**APPENDIX A**

Table A1: Summary of input variables and ranges for the simulation LHD.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **LHD Input**  **Variables** | **Minimum** | **Maximum** | **Derived Analysis Variables** |
| **Loading Condition Variables** | **X** (longitudinal)  Acceleration Pulse Shape | 0 | 1 | Time to Peak **X** Acceleration  (32.5🡪120 ms) |
| **Y** (lateral)  Acceleration Pulse Shape | 0 | 1 | Time to Peak **Y** Acceleration  (32.5🡪120 ms) |
| **Z** (vertical)  Acceleration Pulse Shape | 0 | 1 | Time to Peak **Z** Acceleration  (32.5🡪120 ms) |
| **X** (longitudinal)  Acceleration Direction | -1  (eyeballs out) | 1  (eyeballs in) | Peak X-, Y-, Z- Acceleration  (G) |
| **Y** (lateral)  Acceleration Direction | 0 | 1 |
| **Z** (vertical)  Acceleration Direction | -1  (eyeballs up) | 1  (eyeballs down) |
| Resultant Acceleration  Magnitude | 5 G | 25 G |
| **Environment Variables** | **Y**-axis Seat Rotation | -45° | 45° |  |
| **Z**-axis Seat Rotation | 0° | 20° |  |
| **X**-offset of Occupant from Seat | 0 mm | 20 mm | Settled  Hip/H-Point **X,Z**-location and angle |
| **Z**-offset of Occupant from Seat | 0 mm | 20 mm |
| Belt Tension Force | 22.2 N  (5 lbf) | 155.7 N  (35 lbf) |  |

|  |  |
| --- | --- |
|  | |
| **Figure A1.** Linear regression of injury metric response for matched tests between models. Peak linear head acceleration, BrIC, and peak rotational head acceleration shown. Color determined by loading direction (right), with solid lines representing best fit, and dashed lines representing 95% confidence intervals on the regression. Dashed black line represent equation . |  |

Table A2: Regression coefficients and coefficient of determination (R2) for 1st order polynomial fits shown in Figures 2 and A1. Higher coefficients of determination shaded darker.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Injury Metric | Region |  | | |  | | |  | | |
|  |  |  |  |  |  |  |  |  |
| HIC15 | Full Data | 0.73 | 13.95 | 0.39 | 0.85 | 8.16 | 0.38 | 0.73 | 11.00 | 0.76 |
| +X, +Z | 2.96 | -20.39 | 0.41 | 2.01 | -7.10 | 0.22 | 0.91 | 5.74 | 0.72 |
| -X, +Z | 0.71 | 6.34 | 0.70 | 0.75 | 3.88 | 0.76 | 0.91 | 4.51 | 0.87 |
| -X, -Z | 0.56 | 15.35 | 0.73 | 0.73 | 8.98 | 0.66 | 0.57 | 18.32 | 0.61 |
| +X, -Z | 0.82 | 8.74 | 0.86 | 0.93 | 1.04 | 0.90 | 0.87 | 8.53 | 0.93 |
| BrIC | Full Data | 0.86 | 0.07 | 0.75 | 0.62 | 0.04 | 0.62 | 1.02 | 0.11 | 0.66 |
| +X, +Z | 1.27 | 0.03 | 0.79 | 0.60 | 0.08 | 0.32 | 0.66 | 0.11 | 0.25 |
| -X, +Z | 0.77 | 0.08 | 0.80 | 0.72 | 0.04 | 0.84 | 0.97 | 0.10 | 0.79 |
| -X, -Z | 1.19 | 0.03 | 0.60 | 0.69 | 0.01 | 0.54 | 1.24 | 0.13 | 0.59 |
| +X, -Z | 0.60 | 0.07 | 0.26 | 0.19 | 0.09 | 0.37 | 3.13 | -0.09 | 0.68 |
| Peak Linear  Acceleration (G) | Full Data | 0.91 | 5.68 | 0.40 | 0.89 | 3.01 | 0.36 | 0.73 | 9.64 | 0.56 |
| +X, +Z | 1.89 | -7.74 | 0.40 | 1.82 | -10.94 | 0.36 | 0.74 | 7.76 | 0.57 |
| -X, +Z | 0.89 | 3.24 | 0.81 | 0.80 | 0.62 | 0.84 | 1.03 | 5.10 | 0.82 |
| -X, -Z | 0.70 | 8.19 | 0.67 | 0.78 | 4.32 | 0.46 | 0.47 | 16.36 | 0.40 |
| +X, -Z | 0.89 | 5.39 | 0.60 | 0.80 | 4.21 | 0.77 | 1.05 | 2.94 | 0.69 |
| Peak Rotational  Acceleration (rad/s2) | Full Data | 1.18 | 534.72 | 0.17 | 0.34 | 953.02 | 0.07 | 1.45 | 532.88 | 0.41 |
| +X, +Z | 2.63 | 9.46 | 0.23 | 1.94 | -445.60 | 0.17 | 0.56 | 823.45 | 0.24 |
| -X, +Z | 1.13 | 248.72 | 0.62 | 0.41 | 480.78 | 0.48 | 1.69 | 542.10 | 0.48 |
| -X, -Z | 0.72 | 840.15 | 0.31 | 0.41 | 768.95 | 0.23 | 0.75 | 1196.37 | 0.23 |
| +X, -Z | 0.72 | 730.13 | 0.39 | 0.23 | 839.21 | 0.49 | 3.07 | -457.85 | 0.78 |

|  |  |
| --- | --- |
| **(a)** | **(b)** |
| **(c)** | **(d)** |
| Figure A2. Scatterplots of injury metric response for matched tests between occupants. HIC15 (a), BrIC (b), peak linear acceleration (c), and peak rotational acceleration (d). Color determined by loading direction, with higher saturations corresponding to higher peak resultant accelerations. Dashed lines represent equation . | |

Table A3: Summarized results from matched pair testing. Median [IQR] reported with bold values representing statistical significance tested at Bonferroni-adjusted =0.0042 through Wilcoxon signed rank test.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Injury  Metric** | **Region** | **GHBMC -  Hybrid III** | **GHBMC -  THOR** | **THOR -  Hybrid III** |
| HIC15 | Full Data | **0.80**  **[-2.38, 4.77]** | **-1.09**  **[-7.22, 1.37]** | **2.42**  **[-0.42, 9.40]** |
| +X, +Z | **1.29**  **[-0.03, 5.33]** | -0.83  [-3.97, 1.82] | **2.23**  **[-0.03, 7.43]** |
| -X, +Z | 0.05  [-10.36, 3.42] | **-1.22**  **[-7.15, 1.04]** | 1.60  [-4.28, 8.89] |
| -X, -Z | 0.58  [-3.56, 4.58] | **-1.67**  **[-11.42, 1.00]** | **2.74**  **[0.29, 11.07]** |
| +X, -Z | 0.75  [-1.12, 4.96] | -0.50  [-8.20, 2.57] | **2.76**  **[-0.43, 9.59]** |
| Peak Linear  Acceleration (G) | Full Data | **1.32**  **[-1.39, 4.58]** | **-1.92**  **[-5.32, 1.19]** | **3.51**  **[0.37, 8.04]** |
| +X, +Z | **2.38**  **[0.26, 7.68]** | 0.36  [-2.22, 3.87] | **2.44**  **[-0.16, 6.41]** |
| -X, +Z | 0.54  [-1.99, 3.51] | **-4.48**  **[-6.66, -1.10]** | **5.13**  **[2.28, 9.81]** |
| -X, -Z | 1.17  [-2.03, 3.73] | **-3.17**  **[-6.65, -0.38]** | **3.49**  **[0.51, 7.44]** |
| +X, -Z | **1.32**  **[-1.85, 5.27]** | -1.09  [-4.68, 2.06] | **2.90**  **[-0.33, 7.61]** |
| BrIC | Full Data | **0.03**  **[0.00, 0.08]** | **-0.06**  **[-0.13, -0.01]** | **0.10**  **[0.03, 0.19]** |
| +X, +Z | **0.05**  **[0.02, 0.09]** | -0.00  [-0.06, 0.04] | **0.05**  **[0.0, 0.13]** |
| -X, +Z | 0.01  [-0.04, 0.05] | **-0.08**  **[-0.14, -0.03]** | **0.10**  **[0.03, 0.18]** |
| -X, -Z | **0.04**  **[0.01, 0.11]** | **-0.09**  **[-0.19, -0.05]** | **0.17**  **[0.09, 0.25]** |
| +X, -Z | **0.03**  **[0.00, 0.06]** | **-0.05**  **[-0.14, -0.01]** | **0.09**  **[0.04, 0.19]** |
| Peak Rotational  Acceleration (rad/s2) | Full Data | **374.44**  **[120.10, 748.10]** | **-264.52**  **[-753.11, 113.53]** | **713.42**  **[346.53, 1323.23]** |
| +X, +Z | **352.50**  **[120.28, 739.26]** | -43.46  [-307.83, 254.08] | **459.58**  **[181.52, 874.85]** |
| -X, +Z | **237.32**  **[48.84, 577.78]** | **-620.32**  **[-1094.91, -263.50]** | **971.84**  **[636.94, 1740.15]** |
| -X, -Z | **437.77**  **[124.32, 833.33]** | **-336.42**  **[-874.44, 89.74]** | **794.38**  **[383.33, 1400.16]** |
| +X, -Z | **452.24**  **[164.43, 778.65]** | **-243.38**  **[-678.92, 193.78]** | **705.77**  **[319.57, 1338.46]** |

Table A4: Relative head injury metric sensitivities to independent variables (columns sum to 100). Larger (darker shaded) values represent higher sensitivity.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Variable Type | Independent Variables Regressed Against Head Injury Metrics | HIC15 | Peak Linear Acceleration | BrIC | Peak Rotational Acceleration | HIC15 | Peak Linear Acceleration | BrIC | Peak Rotational Acceleration | HIC15 | Peak Linear Acceleration | BrIC | Peak Rotational Acceleration |
|
|
|
|
| **Hybrid III** | | | | **THOR** | | | | **GHBMC** | | | |
| Loading Condition Variables | X Pulse Time to Peak | 3.2 | 1.6 | 0.2 | 0.6 | 3.0 | 2.1 | 2.2 | 1.7 | 0.3 | 0.3 | 0.6 | 0.0 |
| Y Pulse Time to Peak | 1.9 | 4.7 | 0.6 | 2.1 | 1.6 | 1.6 | 1.3 | 0.6 | 0.4 | 0.1 | 2.8 | 0.0 |
| Z Pulse Time to Peak | 7.4 | 5.1 | 0.7 | 5.0 | 8.5 | 3.1 | 1.8 | 3.2 | 1.7 | 0.6 | 2.2 | 0.0 |
| X Acceleration | 10.9 | 6.2 | 43.1 | 13.6 | 13.0 | 5.7 | 38.1 | 12.2 | 1.4 | 0.2 | 27.0 | 3.3 |
| Y Acceleration | 33.1 | 27.8 | 1.6 | 0.9 | 30.1 | 20.1 | 18.3 | 7.0 | 1.3 | 3.4 | 6.1 | 0.1 |
| Z Acceleration | 27.9 | 20.7 | 42.7 | 56.0 | 25.8 | 23.1 | 18.9 | 39.2 | 63.6 | 51.0 | 18.1 | 75.5 |
| Resultant Acceleration | 7.9 | 25.4 | 8.2 | 15.7 | 11.6 | 33.1 | 15.2 | 31.6 | 25.2 | 32.7 | 19.1 | 11.6 |
| Environment  Variables | Belt Tension | 1.5 | 1.2 | 1.9 | 4.2 | 1.5 | 4.4 | 1.8 | 3.5 | 5.2 | 9.8 | 20.6 | 5.3 |
| H-Point Location (x) | 2.7 | 1.8 | 0.0 | 0.7 | 1.1 | 1.2 | 0.7 | 0.1 | 0.0 | 0.0 | 0.2 | 0.0 |
| H-Point Location (z) | 0.5 | 0.4 | 0.2 | 0.9 | 0.1 | 1.5 | 0.0 | 0.2 | 0.0 | 0.0 | 1.4 | 0.5 |
| Hip Angle | 1.5 | 3.6 | 0.0 | 0.1 | 0.3 | 0.3 | 0.6 | 0.2 | 0.0 | 0.0 | 0.2 | 0.0 |
| Seat Y. Rotation | 0.9 | 0.8 | 0.0 | 0.0 | 1.5 | 2.6 | 0.6 | 0.0 | 0.0 | 0.1 | 1.1 | 0.0 |
| Seat Z. Rotation | 0.8 | 0.9 | 1.0 | 0.3 | 1.8 | 1.3 | 0.6 | 0.5 | 1.0 | 1.8 | 0.8 | 3.8 |
| Total | | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |



**Figure A3.** HIC simulation results for rear impact (+X) response. Positive Z-acceleration values representative of eyeballs down, and negative Z-acceleration representative of eyeballs up. Positive and negative Z-acceleration values regressed separately with power equations (). Solid lines represent best fit and dashed lines represent 95% confidence interval on fit.

**APPENDIX B**

The following is an example of the sensitivity calculation using the data from the Hybrid III HIC15 data. Regression coefficients are provided in Equation 1.



(Eqn 1)

Following the calculation of the regression equation, all zero-value terms were removed (Eqn 2). The absolute values of the remaining coefficients are color coded by magnitude, with larger values more saturated.



(Eqn 2)

The sensitivity of the Hybrid III HIC15to peak Z-acceleration (Z-Acc) is as follows. Each term that contains z-acceleration is highlighted by the boxes in Equation 2. Terms that consist of only z-acceleration were given the full weight of 1, while the interaction terms that contained z-acceleration as one term were divided by 13, the total number of variables (Equation 3).

|  |  |
| --- | --- |
| *Z-acceleration sensitivity* | (Eqn 3) |
| 9.23+161.70+(7.52+11.31+22.03+34.17+34.17+24.23+88.4+67.92+39.93)=196.3 |

These sensitivity values were calculated for each variable and summed; in this case the sum was 704.5. Thus, the relative sensitivity score was 27.9% (196.3/704.5) for the peak z-acceleration in the analysis of Hybrid III HIC15.