NHTSA's Rear Seat Safety Research

Aloke Prasad
NHTSA
USA

Doug Weston
Transportation Research Center, Inc.
USA
Paper # 11-0348

ABSTRACT:

NHTSA has collected a series of rear seat occupant data from full-scale frontal vehicle tests. The data set encompasses Research and Development and New Car Assessment Program (NCAP) tests and a variety of dummies, including adults and children in child restraint systems. This paper examines the effect of the cushion characteristics (shape, stiffness, thickness) and crash pulse on a small adult and a child in a forward facing child restraint (CRS) using sled tests. A controlled dynamic test will help us better understand how these factors influence the CRS crash dynamics. The thickness of the cushions had the most effect on dummy injury assessment values (IAV). The crash pulse characterization Vehicle Pulse Index (VPI) was the best predictor for head and chest injuries in such occupants.

INTRODUCTION

Twelve percent of passenger vehicle occupants in police reported crashes are in the rear seat. In addition, approximately 10 percent of all passenger vehicle occupants killed are in rear seats. Sixty-four percent of outboard rear seat occupants involved in frontal crashes are belted, and among these restrained rear seat occupants, 64 percent are 12 years old and younger, and 78 percent weigh less than 160 lbs. Sixty-five percent of rear seat occupants killed are 16 years and older in age. Therefore, children and older occupants in the rear are of particular concern. [1]

NHTSA has collected a series of rear seat occupant data from full-scale frontal vehicle tests. The data set encompasses Research and Development and New Car Assessment Program (NCAP) tests and a variety of dummies, including adults and children in child restraint systems. The analysis of CRS testing showed that child occupant protection can not only be affected by the characteristic of the crash pulse, but also by other factors such as vehicle cushion stiffness, seat contour, and seat back angle.

----
1. Kuppa Shashi, et al. Rear Seat Occupant Protection in Frontal Crashes. Paper #. 05-212, 19th ESV Conference, Washington, DC.

SEAT PARAMETER EFFECTS

The study reported in this presentation examined the effects of rear seat cushion stiffness, seat top surface angle, cushion height at the front of the seat and seat support structure angle on a Hybrid III 3 year (3 YO) old child dummy in a forward-facing CRS and on a 5th percentile female (5th F) dummy in a 3-point seat belt. The crash simulation (sled) tests were conducted at a ΔV of 35 mph equivalent to a NCAP pulse for a 2006 Ford Taurus.

Seat Cushion Characterization

Twenty four vehicle rear seat cushions were measured and tested under static loads to measure their dimensions and stiffness. The vehicles and the cushion dimensions are listed in Appendix A. The static force-deflection test setup, using an 8-inch diameter indentation plate, is shown in Figure 1.

Figure 1. Static Test Setup

Stiffness measurement at the front of the cushion, where the cushion is most likely to bottom out in CRS sled tests, was considered for this study (Figure 2). The force-deflection characteristics of the vehicle rear seat cushions are in Appendix B.
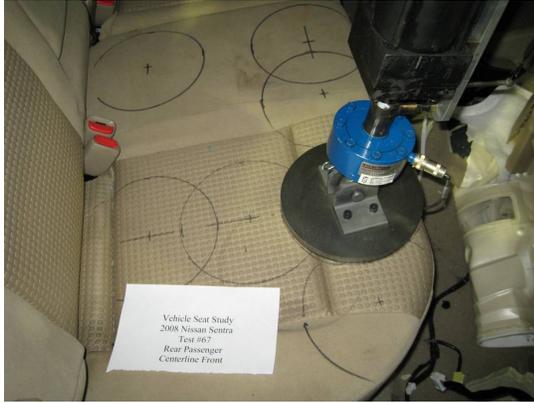
Figure 2. Cushion Test Location

Control Parameters for Rear Seats in Sled Tests

Based on the ranges of shapes, sizes, and stiffness recorded for the 24 vehicles, the following values were selected to characterize the rear seat in the sled tests:
Cushion stiffness = soft, hard
Cushion top surface angle = 7º, 16º
Cushion height at front = 225 mm, 100 mm
Seat frame support angles = 7º, 16º

Note that the seat support frame angle on the current FMVSS No. 213 seat is at 15º and the anti-submarining ramp below the seat cushion in the 2007 Ford 500 is 12º. The seat pan width (1372 mm), depth (508 mm), seat back angle, seat back shape and seat back foam were kept the same as in current FMVSS No. 213 seat. The four cushion shapes thus selected are shown in Appendix C.

Two different cushion stiffnesses (soft, hard) were obtained. They were both polyurethane foam, based on toluene diisocyanate (TDI), used in the North American market automobile seats. The foam characteristics, tested per ASTM D 3574 – 08 (15" x 15" x 4" block using a 8" diameter indenter) are shown in Figure 3.


Comment	Height mm	Force at 25 % Fapply lbf	Force at 50 % Fapply lbf
26 Block - Material A	101.25	22.14	34.59
80 Block - Material B	103.96	79.32	114.59
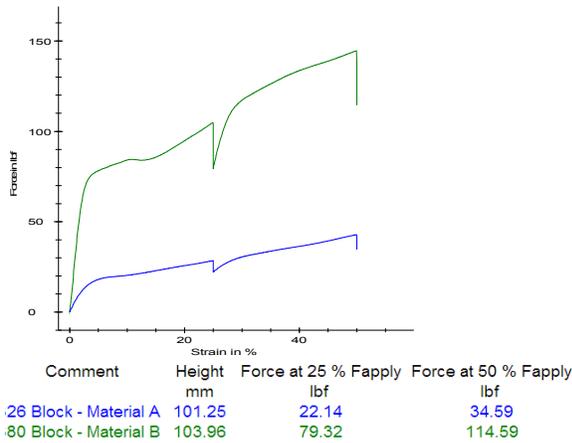
Figure 3. Cushion Foam Properties

The indentation forces at 25% and 50% deformation are 22.1 lb_f and 34.6 lb_f for the soft foam and 79.3 lb_f and 114.6 lb_f for the hard foam, respectively.

The selected sled seat cushions were tested under identical conditions as the vehicle seats (Figure 3). The results are overlaid and shown in Appendix B.


Figure 4. Sled Seat Static Test

Crash Pulse Used

The crash pulse selected for studying the cushion effects was representative of a high severity frontal impact of a mid-size passenger car. The frontal NCAP 35 mph crash pulses for the 2000 and 2004 Ford Taurus are shown in Figure 5. The representative sled pulse is also shown in Figure 5. The peak acceleration and ΔV of the sled pulse were 28.4 G and 36.0 mph (at 106.5 ms).
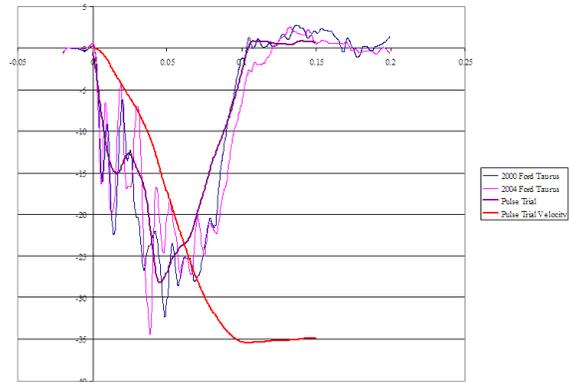

Figure 5. Sled Pulse

Test Matrix Summary

The independent variables defining the seat were:
Foam shapes: 4 (thick, thin; flat, wedge)
Foam Stiffness: 2 (soft; hard)
Base-Plate Angle: 2 (7º; 16º)

That resulted in 16 different rear seats tested in 16 sled tests. Each test had a belted 5th F and a 3 YO dummy in an Evenflo Titan Elite DLX Convertible forward facing CRS. The CRS was mounted to the seat by the lower anchors and top tether for children (LATCH) attachments. The sled pulse was an approximation of the 35 mph frontal NCAP crash pulse of a 2004 Ford Taurus.

The 5th F and the 3 YO dummies had instrumentation in the head, upper neck, and the chest.

Location of Seat Belt and LATCH Anchors

The ranges of cushion thicknesses and stiffnesses result in the occupant being seated at different heights on the sled for each of the cushion and seat angle combinations.

To ensure that the seat belt and LATCH anchors were at the same locations relative to the 5th F and 3YO respectively, belt anchor locations (Figure 6) were recorded in the 2004 Taurus relative to the H-point determined using the SAE J826 OSCAR H-point machine installed in the vehicle.

Figure 6. Seat Belt Attachment Locations

The OSCAR H-point machine was installed on each of the 16 combinations of cushion and seat angles (Figures 7-8).

Figure 7. OSCAR on a Thick Cushion

Figure 8. OSCAR on a Thin Cushion

Belt and LATCH anchor locations (at the same positions relative to the OSCAR H-point) were located for all 16 cushion-seat configurations. The CRS, belts, and retractors were changed after each sled test.

A typical test setup is shown in Figures 9 and 10. Each dummy was photographed by three high speed digital cameras. The position of the head and other landmarks on the dummies were calculated using 3D photogrammetry.

Figure 9. Sled Test Setup

Figure 10. Sled Test Setup

Test Results
The test matrix and IAV, normalized to the injury assessment reference values (IARV) are shown in Appendix D. The maximum head excursions are normalized to the highest value in all 16 tests. This provides a relative measure of head excursion to the worst case result .

5th Percentile Female
Test # 6 (thin, flat, soft cushion at 16 degrees) had the lowest maximum IAV (scaled head excursion of 0.93). Test # 13 (thick, flat, soft cushion at 16 degrees) had the highest maximum IAV (scaled neck tension of 1.53).

3YO Child
Test # 14 (thick, flat, soft cushion at 7 degrees) had the lowest maximum IAV (scaled neck tension of 1.62). Test # 16 (thick, flat, hard cushion at 16 degrees) had the highest maximum IAV (scaled neck tension of 1.88).

ANOVA Analysis

A one-way ANOVA analysis for the effect of cushion thickness, stiffness, shape, and angle on injury data is shown in Appendix E.

Variables that were at least 80% likely to be significant were analyzed using linear regression for each dummy individually and for scaled data analyzed jointly. Cushion thickness was the dominant variable.

Observations

Cushion thickness had the most effect on IAV. The maximum difference in head excursion was 2.3" for the 5th F, and 3.2" for the 3 YO child dummies. The thin cushion provided a more stable surface, while the thick cushion may have caused submarining in the 5th percentile female or slack in the CRS attachment. A different CRS may produce different results.

CRASH PULSE EFFECTS

Background

In response to the Transportation Recall Enhancement, Accountability, and Documentation (TREAD) Act, NHTSA evaluated various CRS in 193 MY 2001-2008 vehicle crash tests [2]. Eighty nine (89) vehicles were evaluated, equipped with a control CRS (Evenflo Vanguard). The vehicle pulse severity was found to affect the dummy performance. However, no solid correlation was found. (Peak chest acceleration somewhat correlated to the vehicle crush). For MY 2001 – 2004 tests, when controlling for the child restraint, vehicle make and model explained 64 percent of the variation in chest acceleration and 63 percent of the variation in HIC. One confounding factor was the presence of too many variables (CRS, pulse, vehicle seat) in these crash tests.

The test plan selected for this study presented below addressed some of those factors by keeping the same vehicle seat, CRS (Evenflo Titan Elite DLX), and ΔV, while changing the crash pulse.

Test Setup

Like the seat parameter effect tests, the pulse effect sled tests used two occupants (5th percentile female, 3 year old child Hybrid III dummies). The seat cushion was selected to be the New Programme for the Assessment of Child-restraint Systems (NPACS) foam, 5" thick and 19"

----
2. Evaluation of Child Occupant Protection In a 56 km/h (35 MPH) Frontal Barrier Crash, Docket Number NHTSA-2004-18682.

deep. The seat back was the same as used in the current FMVSS No. 213 seat. The seat cushion and seat back angles were set to the same values as in the FMVSS No. 213 (cushion at 15 deg, seat back at 20 deg.). The force-deflection characteristics of the NPACS foam as installed on the sled, is shown in Appendix F.

Figure 11. Sled Test Setup

The seat belt anchor locations (for the 5th F) and the LATCH anchor locations (for the 3 YO in FF CRS) were adjusted to be in the same relative location to the OSCAR H-point in the 2006 Ford Taurus rear seat.


Figure 12. Belt anchor Location

The CRS, belts and retractors were changed after each sled test. The 5th F and the 3 YO dummies had instrumentation in the head, upper neck, and the chest.

Crash Pulse Selection

To determine the characteristics of the sled pulses for use in this study, frontal NCAP crash pulses from 2003 to 2008 were examined. These are shown in Figure 13, along with the average of these crash pulses.
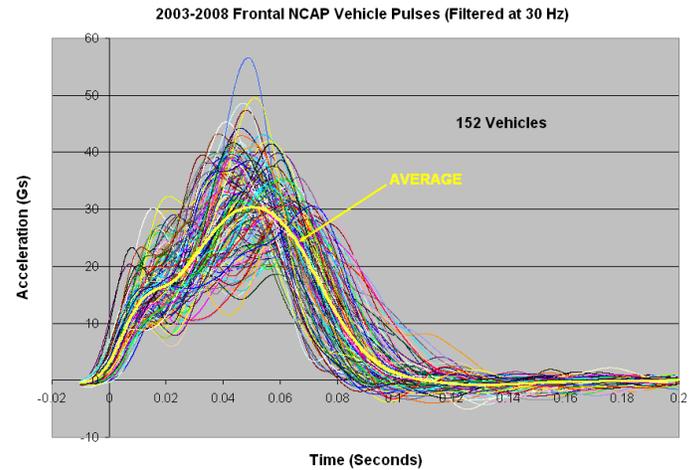
Figure 13 NCAP Crash Pulses

Based on the average NCAP crash pulse, the following criteria were used in selecting the sled pulses:
    $\Delta V = 35$ mph
    Pulse duration = 100 ms +/- 10 ms
The sled pulses from existing HYGE sled pins available at the Transportation Research Center, Inc. (TRC) that satisfied these criteria, along with the current FMVSS No. 213 pulse (scaled to 35 mph), are shown in Fig. 14.
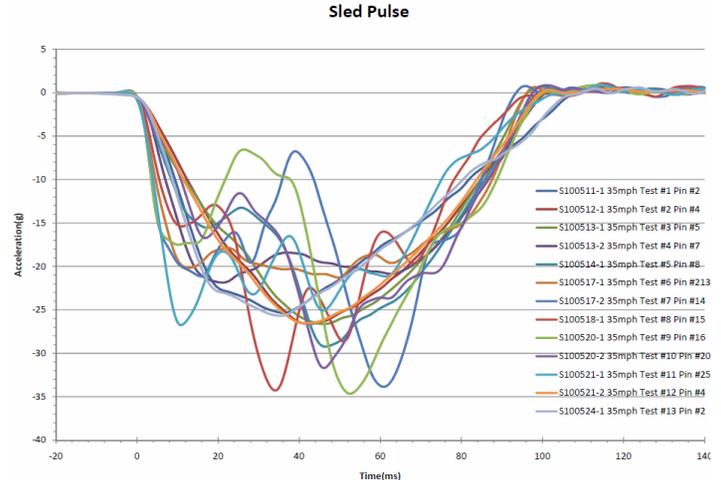
Figure 14 Sled Pulses Used for Pulse Effect

Sled Pulse Characterization

The selected sled pulses were characterized based on their acceleration values and their shapes. These would be used as independent control variables when examining the dummy IAV's from the sled tests.

The acceleration based pulse characteristics used were as follows (refer to Figure 15):
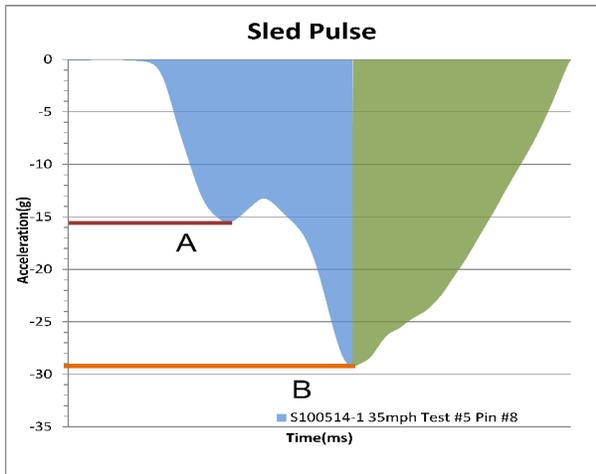
Figure 15. Acceleration-Based Pulse Characterization

Peak G's
    Maximum acceleration
Average G's
   Average acceleration from time zero to return to
        zero G's
Ratio of A/B
    Ratio of relative maximum G's (A) to peak G's (B).
        If multiple relative maximums existed the most
        prominent curve was chosen.
Ratio of C/D
    Ratio of the area (blue) before the maximum peak to
        area (green) after the maximum peak.
Front or Rear Loading
    If the location of the peak is before the mid-point of
        the pulse, the pulse is front loaded. If it is after the
        mid-point, the pulse is rear loaded.
The shape of the sled pulse was characterized by the
centroid of the acceleration vs. time plot (Figure 16).
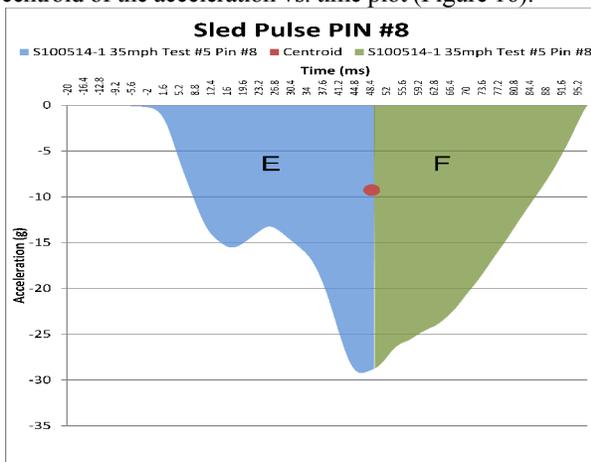
Figure 16. Shape Based Pulse Characterization

Value of Centroid (time, acceleration)
Ratio of E/F

Ratio of area under the curve before the centroid (E)
    to area under the curve after the centroid (F)
Vehicle Pulse Index (VPI)
    Using 2-step pulse approximation, the peak
        acceleration of a belted occupant (estimated from a
        1-D model) in a vehicle with seat belts and air bags.
VPI is the "Vehicle Pulse Index." It is the peak
acceleration on a unit mass representing the occupant,
subject to the crash-pulse input and subject to a lumped-
mass spring representing the restraint system (belt+bag
stiffness). While VPI is calculated for the front seat
occupant, it is still a useful measure when comparing
crash pulses.

The pulse characteristics of the 13 sled pulses are shown
in Appendix G. The dummy IAV's are in Appendix H.

Stepwise Linear Regression Model

The results of a stepwise linear regression model are
shown in Appendix I. The models include all linear
terms significant at the 15% level (i.e., there is at least an
85% probability that the term selected affects the results).

The results of the best fit models (predicted value vs.
actual value) of the IAV's are in Appendix J and K.

Observations

For the 5th percentile female:
    VPI was the best predictor of HIC and peak chest
        acceleration.
    Peak sled acceleration was the best predictor of Nij.
    Pulse centroid acceleration value was correlated to
        head excursion.
    Submarining was observed in some tests.
For the 3 year old child:
    VPI was the best predictor of HIC and peak chest
        acceleration.
    There was a weak correlation of VPI to the neck
        axial force and head excursion.
    Pulse centroid acceleration value was correlated to
        the maximum chest deflection.

LIMITATION OF STUDY

 The cushion effect and pulse effect tests used a
simplified rear seat design. The intent was to identify the
effects of extreme values of seat parameters on dummy
IAV's. Actual rear seats in vehicles use contoured
shapes and cushion materials that may be very different
from those used in the study. Some phenomena like
submarining could be dependent on difference in the
cushions used in this study compared to those used in
vehicles. Also, the results for the 3year old in CRS may
not be applicable to other CRS designs.

Vehicle Description	Front Seat Foam Thickness (A)	Seat Depth Front to Back (B)	Back Seat Foam Thickness (C)	Floor to Top of Seat	Seat Angle Degrees
2008 Ford Taurus X	100	510	90	380	6.7
1999 Volkswagen Beetle	100	450	95	340	8
1994 Honda Civic	105	500	70	275	12.9
2006 Volkswagen Passat	115	530	80	335	11
2002 Ford Focus	120	500	85	375	12.6
2007 Saturn Vue	130	520	80	302	8.6
2008 Subaru Tribeca	140	510	70	325	9
2002 Honda CRV	140	570	40	370	9.4
2007 Ford Expedition	140	520	65	340	10.2
2006 Dodge Durango	140	575	90	372	14.4
2007 Ford Edge	140	520	120	300	15.1
2008 Toyota Highlander	150	505	83	335	8.8
2005 Honda Odyssey	150	570	70	378	12.7
1996 Chevy Cavalier	160	490	60	320	8.2
2009 Chevy Equinox	160	690	60	365	10.8
2007 Jeep Commander	160	560	70	310	12.3
2006 Honda Ridgeline	165	500	50	375	11.4
2007 Mazda CX-9	170	515	50	295	11
2003 Honda Odyssey	170	520	90	373	13.4
1996 Chrysler Concord	170	620	28	330	18
1990 Honda Civic	190	480	90	315	9.3
2007 Ford 500	210	540	70	360	15
1996 Ford Taurus	215	545	40	348	16.8
2008 Nissan Sentra	225	555	48	365	10.3

APPENDIX B Vehicle Rear Seat and Sled Cushion Force-Deflection Plots

Rear Passenger Centerline Front Overlays
Force Displacement

Legend:
- 2006 Honda Ridgeline
- 2006 VW Passat
- 2007 Ford Expedition
- 2007 Ford Five-Hundred
- 2007 Saturn Vue
- 2008 Ford Taurus X
- 2008 Mazda CX-9
- 2008 Nissan Sentra
- 2008 Subaru Tribeca
- 2008 Toyota Highlander
- 2008 Nissan Versa
- 2003 Ford Crown Victoria
- 2005 Crysler 300C
- 213 Seat
- Cushion #1 Hard - Thin Flat
- Cushion #2 Soft - Thin Flat
- Cushion #3 Hard - Thick Flat
- Cushion #4 Soft - Thick Flat
- Cushion #5 Soft - Thick Wedge
- Cushion #6 Hard - Thick Wedge
- Cushion #7 Hard - Thin Wedge
- Cushion #8 Soft - Thin Wedge

APPENDIX C Sled Cushion Shapes
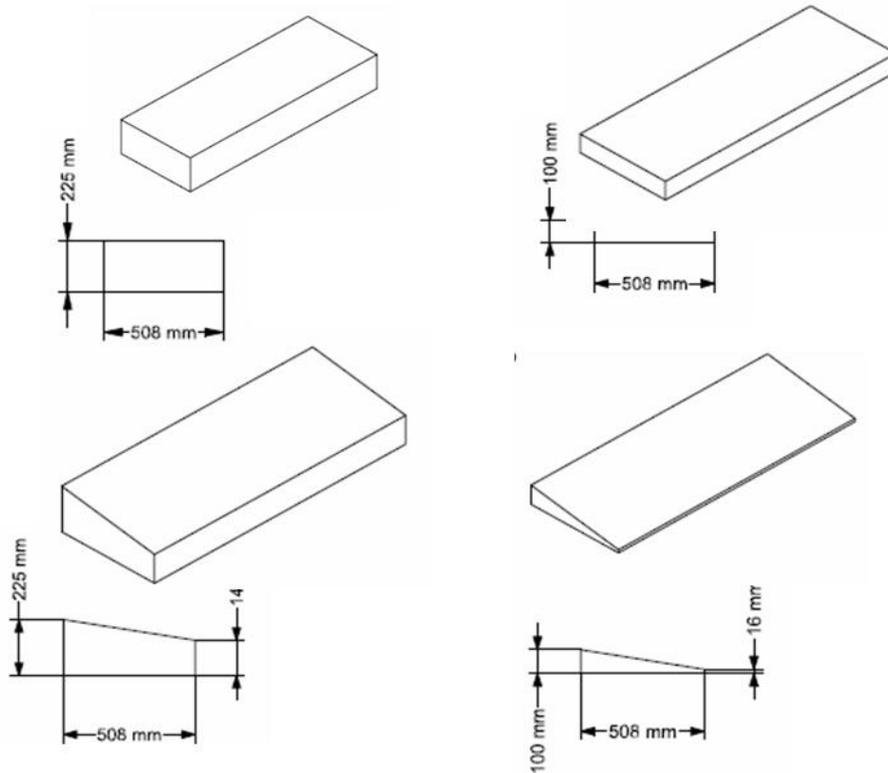
APPENDIX D Test Results

Test#	Configuration	Independent variables				5th F						3 YO					
		thickness	Shape	stiffness	angle	HIC15	ChestG	ChestD	Nij	NeckT	HeadX	HIC15	ChestG	ChestD	Nij	NeckT	HeadX
~~S091006-1 Test 1~~	N	thin	wedge	hard	7	0.85	0.86	0.69	1.16	0.91	0.90	0.46	0.96	0.50	1.17	1.76	0.77
S091007-1 Test 2	H	thin	wedge	hard	16	1.12	0.74	0.59	1.03	1.00	0.88	0.49	0.84	0.50	1.05	1.81	0.85
S091008-1 Test 3	O	thin	wedge	soft	7	0.71	0.96	0.77	1.14	0.82	0.94	0.43	0.91	0.56	1.11	1.76	0.82
S091009-1 Test 4	G	thin	wedge	soft	16	0.92	0.81	0.62	1.14	1.05	0.88	0.40	0.89	0.59	1.04	1.67	0.81
S091009-2 Test 5	I	thin	flat	soft	7	0.70	0.80	0.80	0.82	0.98	0.96	0.45	0.90	0.53	1.21	1.83	0.81
S091014-1 Test 6	B	thin	flat	soft	16	0.82	0.75	0.72	0.86	0.91	0.93	0.48	0.88	0.55	1.11	1.69	0.78
S091014-2 Test 7	A	thin	flat	hard	16	0.83	0.74	0.73	0.90	0.91	0.95	0.50	0.89	0.59	1.16	1.75	0.84
S091015-1 Test 8	P	thin	flat	hard	7	1.14	0.86	0.72	1.33	1.44	0.92	0.45	0.86	0.54	1.20	1.76	0.89
S091015-2 Test 9	E	thick	wedge	soft	16	1.04	0.72	0.63	1.13	1.48	0.88	0.43	0.89	0.64	1.14	1.72	1.00
S091022-1 Test 10	L	thick	wedge	soft	7	1.04	0.75	0.74	1.16	1.28	0.99	0.45	0.92	0.63	1.12	1.69	0.94
S091015-3 Test 11	M	thick	wedge	hard	7	1.03	0.78	0.73	1.00	1.34	0.97	0.51	0.91	0.54	1.26	1.83	0.88
S091019-1 Test 12	F	thick	wedge	hard	16	0.79	0.75	0.60	1.00	1.14	0.96	0.48	0.94	0.64	1.14	1.70	0.98
S091019-2 Test 13	D	thick	flat	soft	16	1.13	0.73	0.74	1.26	1.53	0.91	0.65	0.98	0.65	1.21	1.84	0.91
S091023-1 Test 14	K	thick	flat	soft	7	0.94	0.80	0.77	1.19	1.29	0.92	0.43	0.96	0.69	1.03	1.62	0.96
S091021-1 Test 15	J	thick	flat	hard	7	0.81	0.80	0.72	1.12	1.28	0.94	0.51	0.93	0.62	1.13	1.73	0.92
S091021-2 Test 16	C	thick	flat	hard	16	0.66	0.86	0.61	0.92	0.96	1.00	0.54	0.92	0.56	1.21	1.88	0.91
S091023-2 Repeat of Test 1	N	thin	wedge	hard	7	1.07	0.73	0.65	1.11	1.40	0.92	0.51	0.95	0.62	1.15	1.84	0.86

Effect of Thickness, (95% Probability)			
Injury Criteria	Effect	Values	Statistically Different, $\alpha = 0.20$
Hic15_scaled	Thick > Thin	0.716 | 0.689	No
NIJ_scaled	Thick > Thin	1.126 | 1.085	No
Fz_scaled	Thick > Thin	1.520 | 1.412	No
Chdef_scaled	Thick > Thin	0.655 | 0.630	No
Ch3_scaled	Thick > Thin	0.852 | 0.843	No
Hdx_scaled	Thick > Thin	0.942 | 0.878	**Yes**

APPENDIX F NPACS Foam Cushion Stiffness

NPACS Foam Static Test

Rear Passenger Centerline Front Overlays
Force Displacement
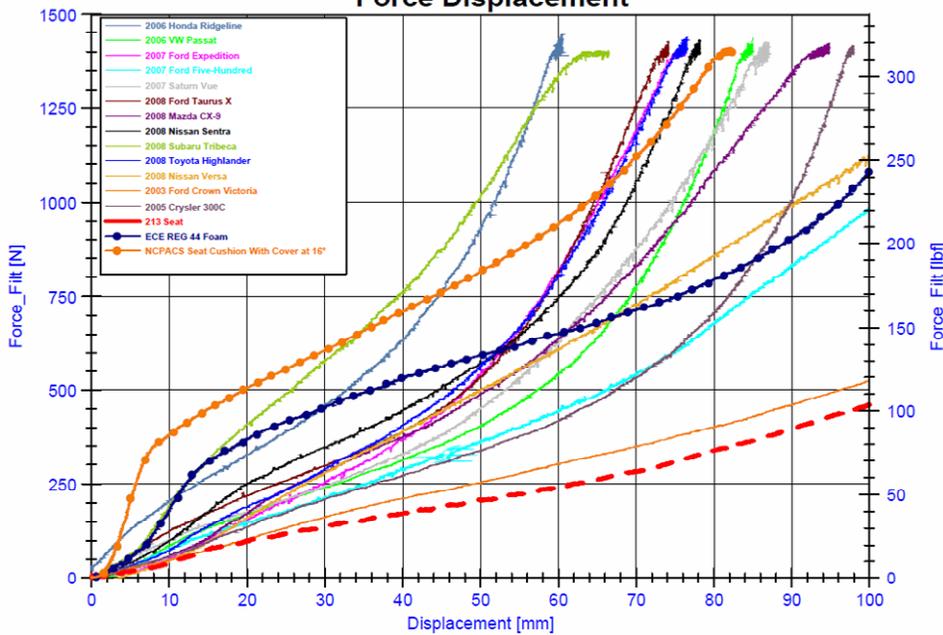
APPENDIX G Sled Pulse Characteristics

		Independent variables								

TEST #	PIN #	Peak Gs		Front or Rear Loading	Average Gs	Ratio A-B	Ratio C-D	Centroid		Ratio E-F (Centroid)	VPI
		Value (g)	Time (ms)		Value (g)	%	%	X Value (ms)	Y Value (g)	%	
1	2	25.36	36.16	Front	15.018	1.00	0.63	46.00	9.47	1.17	50.45
2	4	26.593	42.32	Front	15.81733	1.00	0.70	48.45	10.05	1.05	52.58
3	5	26.627	46.08	Front	16.49715	1.00	0.88	48.17	10.16	1.01	52.55
4	7	21.852	21.12	Front	15.90023	0.95	0.22	46.59	9.18	1.00	46.05
5	8	29.236	46.48	Front	16.33067	0.53	0.76	49.33	10.05	0.94	50.79
6	213	21.279	49.68	Rear	16.4112	0.95	1.28	45.43	9.09	1.02	46.06
7	14	33.854	60.8	Rear	17.00848	0.62	1.90	46.69	10.49	0.74	42.88
8	15	34.273	34.08	Front	16.39544	0.45	0.54	43.71	10.76	1.08	54.12
9	16	34.654	52.56	Rear	15.90221	0.51	0.95	50.08	10.57	0.76	46.23
10	20	31.69	46.08	Front	16.37635	0.53	0.71	50.13	10.20	0.97	51.13
11	25	26.752	10.88	Front	15.14911	0.87	0.11	41.41	9.77	1.00	48.70
12	4	26.517	41.52	Front	15.9318	1.00	0.70	47.61	10.04	1.06	52.54
13	2	25.673	35.44	Front	14.55039	1.00	0.62	45.45	9.62	1.17	51.21

Dependent variables

5th Female					
HIC 15	Chest G	Chest Deflection	NIJ	Neck Fz	Head Ex
700	60	52	1	2620	470
0.71	0.87	0.82	1.32	1.10	0.90
0.88	0.79	0.93	1.17	1.25	0.89
1.00	0.87	0.78	1.40	1.35	0.94
0.77	0.66	0.90	1.09	1.21	0.87
0.91	0.71	0.96	1.45	1.25	0.90
0.61	0.67	0.93	1.21	1.03	0.86
0.79	0.64	0.73	1.50	1.02	0.95
1.00	0.85	0.96	1.64	1.15	1.00
0.69	0.66	0.92	1.58	0.85	0.91
0.82	0.72	0.93	1.50	1.03	0.94
0.77	0.75	0.92	1.05	0.97	0.84
-	-	-	-		-
-	-	-	-		-

Three year old					
HIC 15	Chest G	Chest Deflection	NIJ	Neck Fz	Head Excursion
570	55	34	Value	1130	384.2
0.49	0.85		1.71	1.81	0.96
0.63	0.93	0.55			0.94
0.70	0.98	0.61	1.94	2.04	0.96
0.47	0.82	0.52	1.75	1.79	0.86
0.48	0.90	0.58	1.59	1.74	0.99
0.54	0.86	0.56	1.79	1.83	0.90
0.33	0.69	0.65	1.42	1.50	0.91
0.62	0.93	0.64	1.72	1.81	1.00
0.53	0.98	0.62	1.65	1.70	0.95
0.53	1.00	0.57	1.79	1.79	0.94
0.53	0.85	0.57	1.78	1.80	0.90
0.63	0.94	0.61	2.03	2.02	0.89
0.59	0.89	0.61	1.84	1.91	0.96

5th Percentile Female Dummy

Injury Criteria	Input Term	Partial R^2	Coefficient	Model R^2
HIC_15	VPI Avg G Front_Rear	0.51 0.20 0.10	+0.028 +0.096 Front > Rear	0.81
Chest G	VPI A_B Ratio Peak G E_F Ratio	0.69 0.08 0.08 0.07	+0.009 +0.278 +0.016 +0.426	0.92
Chest Deflection	C_D Ratio Front_Rear	0.30 0.07	-0.085 Front > Rear	0.37
NIJ	Peak G Peak Time E_F Ratio	0.71 0.09 0.06	+0.036 +0.006 +0.539	0.86
Neck Fz	VPI Front_Rear	0.31 0.11	+0.023 Front > Rear	0.41
Head Excursion	Centroid G	0.60	+0.065	0.60

3 Year Old Dummy

Injury Criteria	Input Term	Partial R^2	Coefficient	Model R^2
HIC_15	VPI Front_Rear	0.63 0.05	+0.030 Rear > Front	0.68
Chest G	VPI Centroid Time	0.46 0.18	+0.023 +0.018	0.65
Chest Deflection	Centroid G C_D Ratio Centroid Time	0.56 0.10 0.10	+0.054 +0.040 -0.005	0.77
NIJ	E_F Ratio	0.38	+0.615 Front > Rear	0.52
Neck Fz	VPI Front_Rear	0.31 0.21	+0.029 Front > Rear	0.52
Head Excursion	VPI A_B Ratio	0.31 0.26	+0.011 -0.081	0.57

HIC_15   0.81   Chest G   0.92   Chest D   0.37
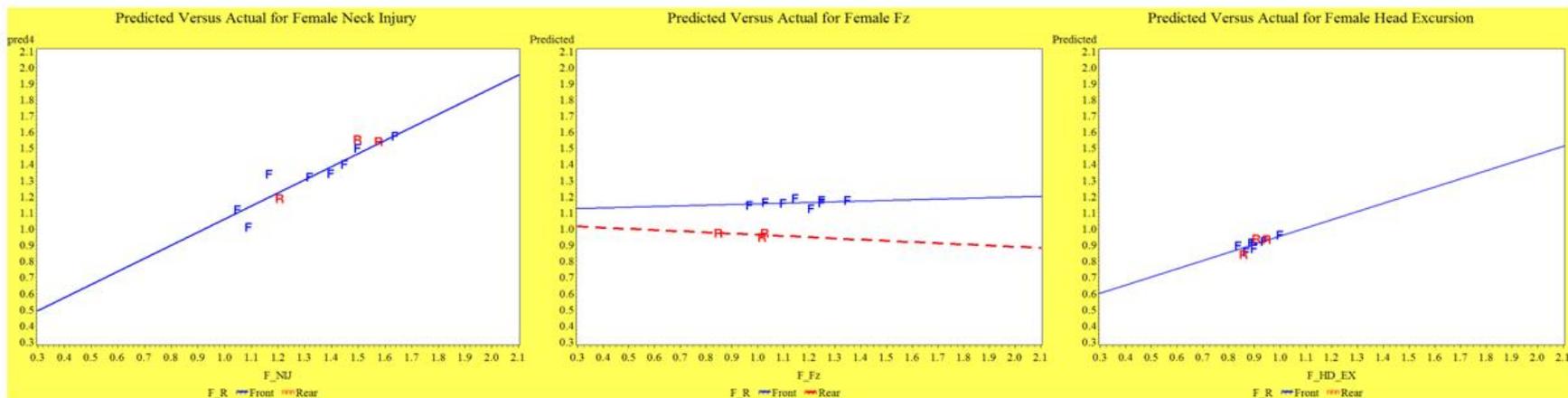
Nij   0.86   Neck Fz   0.41   Head Ex   0.60
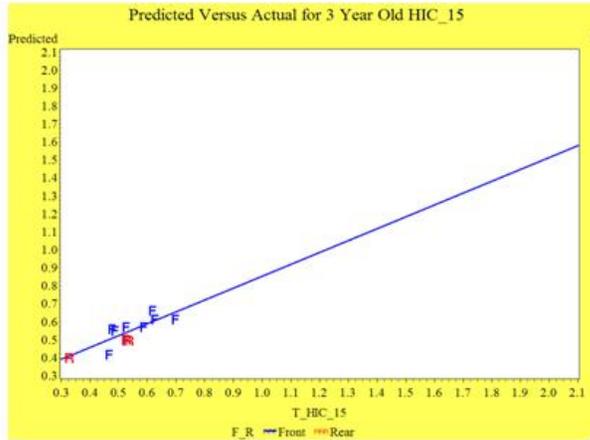
HIC_15   0.68
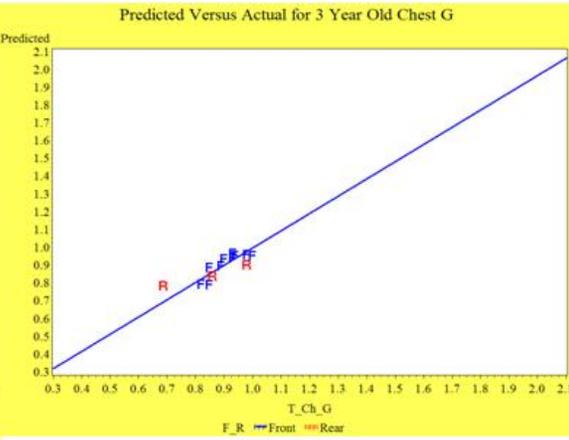
Chest G   0.65
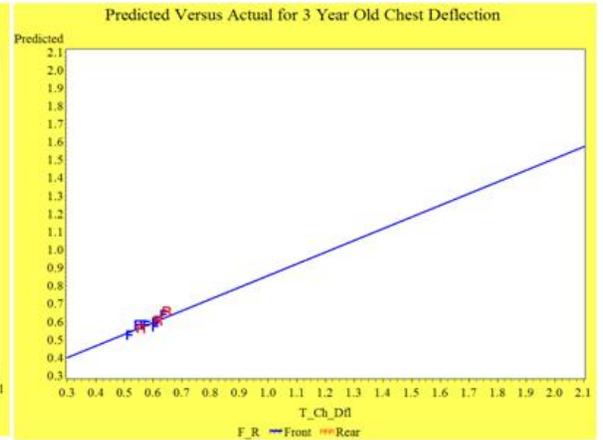
Chest D   0.77
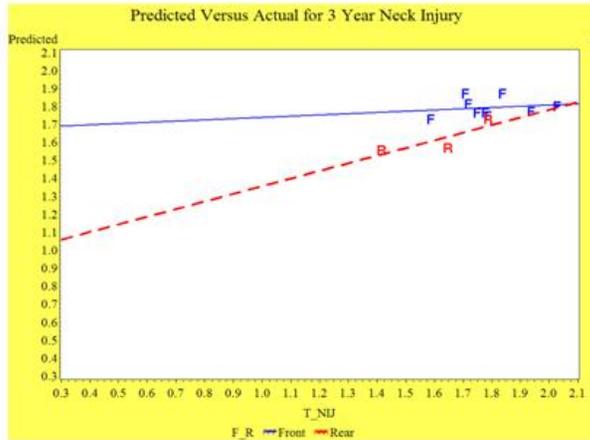
Nij   0.52

Neck Fz   0.52

Head Ex   0.57