Pelvis Impact
BioRID Pelvis test Corridor

- Develop corridor around the 4 baseline pelvis’ used in the BAST seat test study.
- Test each pelvis by impacting on the back of pelvis
- Test each pelvis by impacting on the bottom of pelvis
- Will these corridors indicate differences between the (4) original pelvis’?
- Compare corridor to current production
Collected data from Humanetics Huron prior to shipping to BAST, repeat tests from BAST, post tests from Humanetics Heidelberg and post tests from Humanetics Huron.

- Pelvis Bottom – 30 tests
  - Reduced to 21 after confirmation of difference in test method followed

- Pelvis Back – 30 tests
  - Reduced to 21 after confirmation of difference in test method followed
Statistical analysis was conducted on each of the parameters collected. The mean +/- 2 standard deviations was used to create the proposed test corridor. Rounded to 3 significant digits.
BioRiD Test Corridor

Peak Pendulum Force

- **Pelvis Bottom**
  - Mean = 3937 N
  - Standard Deviation = 343 N
  - (17% of Mean)

- **Proposed Corridor**
  - (3250 N – 4620 N)

- **Pelvis Back**
  - Mean = 2100 N
  - Standard Deviation = 120 N
  - (11.4% of Mean)

- **Proposed Corridor**
  - (1860 N – 2340 N)
BioRiD Test Corridor

Peak Pendulum Force

Pelvis Bottom

Pelvis Back

* BAST data not included in analysis
BioRID Test Corridor

Peak Pendulum Force

Pelvis Bottom Population

Pelvis Back Population

Individual Value Plot of Peak Pendulum Force (N)
BioRID Test Corridor

Peak Sled Acceleration

 ► Pelvis Bottom
   – Mean = 42.49 m/s²
   – Standard Deviation = 3.228 m/s²
   – (15.2% of Mean)

 ► Proposed Corridor
   (48.9 m/s² – 36.0 m/s²)

 ► Pelvis Back
   – Mean = 23.06 m/s²
   – Standard Deviation = 1.37 m/s²
   – (11.9% of Mean)

 ► Proposed Corridor
   (20.3 m/s² – 25.8 m/s²)
Pelvis Bottom

Pelvis Back

Individual Value Plot of Peak Sled Acceleration (m/s^2)

* BAST data not included in analysis
BioRID Test Corridor

Peak Sled Acceleration

Pelvis Bottom Population

Pelvis Back Population

Individual Value Plot of Peak Sled Acceleration (m/s^2)

Serial Number

Peak Sled Acceleration (m/s^2)

36
48.9

Individual Value Plot of Peak Sled Acceleration (m/s^2)

25.8
20.3
BioRID Test Corridor

Peak Sled Velocity

► Pelvis Bottom
  – Peak Sled Velocity
    ▶ Mean = 0.350 m/s
    ▶ Standard Deviation = 0.0123 m/s
  – (7.0% of Mean)

► Pelvis Back
  – Pendulum Force
    ▶ Mean = 0.340 m/s
    ▶ Standard Deviation = 0.0107 m/s
    ▶ (6.3% of Mean)

► Proposed Corridor
  (0.375 m/s – 0.325 m/s)

► Proposed Corridor
  (0.361 m/s – 0.319 m/s)
BioRiD Test Corridor

Peak Sled Velocity

Pelvis Bottom

Individual Value Plot of Sled Velocity Peak (m/s)

Pelvis Back

Individual Value Plot of Sled Velocity Peak (m/s)

* BAST data not included in analysis
BioRID Test Corridor

Peak Sled Velocity

Pelvis Bottom Population

Pelvis Back Population
BioRiD Test Corridor

Peak Pelvis Compression

► Pelvis Bottom
  – Mean = 18.65 mm
  – Standard Deviation = 0.448 mm
  – (4.8% of Mean)

► Proposed Corridor
  (17.8 mm – 19.5 mm)

► Pelvis Back
  – Mean = 21.98 mm
  – Standard Deviation = 0.601 mm
  – (5.5% of Mean)

► Proposed Corridor
  (20.8 mm – 23.2 mm)
BioRID Test Corridor

Peak Pelvis Compression

Pelvis Bottom

Pelvis Back

* BAST data not included in analysis
BioRID Test Corridor

Peak Pelvis Compression

Pelvis Bottom Population

Pelvis Back Population

Individual Value Plot of Peak Part Compression (mm)

Serial Number

Peak Part Compression (mm)

15 - 21

15 - 24

17.8 - 19.5

17.8 - 23.2

01 - 21

01 - 21
Normalized test data to remove influence of parts with different means.
- \( n \) divided by the average of all \( n \)'s in all labs
  \( n = \text{values for one discrete part (same serial number)} \)

Look for influence from input velocity and corrected for statistically significant regressions.

Perform statistical analysis on the normalized ratios.
Pelvis Back (Pendulum Force vs Velocity)

Regression Analysis and Correction

Pendulum Force was statistically significant for influence of test velocity in Pelvis Back Impacts
BioRID Test Lab Comparison

Pelvis Back

2 Sample T-Test

Analysis indicates a less than 5% of mean difference between labs.

<table>
<thead>
<tr>
<th>2-Sample T-Test</th>
<th>Mean*</th>
<th>Est of Difference</th>
<th>P-Value</th>
<th>% of Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Heidelberg</td>
<td>Huron</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pendulum Force</td>
<td>0.9548</td>
<td>0.9896</td>
<td>-0.0348</td>
<td>0.001</td>
</tr>
<tr>
<td>Sled Acceleration</td>
<td>1.0001</td>
<td>0.9941</td>
<td>0.822</td>
<td></td>
</tr>
<tr>
<td>Sled Velocity</td>
<td>1.0081</td>
<td>0.9933</td>
<td>0.597</td>
<td></td>
</tr>
<tr>
<td>Part Compression</td>
<td>0.9897</td>
<td>1.0121</td>
<td>-0.0224</td>
<td>0.025</td>
</tr>
</tbody>
</table>

*Mean is the ratio of the value devided by the average of values for one discrete part
Pelvis Back (Pendulum Force)
Actual and Normalized

Pendulum Force differences is small between Heidelberg and Humanetics Huron test labs for the Pelvis Back impact tests.
There was no statistical difference in Sled Acceleration between Heidelberg and Humanetics Huron test labs in the Pelvis Back Impact tests.
There was no statistical difference in Sled Velocity between Heidelberg and Humanetics Huron test labs in the Pelvis Back Impact tests.
BioRID Test Lab Comparison

Pelvis Back (Part Compression)
Actual andNormalized

There is a small statistical difference in Peak Part Compression between Heidelberg and Humanetics Huron test labs for the Pelvis Back impact tests.
BioRID Test Lab Comparison

Pelvis Bottom (Sled Velocity vs Input Velocity)

Regression Analysis and Correction

Sled Velocity was statistically significant for influence of test velocity for Pelvis Bottom Impacts
# BioRiD Test Lab Comparison

## Pelvis Bottom

### 2 Sample T-Test

Analysis indicates a less than 7.5% of mean between labs.

- Less than 2.3% for any other channel

<table>
<thead>
<tr>
<th>2-Sample T-Test</th>
<th>Mean*</th>
<th>Est of Difference</th>
<th>P-Value</th>
<th>% of Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Heidelberg</td>
<td>Huron</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pendulum Force</td>
<td>1.0139</td>
<td>0.9931</td>
<td>0.189</td>
<td></td>
</tr>
<tr>
<td>Sled Acceleration</td>
<td>1.0481</td>
<td>0.976</td>
<td>0.0721</td>
<td>0.001</td>
</tr>
<tr>
<td>Sled Velocity</td>
<td>0.9746</td>
<td>0.9965</td>
<td>-0.0219</td>
<td>0.000</td>
</tr>
<tr>
<td>Part Compression</td>
<td>0.9939</td>
<td>1.0032</td>
<td>0.274</td>
<td></td>
</tr>
</tbody>
</table>

*Mean is the ratio of the value divided by the average of values for one discrete part
Pelvis Bottom (Pendulum Force) Actual and Normalized

There was no statistical difference in Pendulum Force between Heidelberg and Humanetics Huron test labs in the Pelvis Bottom Impact tests.
There is a small statistical difference in Peak Sled Acceleration between Heidelberg and Humanetics Huron test labs for the Pelvis Bottom impact tests.
There is a small statistical difference in Peak Sled Velocity between Heidelberg and Humanetics Huron test labs for the Pelvis Bottom impact tests.
There was no statistical difference in Part Compression between Heidelberg and Humanetics Huron test labs in the Pelvis Bottom Impact tests.
Conclusion

- Proposed Corridors Complete (based off 4 R&R pelvis)
- Current production population fit the proposed corridors.
- All but one of the original (4) dummy pelvis’ would have failed the proposed corridor
- Others studies show sled accel & pendulum force are highly correlated. This study as well shows no need for bother, so eliminate sled accel parameter
Conclusion

- Lab to Lab
  - All lab to lab variation was less than 7.5% of mean.
    - Less than 2.3% if we don’t use sled accel.
  - Repeatability should be worked on to reduce the within lab variation.
    - Reduce velocity corridor
    - Make sure wait times are followed
  - Repeat Lab to Lab when larger population of labs exists.

- No need for both back and bottom to control pelvis
  - Only use bottom impact
Jacket Only Impact
Create a test corridor around the (4) R&R jackets

Test each jacket on the BioRID sled impacting it with a 14kg impact probe (H-III5F)

Will these corridors indicate any differences in the original jackets replaced?

Compare the corridor to current production
BioRID Jacket Test Corridor

- Collected data from Humanetics Huron prior to shipping to BAST, repeat tests from BAST, post tests from Humanetics Heidelberg and post tests from Humanetics Huron.
- All data from all labs on these (4) jackets was used to determine the corridor
  - A Total of 33 tests was conducted
    - Data was reduced to 24 for part compression due to no data provided from one lab.
► Statistical analysis was conducted on the each of the parameters collected
► The mean +/- 2 standard deviations was used to create the proposed test corridor.
► Rounded to 3 significant digits
**BioRID Jacket Test Corridor**

► **Peak Pendulum Force**
  - Mean = 1233 N
  - Std Dev = 62
  - (10.1% of mean)

► **Proposed Corridor**
  - 1110N - 1360N
BioRID Jacket Test Corridor

Peak Pendulum Force (N) (Population)

Serial Number

Peak Pendulum Force (N)

1360
1110
BioRID Jacket Test Corridor

► Peak Sled Acceleration
  – Mean = 16.782 m/s^2
  – Std Deviation = 0.886 m/s^2
  – (10.3% of mean)

► Proposed Corridor
  – 15.0m/s^2 – 18.6m/s^2

Individual Value Plot of Peak Sled Acceleration (m/s^2)
BioRID Jacket Test Corridor

Peak Sled Acceleration (m/s^2) (Population)

Serial Number

Peak Sled Acceleration (m/s^2)

15
18.6

18.6
15
BioRID Jacket Test Corridor

► Peak Sled Velocity
  – Mean = 0.400 m/s
  – Std Deviation = 0.0109 m/s
  – (5.5% of Mean)

► Proposed Corridor
  – 0.378m/s – 0.422m/s

Individual Value Plot of Sled Velocity Peak (m/s)
BioRID Jacket Test Corridor

Sled Velocity Peak (m/s) (Population)

Serial Number

Sled Velocity Peak (m/s)
0.378
0.422

Serial Number

200000546
200000643
200000745
200000872
200000993
DL8918
DL9232
DK8666
DN5019
DN6062
DN9618
DK8666
DN1014
DL6027
DL7150
DN7431
DN8320
DN9039
DK1088
DK1096
DN8431
DN8043
DN8022
DN6072
DN6015
DN5911
DN3976
DN2618
DM7300
DM7030
DM5631
DM1454
DL7436
DL7150
DL5027
DL0870
DL...
BioRID Jacket Test Corridor

- **Peak Part Compression**
  - Mean = 19.258mm
  - Std Deviation = 0.504mm
  - (5.2% of mean)

- **Proposed Corridor**
  - 18.3mm – 20.3mm
BioRID Jacket Test Corridor

Peak Part Compression (mm) (Population)

Serial Number

Peak Part Compression (mm)

18.3
20.3
Normalized test data to remove influence of parts with different means.

- $n$ divided by the average of all $n$’s in all labs

$n = \text{values for one discrete part (same serial number)}$

Look for influence from input velocity and corrected for statistically significant regressions.

Perform statistical analysis on the normalized ratios.
► All Normalized Test Parameters are statistically significant velocity sensitivity.

► Normalized data was corrected for regressions

<table>
<thead>
<tr>
<th>Regression Summary (Normalized Test Parameter vs Input Velocity)</th>
<th>P-Value</th>
<th>R-sq(adj)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Pendulum Force</td>
<td>0.002</td>
<td>11.40%</td>
</tr>
<tr>
<td>Peak Sled Acceleration</td>
<td>0.006</td>
<td>8.80%</td>
</tr>
<tr>
<td>Peak Sled Velocity</td>
<td>0.000</td>
<td>16.60%</td>
</tr>
<tr>
<td>Peak Part Compression</td>
<td>0.005</td>
<td>10.80%</td>
</tr>
</tbody>
</table>
BioRID Jacket Test Lab Comparison

Pendulum Force

**Fitted Line Plot**

Pendulum Force Normalized = -1.409 + 1.576 Velocity (m/s)

**Fitted Line Plot**

PF Corr = 0.9943 - 0.0000 Velocity (m/s)

S = 0.0389194
R-Sq = 0.0%
R-Sq(adj) = 0.0%
Sled Acceleration

Fitted Line Plot
Sled Acceleration Normalized = -1.298 + 1.503 Velocity (m/s)

Fitted Line Plot
Sled Accel corr = 0.9945 - 0.0000 Velocity (m/s)
BioRID Jacket Test Lab Comparison

Sled Velocity

Fitted Line Plot
Sled Velocity Normalized = -0.4906 + 0.9751 Velocity (m/s)

Fitted Line Plot
Sled Vel Corr = 0.9965 - 0.0000 Velocity (m/s)
BioRID Jacket Test Lab Comparison

Part Compression

Fitted Line Plot
Part Compression Normalized = 2.350 - 0.8835 Velocity (m/s)

Fitted Line Plot
Part Compression Normalized and = 1.002 + 0.0000 Velocity (m/s)
ANOVA analysis indicates a statistical difference between labs after normalizing (removing any differences associated with part).

► The Huron test lab had a higher means than either BAST or Heidelberg for Pendulum Force, Sled Acceleration, and Sled Velocity

► There was no difference between labs for part compression
BioRID Jacket Conclusions

► Conclusion
  – Proposed Corridors Complete (based off 4 R&R Jackets)
  – Current production population fits the proposed corridors.
  – All but one of the original (4) dummy jackets would fail the proposed corridors.
  – Others studies show sled accel & pendulum force are highly correlated. This study as well shows no need for bother, so eliminate sled accel parameter
Conclusions

- Lab to Lab
  - Largest lab to lab variation was about 6% of mean, which is a large portion of the corridors
  - Lab differences should be investigated
  - Repeat Lab to Lab when larger population of labs exists.

- Repeatability should be worked on to reduce the within lab variation.
  - Reduce velocity corridor
  - Make sure wait times are followed