**APPENDIX**

**Table A1. Injury summary, AIS code and notes for six cases with thoracolumbar fractures.**

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| --- | --- | --- | --- |
| Case Vehicle | AIS Code | Spine Injury Description | Injury Notes |
| 2006 Chevrolet Silverado | 650434.3  650634.3 | T12 compression fracture  L1 compression fracture | Burst fracture, 50% major compression at T12 superior, 25% at L1 inferior region |
| 2007 Toyota  Solara | 650418.2  650432.2  650632.2 | T1,T2,T3,T4,T6,T8 compression fractures  T5 spinous process fracture  L1 and L2 compression fracture | T1-T3 superior endplate, vertebral body fractures; minor compression deformity at T2-T6, T8 and L1 levels |
| 2007 Toyota  Corolla | 650634.3 | L4 endplate fracture | Anterior-superior endplate of L4 acute, compression fracture, slight wedging |
| 2006 Chevrolet Malibu | 650632.2  650620.2 | L1 compression fracture  L1-L2 transverse process fracture | Minor compression fracture, L1 vertebral body, inferior L1 and L2 transverse process fracture |
| 2006 Chevrolet Cobalt | 650632.2 | L1 and L3 compression fractures | Cranial endplate fracture, mild compression of L1, ventral compression fracture of L3 |
| 2012 Ford  Escape | 650632.2 | L3 compression fractures | Inferior/lower burst fracture of L3, minor compression |

**Table A2.** **Occupant positioning parameters for 11 reconstructed cases. Intervals indicate the range for the corresponding DOE for cases with thoracolumbar fractures.**

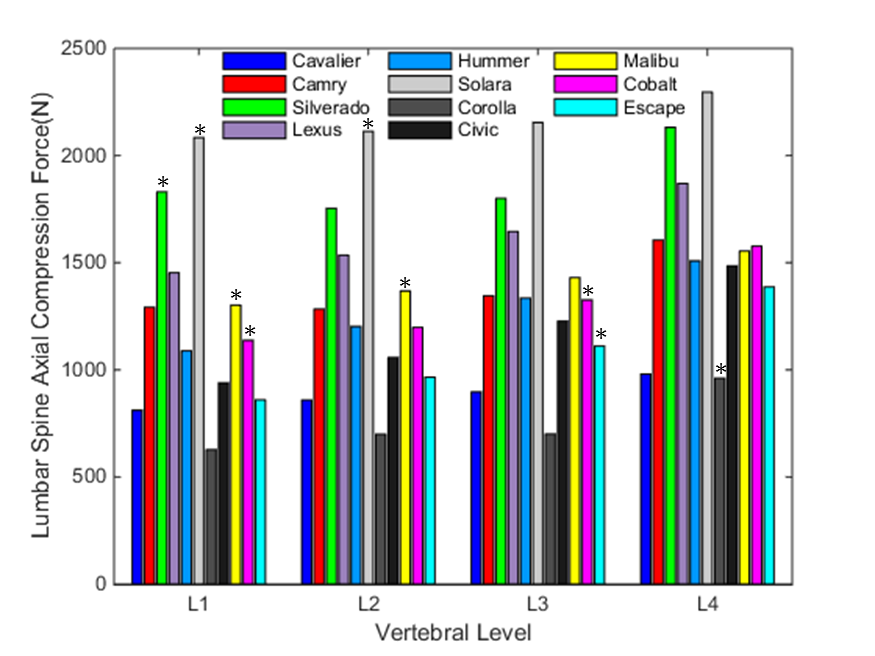
|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Case | Seat Track Position (mm) | | Seatback Angle  (°) | | D-Ring Height (mm) | | Steering Column Position (mm) | | Steering Column Angle (°) | |
| Cavalier | 120 |  | 15 |  | 0 |  | 0 |  | 24 |  |
| Camry | 0 |  | 12 |  | 0 |  | 0 |  | 5 |  |
| Silverado | 0 | [-50,75] | 12 | [0,35] | NA |  | 0 | [-10,10] | 21 | [11.3,36.7] |
| Lexus | 100 |  | 15 |  | 75 |  | 0 |  | 25 |  |
| Hummer | 10 |  | 15 |  | 50 |  | 0 |  | 9.7 |  |
| Solara | -80 | [-120,25] | 5 | [-3,25] | 25 | [0,75] | 0 | [-22.5,22] | 25 | [17.2,33.3] |
| Corolla | -75 | [-40,125] | 10 | [-5,35] | 25 | [-10,85] | 25 | [-30,30] | 29.1 | [25.5,29.1] |
| Civic | 0 |  | 10 |  | 75 |  | 0 |  | 24 |  |
| Malibu | 0 | [-75,75] | 16 | [0,35] | 0 | [0,100] | 0 | [-26,26] | 23 | [20.7,25] |
| Cobalt | 65 | [-40,130] | 12 | [0,33] | 75 | [0,100] | 0 | [-30,30] | 20 | [18,22] |
| Escape | 65 | [-40,130] | 12 | [0,33] | 75 | [0,100] | 0 | [-30,30] | 20 | [18,22] |

|  |
| --- |
| **Y:\Rib_Fracture\20_Cobalt\image_000.tif** |

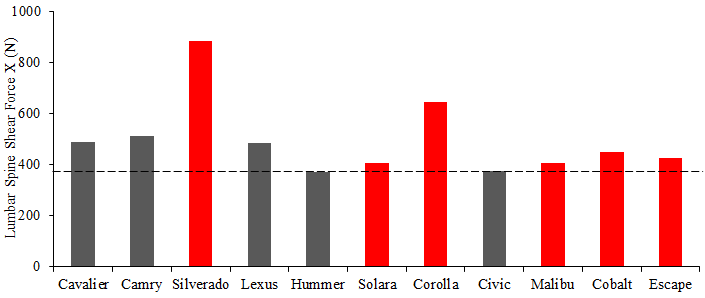
**Figure A1. THUMS thoracolumbar spine local coordinate systems and cross-section instrumentation.**

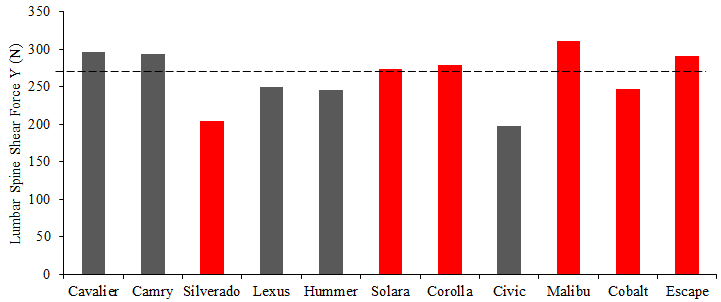
S:\shared\03_conferences\2018_AAAM\Xin\Draft\Final\Figures\FigureA2.tif

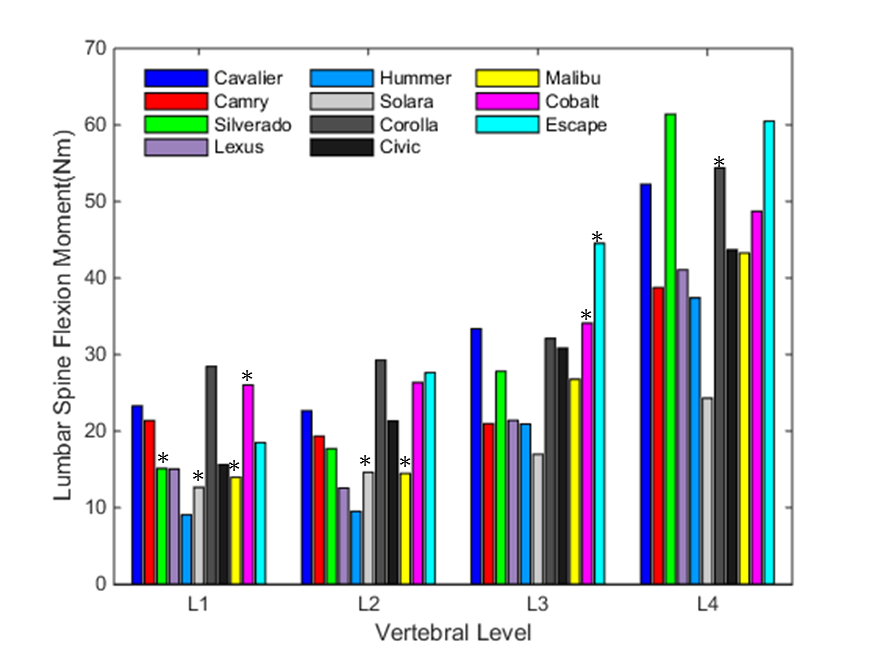
**Figure A2. Age adjustment factor as a function of occupant age for age-adjusted lumbar spine index.**

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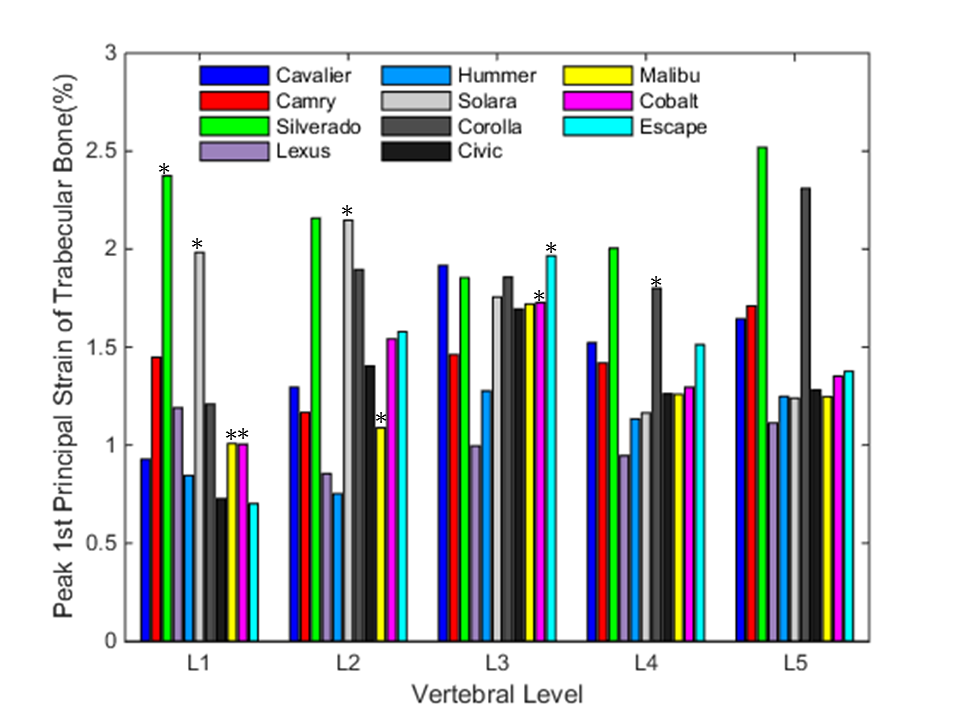
**Figure A3. Lumbar spine axial compression force of 11 reconstructed baseline cases. Asterisks indicate lumbar spine fractures.**

**Figure A4. Average L1-L4 vertebrae shear force of 11 reconstructed cases (threshold: 373.2 N, sensitivity: 1.00, specificity: 0.40, TP: 6, FP: 3, TN: 2, FN: 0). Red bars indicate cases with lumbar spine fractures.**

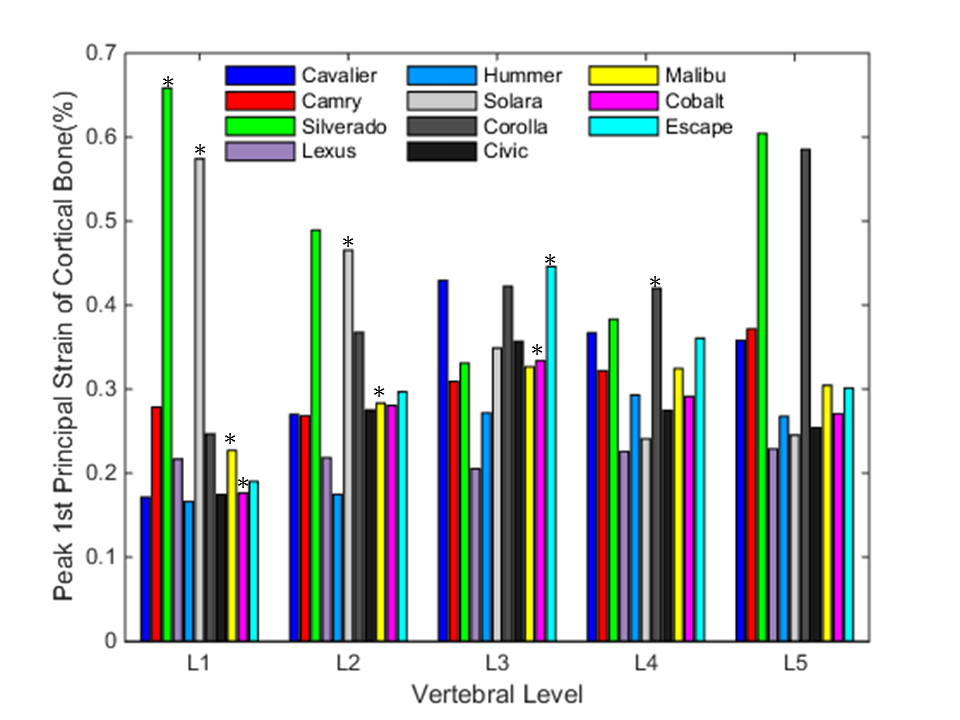
**Figure A5. Average L1-L4 vertebrae shear force of 11 reconstructed cases (threshold: 273.4 N, sensitivity: 0.67, specificity: 0.60, TP: 4, FP: 2, TN: 3, FN: 2). Red bars indicate cases with lumbar spine fractures.**

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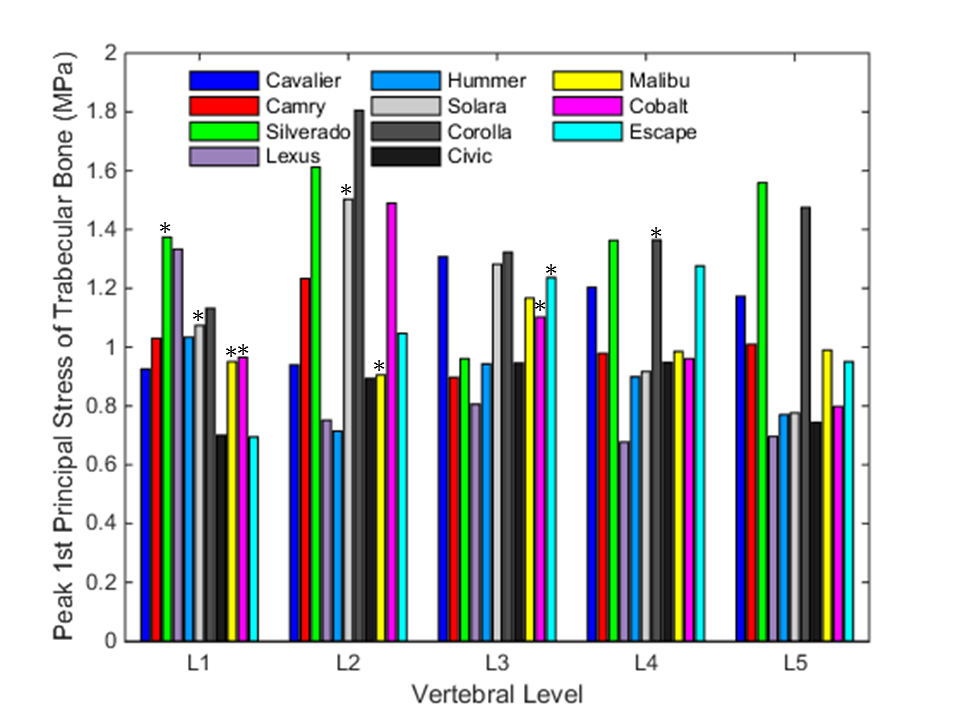
**Figure A6. Lumbar spine flexion moment of 11 reconstructed baseline cases. Asterisks indicate lumbar spine fractures.**



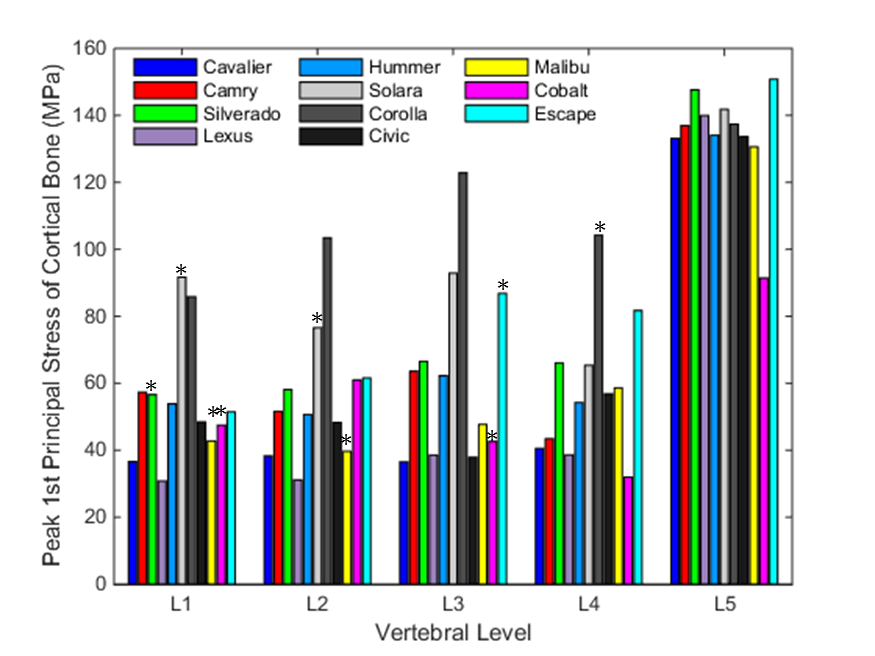
**Figure A7. Maximum principal strain of trabecular bone in the vertebrae. Asterisks indicate lumbar spine fractures.**



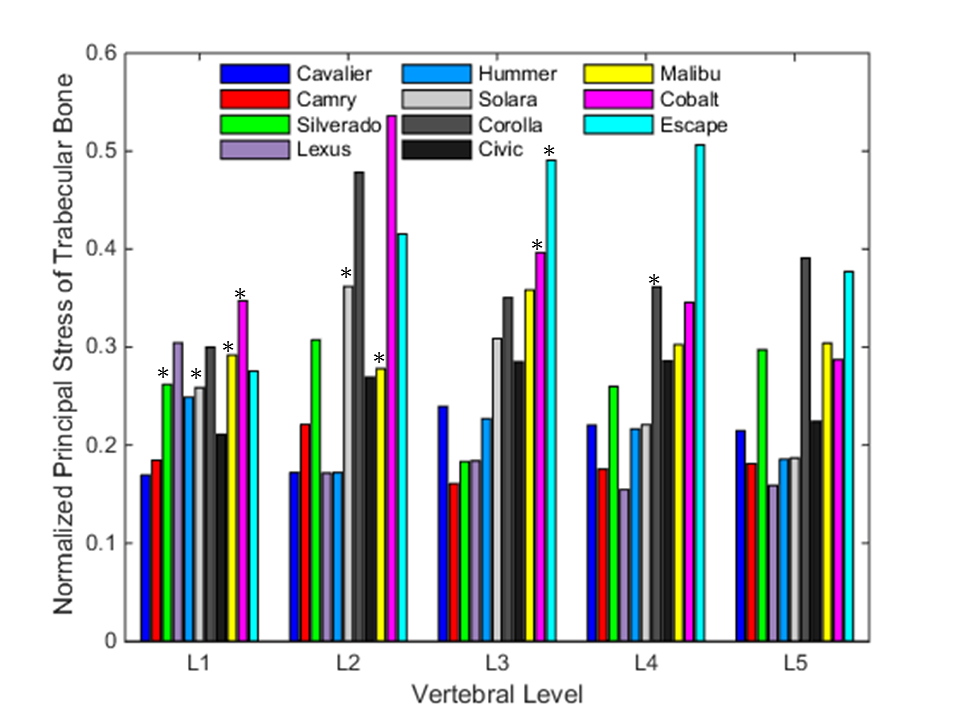
**Figure A8. Maximum principal strain of cortical bone in the vertebrae. Asterisks indicate lumbar spine fractures.**



**Figure A9. Maximum principal stress of trabecular bone in the vertebrae. Asterisks indicate lumbar spine fractures.**



**Figure A10. Maximum principal stress of cortical bone in the vertebrae. Asterisks indicate lumbar spine fractures.**



**Figure A11. Age-normalized maximum principal stress of trabecular bone in the vertebrae. Age-normalized maximum principal stress was derived from peak principal stress divided by age-adjusted yield stress from Eqn. 7. Asterisks indicate lumbar spine fractures.**

Table A3. Linear regression models (*y=A+B\*x*) of spine response (y) versus occupant positioning parameters (x) for cases with thoracolumbar fractures.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Cobalt** | D-Ring Height  (mm) | | Seat Track Position  (mm) | | Seatback Angle  (degree) | | Column Telescoping (mm) | | Column Angle  (degree) | |
| *Parameters* | *A* | *B* | *A* | *B* | *A* | *B* | *A* | *B* | *A* | *B* |
| L1 Axial  Force (N) | -1727.76 | +1.45 | -1710.25 | +1.18 | -1568.59 | -5.23 | -1655.69 | -2.56 | -1559.88 | -4.76 |
| (R2adj <0.01) | | (R2adj =0.02) | | (R2adj <0.01) | | (R2adj <0.01) | | (R2adj <0.01) | |
| L1 Flexion Moment (Nm) | +28.26 | -0.03 | +26.74 | +0.01 | +23.85 | +0.18 | +26.92 | +0.09 | +15.76 | +0.56 |
| (R2adj =0.02) | | (R2adj <0.01) | | (R2adj =0.12) | | (R2adj =0.09) | | (R2adj <0.01) | |
| L3 Axial  Force (N) | -1955.38 | +1.35 | -1903.28 | +0.33 | -1642.53 | -14.83 | -1888.49 | -2.98 | -1975.74 | +4.38 |
| (R2adj <0.01) | | (R2adj <0.01) | | (R2adj =0.10) | | (R2adj <0.01) | | (R2adj <0.01) | |
| L3 Flexion Moment (Nm) | +38.06 | -0.01 | +38.18 | -0.01 | +27.80 | +0.60 | +3771 | +0.15 | +26.48 | +0.56 |
| (R2adj <0.01) | | (R2adj <0.01) | | (R2adj =0.52) | | (R2adj =0.11) | | (R2adj <0.01) | |
| **Corolla** | D-Ring Height  (mm) | | Seat Track Position  (mm) | | Seatback Angle  (degree) | | Column Telescoping (mm) | | Column Angle  (degree) | |
| *Parameters* | *A* | *B* | *A* | *B* | *A* | *B* | *A* | *B* | *A* | *B* |
| L4 Axial  Force (N) | -1622.49 | -0.70 | -1475.47 | +4.50 | -914.49 | -48.79 | -1645.56 | -3.45 | -848.36 | -29.23 |
| (R2adj <0.01) | | (R2adj =0.11) | | (R2adj =0.68) | | (R2adj <0.01) | | (R2adj <0.01) | |
| L4 Flexion Moment (Nm) | +55.27 | -0.02 | +56.17 | +0.04 | +29.49 | +1.67 | +54.54 | +0.12 | +41.73 | +0.47 |
| (R2adj <0.01) | | (R2adj <0.01) | | (R2adj =0.89) | | (R2adj <0.01) | | (R2adj <0.01) | |
| **Escape** | D-Ring Height  (mm) | | Seat Track Position  (mm) | | Seatback Angle  (degree) | | Column Telescoping (mm) | | Column Angle  (degree) | |
| *Parameters* | *A* | *B* | *A* | *B* | *A* | *B* | *A* | *B* | *A* | *B* |
| L3 Axial  Force (N) | -1238.63 | +2.47 | -1356.93 | +5.13 | -704.21 | -19.95 | -1145.29 | -1.81 | -1024.79 | -4.42 |
| (R2adj =0.01) | | (R2adj =0.54) | | (R2adj =0.24) | | (R2adj <0.01) | | (R2adj <0.01) | |
| L3 Flexion Moment (Nm) | +46.47 | -0.02 | +44.55 | +0.03 | +28.07 | +0.80 | +45.83 | -0.05 | +31.51 | +0.52 |
| (R2adj <0.01) | | (R2adj =0.03) | | (R2adj =0.82) | | (R2adj <0.01) | | (R2adj <0.01) | |
| **Malibu** | D-Ring Height  (mm) | | Seat Track Position  (mm) | | Seatback Angle  (degree) | | Column Telescoping (mm) | | Column Angle  (degree) | |
| *Parameters* | *A* | *B* | *A* | *B* | *A* | *B* | *A* | *B* | *A* | *B* |
| L1 Axial  Force (N) | -1570.52 | +0.70 | -1540.67 | +1.94 | -1154.95 | -21.18 | -1537.18 | -3.99 | -2030.90 | +21.71 |
| (R2adj <0.01) | | (R2adj =0.05) | | (R2adj =0.35) | | (R2adj =0.02) | | (R2adj <0.01) | |
| L1 Flexion Moment (Nm) | +14.03 | -0.01 | +13.63 | +0.09 | +9.77 | +0.23 | +13.87 | -0.02 | +8.62 | +0.23 |
| (R2adj <0.01) | | (R2adj =0.58) | | (R2adj =0.20) | | (R2adj <0.01) | | (R2adj <0.01) | |
| L2 Axial  Force (N) | -1625.82 | +0.68 | -1596.30 | +1.81 | -1171.18 | -23.39 | -1593.22 | -4.02 | -2061.45 | +20.59 |
| (R2adj <0.01) | | (R2adj =0.04) | | (R2adj =0.39) | | (R2adj =0.02) | | (R2adj <0.01) | |
| L2 Flexion Moment (Nm) | +16.94 | -0.01 | +16.73 | +0.07 | +9.46 | +0.42 | +16.97 | +0.07 | +18.33 | -0.06 |
| (R2adj <0.01) | | (R2adj =0.26) | | (R2adj =0.50) | | (R2adj =0.02) | | (R2adj <0.01) | |
| **Silverado** | D-Ring Height  (mm) | | Seat Track Position  (mm) | | Seatback Angle  (degree) | | Column Telescoping (mm) | | Column Angle  (degree) | |
| *Parameters* | *A* | *B* | *A* | *B* | *A* | *B* | *A* | *B* | *A* | *B* |
| T12 Axial  Force (N) | ‒ | ‒ | -2148.56 | +3.91 | -1345.83 | -42.09 | -2105.18 | -10.71 | -1511.66 | -24.46 |
|  | | (R2adj =0.05) | | (R2adj =0.49) | | (R2adj <0.01) | | (R2adj =0.09) | |
| T12 Flexion Moment (Nm) | ‒ | ‒ | +15.37 | +0.10 | +10.72 | +0.32 | +16.52 | +0.12 | +13.07 | +0.14 |
|  | | (R2adj =0.40) | | (R2adj =0.27) | | (R2adj <0.01) | | (R2adj =0.02) | |
| L1 Axial  Force (N) | ‒ | ‒ | -2168.27 | +4.29 | -1337.40 | -43.42 | -2120.71 | -10.70 | -1513.17 | -25.04 |
|  | | (R2adj =0.06) | | (R2adj =0.49) | | (R2adj <0.01) | | (R2adj =0.09) | |
| L1 Flexion Moment (Nm) | ‒ | ‒ | +18.28 | +0.13 | +13.66 | +0.34 | +19.75 | +0.17 | +16.95 | +0.12 |
|  | | (R2adj =0.47) | | (R2adj =0.22) | | (R2adj =0.01) | | (R2adj <0.01) | |
| **Solara** | D-Ring Height  (mm) | | Seat Track Position  (mm) | | Seatback Angle  (degree) | | Column Telescoping (mm) | | Column Angle  (degree) | |
| *Parameters* | *A* | *B* | *A* | *B* | *A* | *B* | *A* | *B* | *A* | *B* |
| T1-T4 Axial  Force (N) | -558.41 | +0.11 | -530.65 | +0.54 | -538.88 | -1.41 | -554.51 | -0.29 | -405.84 | -5.93 |
| (R2adj <0.01) | | (R2adj =0.03) | | (R2adj <0.01) | | (R2adj <0.01) | | (R2adj =0.06) | |
| T1-T4 Flexion Moment (Nm) | +7.70 | -0.01 | +6.67 | -0.02 | +9.29 | -0.15 | +7.59 | -0.05 | +8.50 | -0.04 |
| (R2adj <0.01) | | (R2adj =0.06) | | (R2adj =0.12) | | (R2adj =0.03) | | (R2adj <0.01) | |
| T5-T8 Axial  Force (N) | -894.49 | -0.09 | -758.14 | +3.17 | -1078.17 | +13.64 | -898.69 | -2.45 | -730.02 | -6.70 |
| (R2adj <0.01) | | (R2adj =0.25) | | (R2adj =0.16) | | (R2adj <0.01) | | (R2adj <0.01) | |
| T5-T8 Flexion Moment (Nm) | +8.84 | -0.03 | +6.02 | -0.04 | +11.56 | -0.34 | +7.85 | +0.03 | +8.34 | -0.02 |
| (R2adj =0.01) | | (R2adj =0.17) | | (R2adj =0.42) | | (R2adj <0.01) | | (R2adj <0.01) | |
| L1 Axial  Force (N) | -1506.07 | +0.79 | -1162.80 | +7.13 | -1651.01 | +15.83 | -1478.37 | -5.12 | -1235.76 | -9.62 |
| (R2adj <0.01) | | (R2adj =0.55) | | (R2adj =0.09) | | (R2adj =0.02) | | (R2adj <0.01) | |
| L1 Flexion Moment (Nm) | +20.46 | +0.02 | +25.50 | +0.10 | +14.48 | +0.60 | +21.15 | +0.13 | +18.82 | +0.09 |
| (R2adj <0.01) | | (R2adj =0.36) | | (R2adj =0.47) | | (R2adj =0.06) | | (R2adj <0.01) | |
| L2 Axial  Force (N) | -1559.50 | +0.84 | -1230.53 | +6.77 | -1689.05 | +14.58 | -1530.19 | -5.15 | -1291.57 | -9.46 |
| (R2adj <0.01) | | (R2adj =0.52) | | (R2adj =0.08) | | (R2adj =0.02) | | (R2adj <0.01) | |
| L2 Flexion Moment (Nm) | +21.80 | +0.03 | +27.41 | +0.10 | +15.31 | +0.71 | +23.14 | +0.18 | +21.99 | +0.04 |
| (R2adj <0.01) | | (R2adj =0.28) | | (R2adj =0.54) | | (R2adj =0.09) | | (R2adj <0.01) | |
| \*All linear regressions followed the form y= A+B\*x, where A is the intercept (1st column), B is the slope (2nd column). Adjusted R-squared indicated the goodness of fit, and shaded regions indicated strong linear correlation (R2adj>0.50).  \*Spine force and moment followed SAE J211 polarity: tension (+), compression (-), flexion (+), extension (-). | | | | | | | | | | |

|  |  |  |  |
| --- | --- | --- | --- |
| **T= 0 ms** | **T=30 ms** | **T = 60 ms** | **T = 90 ms** |
|  |  |  |  |
| **T = 120 ms** | **T = 150 ms** | **T = 180 ms** |  |
|  |  |  |  |

**Figure A12. Example of thoracolumbar spine motion throughout the crash event for the Cobalt baseline case, with the L5 vertebral level set as reference for trace.**