS 4+ (m/s)	1.39 – 1.70	1.51 – 1.86
Abdomen Deflection AIS 3+ (mm)	70.3 – 84.3	73.5 – 92.0
Abdomen VC AIS 3+ (m/s)	1.06 – 1.41	1.10 – 1.64
Lower Spine Acceleration AIS 3+ (m/s^2)	643 - 689	658 - 742
Pelvis Force AIS 3+ (N)	2334 - 2914	2535 - 3387
Pelvis Acceleration AIS 3+ (m/s^2)	707 - 1034	774 - 1215

Analytical effort needed to asses 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)