# EVALUATION OF FRONTAL AIR BAG PERFORMANCE

**Aloke K. Prasad**
**Allison E. Louden**
**Ron Pack**
National Highway Traffic Safety Administration
US Department of Transportation

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Abstract: In May of 2000, the NHTSA issued a Final Rule upgrading Federal Motor Vehicle Safety Standard (FMVSS) No. 208, 65 FR 30680. This advanced air bag rule specified significant changes in the frontal occupant protection requirements for light passenger vehicles (GVWR≤8500 lbs), to be phased in over several years. These included adding requirements for protecting small adult female occupants, adding requirements to minimize the risk of deploying air bags to out-of-position (OOP) children and small adult occupants, increasing the test speed for the belted 50th percentile male dummy, adding a rigid barrier test condition for the unbelted 50th percentile male test dummy and eliminating the unbelted sled test option.

In 2001, the agency initiated research to monitor the overall performance of advanced air bags. This paper updates the status of the research and presents results of the testing performed since the 18th ESV Conference. Results from static deployment tests for OOP occupants and dynamic crash tests are presented.

## 1.0 BACKGROUND

FMVSS No. 208 (49 CFR Part 571.208) is the occupant frontal crash protection regulation in the United States. In May 2000 and December 2001, NHTSA amended the standard to require future air bags to be less aggressive to small stature adults and young children, but still provide protection for all occupants. The new rule improved protection and minimizes risk by requiring new tests and injury criteria for the entire family (12 month CRABI (12MO), 3-year-old (3YO), 6-year-old (6YO), 50th percentile male (50th M) and 5th percentile female (5th F) Hybrid III) of test dummies.

Automobile manufacturers must meet one of the following minimum requirements designed to minimize air bag risks: Option 1 – Automatic Suppression feature, Option 2 – Dynamic Automatic Suppression system, or Option 3 – Low Risk Deployment (LRD) or (OOP) testing. This paper looks at Option 3- OOP testing on selected model year (MY) 2002 and 2004 vehicles.

NHTSA has been evaluating the performance of air bags in frontal crashes for the past few years, during the phase-in of the current FMVSS No. 208 regulations. In June of 2001, NHTSA published in the Federal Register a request for comments on a plan to monitor the performance of advanced air bags and to develop data for potential future air bag rulemaking. An ongoing research program was created to look at air bags by following the new procedures in FMVSS No. 208.

Crash tests with MY 1998 and 1999 vehicles, reported by Summers [1] and Beuse [2] showed the need for optimized crash protection for small female and mid-sized male occupants. Results from crash tests on MY 2001 vehicles showed similar results [3]. The results of OOP tests on model year 2001 vehicles (Honda Accord, Chevrolet Impala, Dodge Caravan, Toyota Echo, Ford Escape and Ford F150) were presented in Paper No. 427 at the 18th ESV [4]. This paper updates the findings from a similar ongoing study of MY 2002 through 2004 vehicles.

## 2.0 INTRODUCTION

Vehicles were chosen for this study depending on what advanced safety features they had. A wide variety of vehicles: passenger cars, light trucks and vans were included in this selection. Several vehicles had dual stage air bags and advanced air bags. Table 2.1 shows the vehicles selected and their safety features. After September 1, 2006, 100 percent of the fleet (GVWR≤8500 lbs and unloaded weight≤5500 lbs) shall be certified to the first phase of the new advanced FMVSS No. 208 rule.

Two vehicles selected for the tests, MY 2004 Honda Accord and Odyssey, were certified to the LRD option for the 6YO as required in S23.4 of the new FMVSS No. 208. As such, the other vehicles in the matrix were not expected to meet the current FMVSS No. 208 requirements for LRD tests. The MY 2002 vehicles were certified to the pre-advanced airbag version of FMVSS No. 208, which required crash tests or sled tests. MY 2004 vehicles were certified to the current FMVSS No. 208 regulations using the suppression option, except for the Honda Accord and Odyssey.

The LRD performance for MY 2004 was evaluated using a Hybrid III 10-year-old (10YO) dummy. This dummy was developed recently in order to study the injury risks to the large child occupant. These tests were used to understand the baseline safety performance of vehicle restraints systems for such occupants. The 10YO dummy is not a part of FMVSS No. 208.

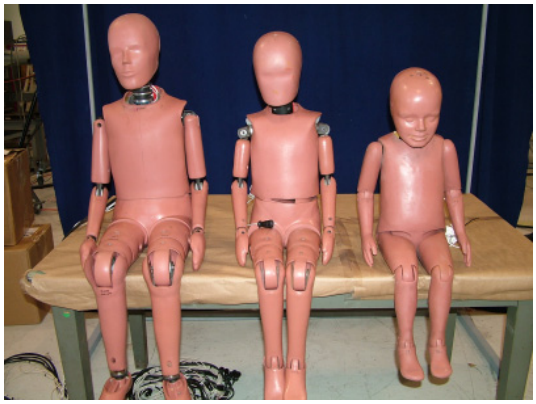

**Figure 2.1 10YO, 6YO, and 3YO dummies.**

A test program was initiated to study the injury risks to small child occupants in the proximity of the deploying air bags. FMVSS No. 208 uses two dummy positions in the LRD option that places the dummy's head/neck and chest close to the air bag. It is of interest, however, to understand how the injury risk to the occupant varies in the space around these LRD positions. This will allow the agency to assess injury potential for situations not covered by the two positions currently used in FMVSS No. 208.

**Table 2.1**
**Vehicle Selection.**

| Vehicle | Dual Stage Air bags | Passenger Suppression System |
|---|---|---|
| 2002 Saturn Vue | | |
| 2002 Honda Civic | X | |
| 2003 Toyota Corolla | X | |
| 2002 Ford Windstar | X | |
| 2004 Honda Accord | X | X* |
| 2004 Honda Odyssey | X | X* |
| 2004 Chevy Avalanche | X | X |
| 2004 Jeep Liberty | X | X |
| 2004 Ford Taurus | X | X |

*- The Accord and Odyssey use suppression for 12MO and 3YO and LRD for 6YO.

## 3.0 LOW RISK DEPLOYMENT TEST MATRIX

The vehicles selected for crash and LRD tests are shown in Table 3.1. The test conditions are the same as in the advanced air bag requirements of FMVSS No. 208 (Test Procedure 208-12, dated 1/14/03), and are described in [4]. Dual stage bags can typically be deployed with less energy or inflation rates (low mode) or higher energy or inflation rates (high mode). This is usually determined by changing the time elapsed between deploying the two sates of the inflator. Vehicles with the dual stage air bags were tested in the low mode first. If the dummy readings passed the injury assessment reference values (IARV) in the low mode, then the high mode was tested as well. Table 3.2 shows the different fire times used during testing. Only the MY 2004 Accord and Odyssey were certified to the LRD option of FMVSS No. 208 for the passenger side.

For the MY 2002 and 2003 vehicles, the OOP testing was done with the Hybrid III 5th percentile female dummy on the driver's side and Hybrid III 6-year-old (6YO) dummy on the passenger's side. For the MY 2004 vehicles, only the passenger side was tested (using the Hybrid III 10YO dummy). The 10YO positions (Figures 3.1 and 3.2) were based on the Hybrid III 6YO LRD Positions in FMVSS No. 208.

**Table 3.1**
**Air Bag Fire Times.**

| MY2002 Vehicles | Time gap between stages, msec | | | | Pass. Bag Loc. |
|---|---|---|---|---|---|
| | Driver | | Passenger | | |
| | Low | High | Low | High | |
| 2002 Saturn Vue | N/A | N/A | N/A | N/A | Mid |
| 2002 Honda Civic | 20 | 0 ms | 40 | 0 | Top |
| 2003 Toyota Corolla | 30 | 0 | 100 | 0 | Top |
| 2002 Ford Windstar | 100 | 15 | 100 | 15 | Mid |
| 2004 Honda Accord | N/A | N/A | 130 | 5 | Top |
| 2004 Honda Odyssey | N/A | N/A | 130 | 5 | Top |
| 2004 Chevy Avalanche | | | Primary only | 22 | Front |
| 2004 Jeep Liberty | | | 102 | 10 | Front |

**Figure 3.1 Chev. Avalanche, 10YO Position 1.**

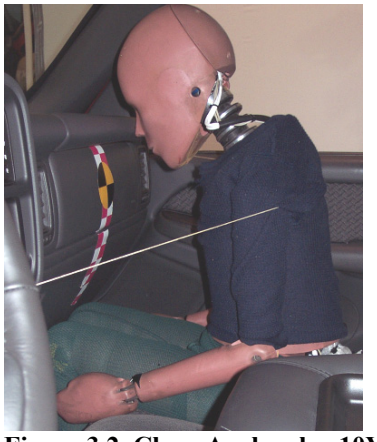

**Figure 3.2 Chev. Avalanche, 10YO Position 2.**

### 3.1 Injury Criteria

The results were analyzed using the FMVSS No. 208 injury criteria for out-of-position occupants for the Hybrid III 6YO, 5th percentile female dummies. The IARV for the 10YO dummy was obtained from [5]. The IARVs used for this study are listed in Table 3.2.

**Table 3.2**
**Injury Values for OOP Testing.**

| OOP Injury Criteria | Injury Assesment Reference Values (IARV) | | |
|---|---|---|---|
| | 5th% Female* | 6YO Child^ | 10YO Child^ |
| 15ms HIC | 700 | 700 | 700 |
| 3ms Clip (g) | 60 | 60 | 60 |
| Chest Deflection (mm) | 52 | 40 | 44 |
| Neck Tension (N) | 2070 | 1490 | 1810 |
| Neck Compression (N) | 2520 | 1820 | 2200 |
| Nij | 1.0 | 1.0 | 1.0 |
| Critical Values to Calculate Nij | | | |
| Tension (N) | 3880 | 2800 | 3390 |
| Compression (N) | 3880 | 2800 | 3390 |
| Flexion (Nm) | 155 | 93 | 128 |
| Extension (Nm) | 61 | 37 | 50 |

* Calculated on data recorded for 125 ms after the initiation of the final stage airbag
^ Calculated on data recorded for 100 ms after intial deployment

### 3.2 Observations

The test results are summarized in Tables 3.3 to 3.5. It should be noted that only the 2004 Honda Accord and Odyssey were certified to the LRD option on the passenger side.

#### 3.2.1 MY 2002 and 2003 Vehicles

Four MY 2002 and 2003 vehicles were tested. The 2002 Honda Civic, 2002 Ford Windstar, and 2003 Toyota Corolla had dual stage air bags. The 2002 Saturn Vue had single stage air bags, which were considered 'high mode' for the purposes of the following discussion.

##### 3.2.1.1 Passenger side (6YO)

A total of 14 tests were run on these vehicles and the results are summarized in Table 3.3 and Figures 3.3 and 3.4. Nij values and either neck tension or compression exceeded the IARVs in

six of the eight high mode tests, which included the Saturn Vue. None of the neck IARVs were exceeded in the six low mode tests. Only one test (Civic, high mode, position 1) exceeded the IARV for the 15 millisecond HIC. The other 13 were all below 80 percent of the IARV. Also, none of the chest responses exceeded either chest IARV. Only the Corolla produced responses that were below all the IARVs for all four of its tests.

#### 3.2.1.2 Driver Side (5th Female)

The results from these tests are shown in Table 3.4 and Figures 3.5 and 3.6. The 5th F had low injury values for the head and chest. The neck values were somewhat higher for both positions and air bag modes, although only one of the neck responses exceeded an IARV (Nij for Windstar, position 1, high mode). All the other injury measures were below 80 percent of the IARVs.

### 3.2.2 MY 2004 Vehicles

Nineteen tests were conducted on the five vehicles, with an average of about four tests per vehicle (two positions, two air bag modes each), and the results are shown in Table 3.5 and Figures 3.7 and 3.8. The Nij values exceeded the IARV in four out of 19 tests. The 2004 Chevy Avalanche exceeded Nij, neck tension and chest deflection IARV's for Position 1 in both the low and high modes. This vehicle also had a high Nij value for Position 2 in the high mode. Position 1 produced higher neck values than Position 2, because of how the dummy sat in the vehicle. This particular vehicle had a grab handle on the instrument panel just below the air bag, which caused the dummy to be seated farther back for position 2 (see Figures 3.1 and 3.2). The Ford Taurus, in the test at position 1, low air bag mode, produced the other high Nij. This test also resulted in a neck compression response that exceeded that IARV.

Fifteen out of nineteen tests passed all the injury criteria for a 10YO OOP occupant. Only, the Honda Accord and Odyssey were certified for LRD with a Hybrid III 6YO. The Accord, along with the Honda Odyssey and Jeep Liberty, passed all IARVs at both positions and for both low and high modes.

## 4.0 PARAMETRIC TESTS

The purpose of this series of static tests was to study how air bags react with dummies in locations other than FMVSS No. 208 LRD, Position 1 and Position 2. Additionally, the baseline condition was repeated to examine the degree of repeatability achieved for seemingly identical test conditions.

Three vehicle platforms (2002 Ford Windstar, 2002 Honda Civic, and 2003 Honda Odyssey) were selected, with two test conditions, the 5th F on the driver side, and 6YO on the passenger side. The test matrix is in Table 4.1.

For each vehicle, the air bag mounting location was replicated on a test buck, along with the windshield and the seat location (Figure 4.1). The dummy was seated according to the FMVSS No. 208 position, which was considered to be the baseline test condition. Tests at this baseline condition were repeated to study the repeatability of the overall test results, encompassing the variability of air bag modules, dummy seating, and bag interaction with the dummy. The dummy was reseated two and four inches, in the three principal directions, away from the baseline position (laterally to the left and right, longitudinally away from the air bag, vertically above and below). On the driver side, the baseline positions had a gap between the air bag and the dummy chest. Therefore, an additional test bringing the dummy two inches closer to the air bag was run.

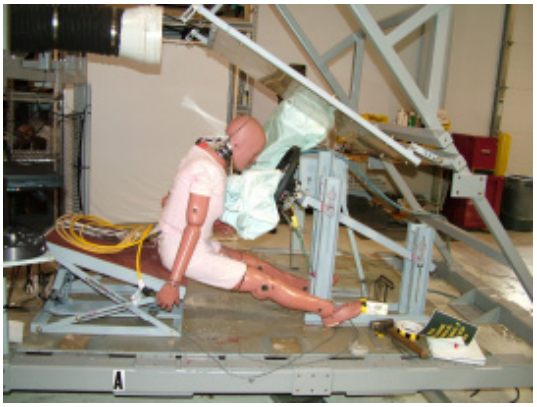

**Figure 4.1 Buck with adjustable metal seat.**

The dummy positions were documented using a digitizing arm for accurate measurements.

This is an ongoing program, and the results to date are in Tables 4.2 to 4.4 and Figures 4.6 to 4.17. Some of the test positions were omitted using engineering judgment, to reduce the number of tests involved. The small sample size (of mostly one test per condition) precludes any determination about the statistical significance of any findings.

**Figure 3.3 MY 2002 and 2003 Vehicles 6YO OOP Position 1**

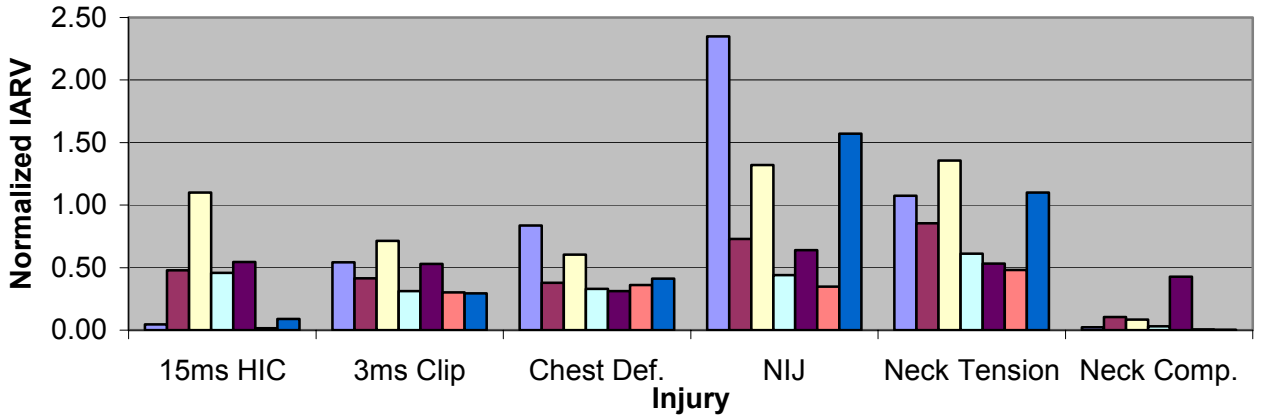


**Figure 3.4 MY 2002 and 2003 Vehicles 6YO OOP Position 2**

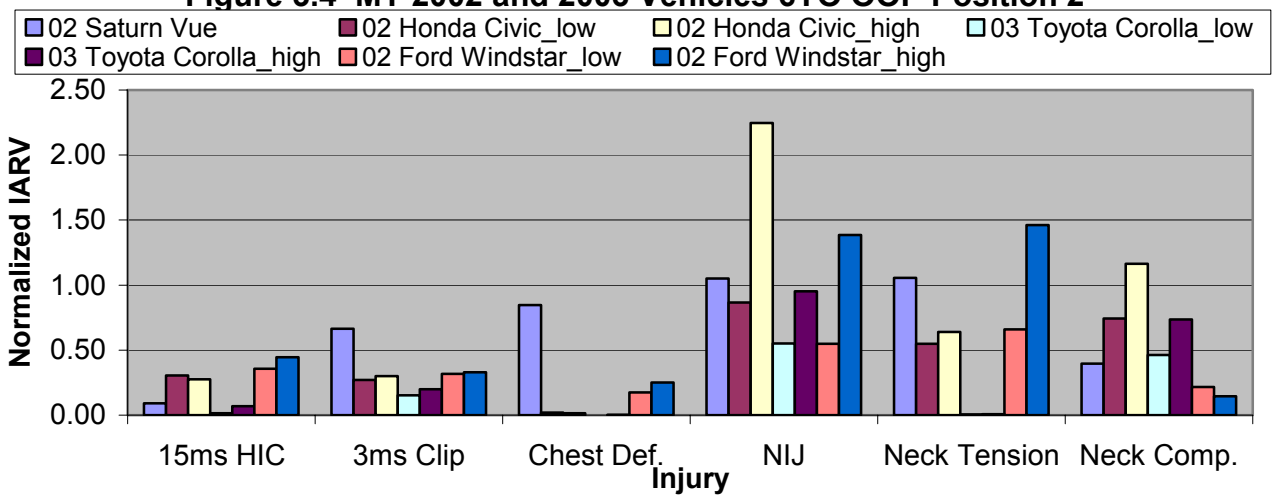


**Figure 3.5 MY2002 and 2003 Vehicles 5th Female Position 1**

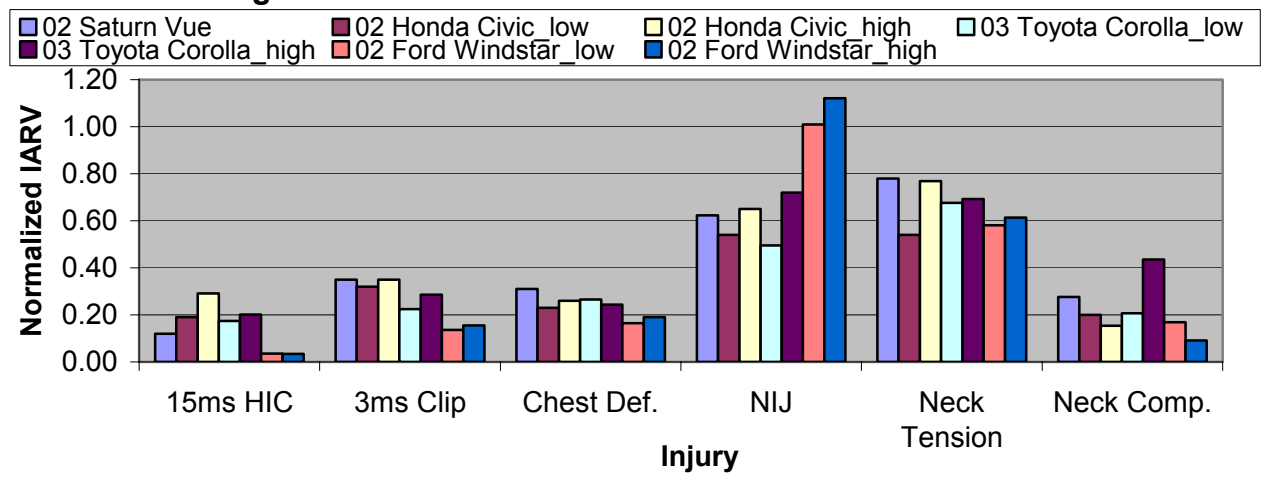

**Figure 3.6 MY 2002 and 2003 Vehicles 5th Female Position 2**

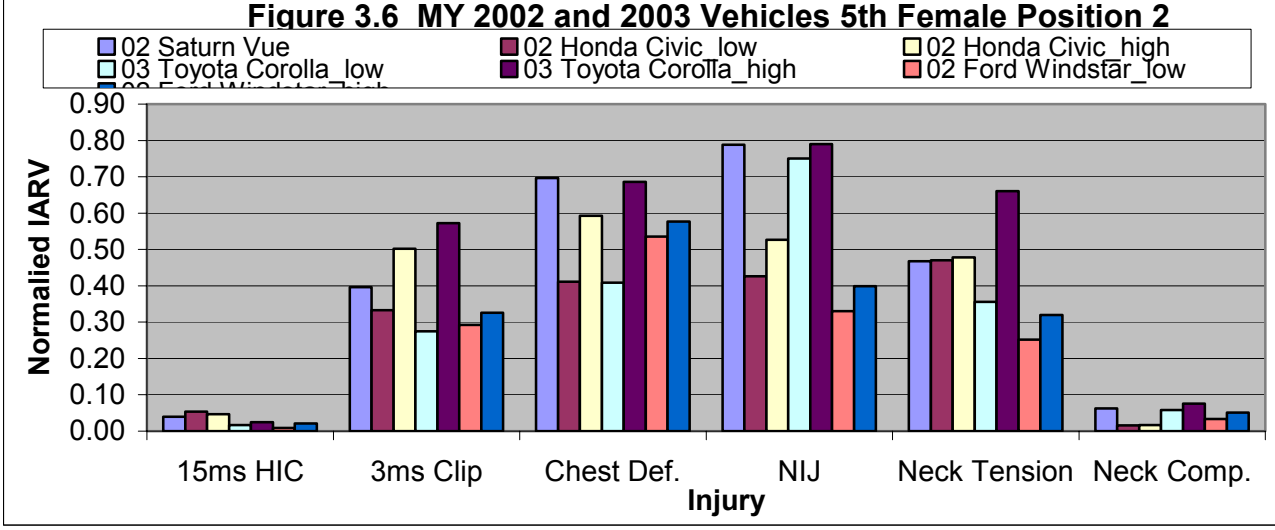


**Figure 3.7 MY 2004 10YO OOP Position 1**

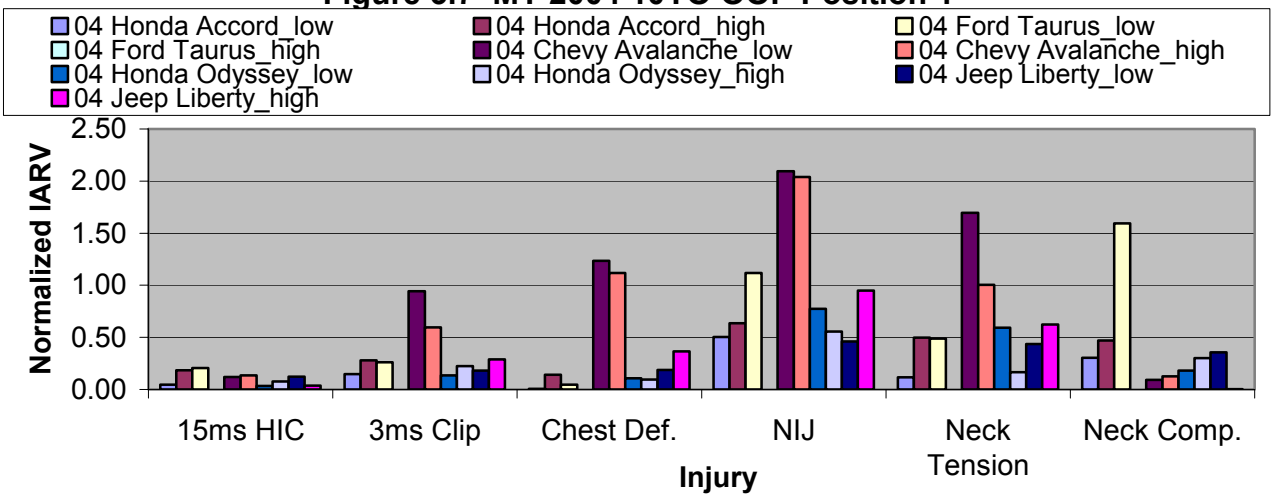


**Figure 3.8 MY 2004 10YO OOP Position 2**

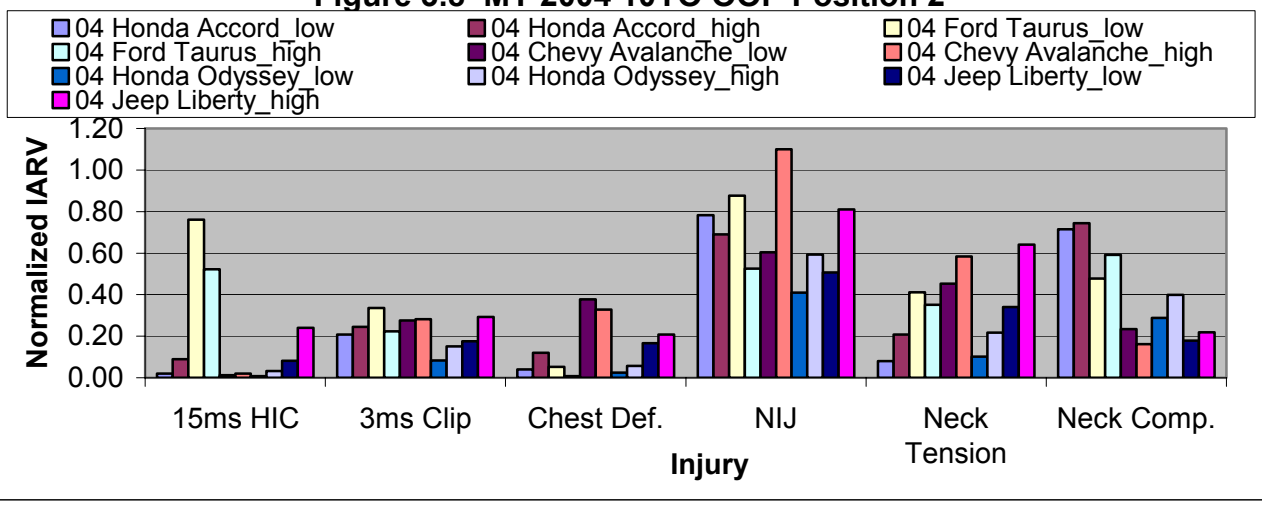

**Table 3.3**
**MY 2002 and 2003 6YO OOP Test Results.**

| Vehicles | Test No. | Position | Air bag Mode | 15ms HIC | 3ms Clip g's | Chest Def. mm | Nij | Neck Tension N | Neck Comp. N |
|---|---|---|---|---|---|---|---|---|---|
| 02 Saturn Vue | B02_002 | 1 | single stage | 32.0 | 32.5 | 33.5 | 2.4 | 1603.2 | 42.6 |
| | B02_001 | 2 | single stage | 63.0 | 39.9 | 33.9 | 1.1 | 1572.0 | 722.4 |
| 02 Honda Civic | B02_004 | 1 | Low Mode | 335.0 | 24.8 | 15.1 | 0.7 | 1272.5 | 192.6 |
| | B02_003 | 2 | Low Mode | 213.0 | 16.3 | 0.8 | 0.9 | 816.4 | 1350.9 |
| | B02_005 | 1 | High Mode | 771.0 | 42.9 | 24.2 | 1.3 | 2020.3 | 152.7 |
| | B02_014 | 2 | High Mode | 193.0 | 18.0 | 0.5 | 2.2 | 952.3 | 2120.1 |
| 03 Toyota Corolla | B02_006 | 1 | Low Mode | 320.0 | 18.8 | 13.2 | 0.4 | 910.0 | 54.3 |
| | B02_007 | 2 | Low Mode | 11.0 | 9.2 | 0.0 | 0.6 | 6.3 | 840.8 |
| | B02_013 | 1 | High Mode | 381.0 | 31.8 | 12.5 | 0.6 | 791.2 | 776.9 |
| | B02_008 | 2 | High Mode | 48.0 | 11.9 | 0.1 | 1.0 | 10.9 | 1337.4 |
| 02 Ford Windstar | B02_011 | 1 | Low Mode | 10.0 | 18.1 | 14.5 | 0.3 | 717.2 | 10.2 |
| | B02_009 | 2 | Low Mode | 249.0 | 19.0 | 7.0 | 0.5 | 987.1 | 395.2 |
| | B02_012 | 1 | High Mode | 62.0 | 17.6 | 16.5 | 1.6 | 1640.8 | 5.5 |
| | B02_010 | 2 | High Mode | 311.0 | 19.7 | 10.0 | 1.4 | 2177.5 | 263.1 |

**Table 3.4**
**MY 2002 and 2003 5th FEMALE OOP Test Results.**

| **Vehicles** | **Test No.** | **Position no.** | **High or Low Mode** | **15ms HIC** | **3ms Clip** | **Chest Def.** | **NIJ** | **+FZ Neck Tension** | **Neck Comp.** |
|---|---|---|---|---|---|---|---|---|---|
| 02 Saturn Vue | C02_002 | 2 | not dual stage | 28.0 | 23.8 | 36.2 | 0.8 | 967.5 | 156.8 |
| | C02_001 | 1 | not dual stage | 83.0 | 20.7 | 16.0 | 0.6 | 1612.7 | 697.1 |
| 02 Honda Civic | C02_004 | 1 | Low Mode | 130.0 | 19.2 | 12.1 | 0.5 | 1122.5 | 502.7 |
| | C02_003 | 2 | Low Mode | 37.3 | 20.0 | 21.4 | 0.4 | 972.9 | 39.7 |
| | C02_005 | 1 | High Mode | 204.0 | 21.0 | 13.5 | 0.7 | 1590.0 | 386.8 |
| | C02_006 | 2 | High Mode | 32.9 | 30.1 | 30.8 | 0.5 | 989.3 | 42.2 |
| 03 Toyota Corolla | C02_021 | 1 | Low Mode | 122.0 | 13.5 | 13.8 | 0.5 | 1400.3 | 522.0 |
| | C02_025 | 2 | Low Mode | 12.0 | 16.5 | 21.2 | 0.8 | 736.6 | 145.4 |
| | C02_022 | 1 | High Mode | 141.0 | 17.2 | 12.6 | 0.7 | 1432.6 | 1095.6 |
| | C02_024 | 2 | High Mode | 17.3 | 34.4 | 35.7 | 0.8 | 1367.5 | 189.8 |
| 02 Ford Windstar | C02_014 | 1 | Low Mode | 25.0 | 8.2 | 8.6 | 1.0 | 1202.1 | 424.0 |
| | C02_015 | 2 | Low Mode | 6.0 | 17.6 | 27.8 | 0.3 | 521.6 | 85.2 |
| | C02_016 | 2 | High Mode | 15.0 | 19.5 | 30.0 | 0.4 | 661.2 | 129.7 |
| | C02_017 | 1 | High Mode | 24.0 | 9.3 | 9.9 | 1.1 | 1271.4 | 229.9 |

**Table 3.5**
**MY 2004 10YO OOP Test Results.**

| Vehicles | Test No. | Position no. | High or Low Mode | 15ms HIC | 3ms Clip | Chest Def. | Nij | +FZ Neck Tension | Neck Comp. |
|---|---|---|---|---|---|---|---|---|---|
| 04 Honda Accord | 10YO_002 | 1 | LOW | 31.4 | 8.9 | 0.2 | 0.5 | 212.0 | 669.1 |
| | 10YO_001 | 2 | LOW | 14.0 | 12.5 | 1.8 | 0.8 | 145.5 | 1572.0 |
| | 10YO_014 | 1 | HIGH | 128.8 | 16.7 | 6.2 | 0.6 | 898.2 | 1030.7 |
| | 10YO_015 | 2 | HIGH | 62.8 | 14.7 | 5.3 | 0.7 | 376.8 | 1637.6 |
| 04 Ford Taurus | 10YO_003 | 1 | LOW | 145.0 | 15.6 | 2.0 | 1.1 | 882.7 | 3505.9 |
| | 10YO_004 | 2 | LOW | 533.0 | 20.2 | 2.3 | 0.9 | 743.9 | 1049.4 |
| | 10YO_005 | 2 | HIGH | 365.7 | 13.4 | 0.4 | 0.5 | 634.4 | 1301.0 |
| 04 Chevy Avalanche | 10YO_008 | 1 | LOW | 83.3 | 56.7 | 54.3 | 2.1 | 3069.4 | 205.2 |
| | 10YO_006 | 2 | LOW | 9.0 | 16.5 | 16.6 | 0.6 | 820.0 | 515.5 |
| | 10YO_009 | 1 | High | 94.0 | 35.7 | 49.2 | 2.0 | 1817.6 | 279.4 |
| | 10YO_007 | 2 | HIGH | 14.0 | 17.0 | 14.5 | 1.1 | 1056.0 | 356.0 |
| 04 Honda Odyssey | 10YO_010 | 1 | LOW | 24.0 | 8.1 | 4.7 | 0.8 | 1074.2 | 396.8 |
| | 10YO_011 | 2 | LOW | 5.0 | 5.0 | 1.1 | 0.4 | 184.1 | 634.9 |
| | 10YO_013 | 1 | High | 54.3 | 13.5 | 4.1 | 0.6 | 300.1 | 661.9 |
| | 10YO_012 | 2 | High | 23.0 | 9.0 | 2.5 | 0.6 | 393.3 | 878.6 |
| 04 Jeep Liberty | 10YO_019 | 1 | LOW | 86.6 | 10.9 | 8.2 | 0.5 | 790.1 | 48.9 |
| | 10YO_016 | 2 | LOW | 56.6 | 10.6 | 7.3 | 0.5 | 615.8 | 393.6 |
| | 10YO_020 | 1 | High | 25.0 | 17.4 | 16.1 | 1.0 | 1129.3 | 4.0 |
| | 10YO_018 | 2 | High | 168.8 | 17.6 | 9.2 | 0.8 | 1159.7 | 482.7 |

### 4.1 Observations

#### 4.1.1 Repeatability

Driver and passenger side tests for the Windstar air bags were done first with the dummy seated on wooden blocks (Figure 4.2). The baseline and repeat tests are shown as the first two columns in Figure 4.6. The tests were subsequently run (for the Windstar and all other tests) with the dummy seated on an adjustable metal seat (Figure 4.1). The baseline and repeat tests under these conditions are shown as the 3rd and 4th columns in Figure 4.6. The results were repeatable, except that the Nij values were different for the two methods of seating. Based on the ease of use, all further tests were conducted with the adjustable metal seat.

Passenger side tests on the Windstar (Figure 4.10) showed the head and chest injury values to be repeatable. The Nij and neck tension values were not similar in all three repeat tests. The results in the Odyssey tests were similar, with very low injury values (Figure 4.14).

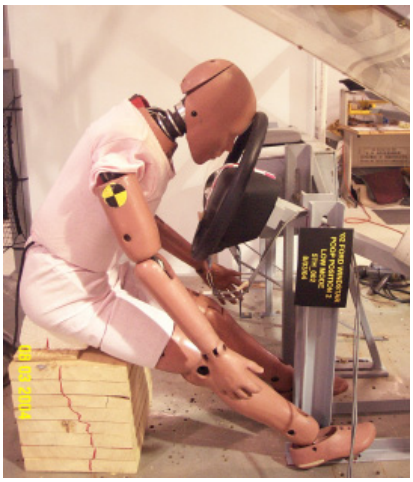

**Figure 4.2 Test using wooden blocks**

#### 4.1.2 Lateral shifts

These tests examine the loads from deploying air bags on an occupant who is shifted laterally compared to the position in FMVSS No. 208. On the driver side, the Windstar tests showed no significant effect of the lateral shifting of the 5th

female dummy. That includes the chest injury and neck injury values (Figure 4.7)
Tests were conducted on the Windstar passenger side with the 6 YO dummy shifted laterally from the baseline position. The results are in Figure 4.11. The head and neck injury values reduced significantly when the dummy was shifted. However, the chest accelerations remained unchanged, with the chest deflection increasing in some of the shifted positions. The chest injury measures were still well below the IARVs.

Two series of lateral shift tests were conducted in the Odyssey. One series was with the dummy in the baseline position (Figure 4.3), shifted left by two and four inches, and right by two inches. These are the left four bars of each cluster in the accompanying Figure 4.15. HIC values and neck tensions were low in all such tests. The chest injury values were very low and unaffected by the shifting. The Nij increased with the dummy shift. The vehicle had a top mounted air bag, with a pocket shaped space that fit the 6 YO head when the dummy was located in the FMVSS No. 208 Position 2 (Figure 4.4). So, a second series of three tests (centered, shifted two inches left and two inches right) was run with the dummy elevated to bring the head/neck closer to the air bag location (Figure 4.4). As expected, the injury values in these tests were higher than the tests with the dummy at the FMVSS No. 208 Position 2 height. However, the injury values dropped significantly when the dummy was shifted laterally at this elevated position.

**Figure 4.3 Baseline Odyssey position.**


**Figure 4.4 2004 Odyssey passenger air bag.**

**Figure 4.5 Elevated Odyssey position.**

### 4.1.3 Longitudinal shifts

These tests examined the effect of increased distance from the air bag on the injury values. On the driver side in the Windstar, the injury numbers reduced with increasing distance from the air bag (Figure 4.8). This effect is especially noticeable for neck injury numbers (Nij reduced from 0.8 to 0.35 by moving the dummy two inches back from the baseline position).

For the passenger side, tests on the Windstar showed lower injury values as the dummy was placed two and four inches from the bag (Figure 4.12). This effect was especially noticeable for the neck injury numbers.

In the Odyssey, the results were counter-intuitive (Figure 4.16). The neck and chest numbers increased with distance from the air bag. This was thought to be because of the design of the air bag, which has a recess for the head of the dummy placed in close proximity to the bag (as in FMVSS No. 208, Position 2). Therefore, the air bag does not directly load the chest of the 6YO dummy when in FMVSS No. 208, Position 2. When the dummy was moved further away, the inflating bag got between the dummy chest and the vehicle instrument panel, directly loading the chest.

### 4.1.4 Vertical shifts

In the Windstar driver side, raising the dummy moved the head/neck away from the bag, while lowering the dummy had the opposite effect. This is reflected in the neck injury numbers (Figure 4.9)

In the Windstar passenger side, moving the dummy up placed the chest closer to the bag, increasing the chest injury numbers (Figure 4.13). Lowering the dummy increased the head injury numbers by bringing the head closer to the air bag.

The 3 tests in this series for the Odyssey were the baseline test, 2" lower than the baseline, and 2" shifted up (as in Figure 4.5) compared the baseline. The Odyssey is a top mounted bag with a pocket for the dummy head when the dummy is at the FMVSS No. 208 position. Thus, the dummy injury values were very low when in the baseline position. Moving the dummy up increased the head and neck loads significantly (Figure 4.17).

## 5.0 CRASH TESTS - INTRODUCTION

The purpose of this testing was to evaluate and compare vehicle and occupant responses in full frontal rigid barrier crash tests conducted using model year 2002, 2003 and 2004 vehicles in support of the FMVSS No. 208 implementation plan. Three matched vehicles were tested and evaluated with the 5th F, 50th M and 95th percentile male (95th M) dummies seated in both the driver and passenger front seating positions. Although the 95th percentile male dummy is not in FMVSS No. 208, it was decided to perform research tests using this dummy to assess the performance of air bags in these vehicles with very heavy occupants. This paper presents results of a series of full frontal crash tests with the unbelted and belted small adult female Hybrid III dummies, unbelted mid-sized male Hybrid III dummies and the belted and unbelted full-sized male Hybrid III dummies. The test matrices for these tests are found in Tables 5.1 and 5.2.

**Table 5.1**
**Test Matrix for 95th M and 50th M.**

| | | Occupant => | 50th Male | 95th Male | |
|---|---|---|---|---|---|
| | | Restraint => | Unbelted | Unbelted | Belted |
| | | Speed => | 48 | 48 | 56 |
| Vehicle | Class | Model Year | | | |
| Saturn Vue | SUV | 2002 | X | X | |
| Honda Civic | Small Pass. Car | 2002 | X | X | |
| Ford Windstar | Minivan | 2002 | X | X | |
| Toyota Corolla | Small Pass. Car | 2003 | X | X | |
| Chevrolet Avalanche | Pickup Truck | 2004 | X | | X |
| Honda Odyssey | Minivan | 2004 | X | | X |
| Honda Accord | Midsize Pass. Car | 2004 | X | | X |
| Toyota Camry | Midsize Pass. Car | 2004 | X | | X |
| Jeep Liberty | SUV | 2004 | X | | X |

**Table 5.2**
**Test Matrix for 5th F.**

| | | Occupant => | 5th Female | |
|---|---|---|---|---|
| | | Restraint => | Unbelted | Belted |
| | | Speed => | 40 | 56 |
| Vehicle | Class | Model Year | | |
| Saturn Vue | SUV | 2002 | X | |
| Honda Civic | Small Pass. Car | 2002 | X | |
| Ford Windstar | Minivan | 2002 | X | |
| Toyota Corolla | Small Pass. Car | 2003 | X | |
| Chevrolet Avalanche | Pickup Truck | 2004 | | X |
| Honda Odyssey | Minivan | 2004 | | X |
| Honda Accord | Midsize Pass. Car | 2004 | | X |
| Ford Taurus | Midsize Pass. Car | 2004 | | X |
| Jeep Liberty | SUV | 2004 | | X |

**Table 4.1**
**Parametric OOP Test Matrix.**

| | 5th Female Driver, Position 1 (Head on bag) | | | | | | | 6 YO Passenger, Position 2 (Head on bag) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Baseline | Lateral Shift | | Longitudinal Shift | | Vertical Shift | | Baseline | Lateral Shift | | Longitudinal Shift | | Vertical Shift | |
| | | Left | Right | Front | Rear | Up | Down | | Left | Right | Front | Rear | Up | Down |
| 2002 Ford Windstar | 4 tests | 2” | 2” | 2” | 2” | 2” | 2” | 3 tests | 2”, 4” | 2”, 4” | | 2”, 4” | 3.3” | 3.3” |
| 2002 Honda Civic | In Progress | | | | | | | In Progress | | | | | | |
| 2003 Honda Odyssey | Not planned | | | | | | | 2 tests | 2”, 4”<br>2”+up | 2”<br>2”+up | | 2”, 4” | 2” | 2” |

**Table 4.2**
**Ford Windstar Passenger Side.**

| **Vehicle:** 02 Ford Windstar<br>**Dummy**: 6 YO<br>**LRD Position**: 2<br>**Bag Mode**: Low (100 ms delay) | **Test Number.** | **Injury values normalized to IARV** | | | | | |
|---|---|---|---|---|---|---|---|
| | | **15ms HIC** | **3ms Clip** | **Chest Def.** | **Nij** | **Neck Tension** | **Neck Comp.** |
| Baseline | 2 | 0.8 | 0.5 | 0.3 | 1.1 | 1.5 | 0.1 |
| Repeat | 3 | 0.5 | 0.6 | 0.3 | 1.6 | 2.5 | 0.0 |
| Repeat | 4 | 0.6 | 0.5 | 0.4 | 1.5 | 2.1 | 0.1 |
| 2" rear | 5 | 0.5 | 0.4 | 0.3 | 0.7 | 0.8 | 0.1 |
| 4" left | 6 | 0.3 | 0.5 | 0.4 | 0.9 | 1.0 | 0.0 |
| 3.3” up | 7 | 0.1 | 0.8 | 0.7 | 0.8 | 1.4 | 0.0 |
| 4" right | 8 | 0.2 | 0.4 | 0.1 | 0.6 | 0.7 | 0.0 |
| 2" right | 9 | 0.3 | 0.5 | 0.5 | 0.9 | 1.2 | 0.1 |
| 2" left | 10 | 0.4 | 0.6 | 0.5 | 1.0 | 1.3 | 0.0 |
| 3.3” down | 11 | 1.2 | 0.3 | 0.1 | 0.9 | 0.8 | 0.4 |
| 4" rear | 12 | 0.6 | 0.3 | 0.3 | 0.4 | 0.5 | 0.1 |

**Table 4.3**
**Ford Windstar Driver Side.**

| **Dummy**: 5th F<br>**LRD Position**: 1<br>**Bag Mode**: High (15 ms delay) | **Test Number** | **Injury values normalized to IARV** | | | | | |
|---|---|---|---|---|---|---|---|
| | | **15ms HIC** | **3ms Clip** | **Chest Def.** | **NIJ** | **Neck Tension** | **Neck Comp.** |
| Baseline on wooden blocks | 1 | 0.01 | 0.14 | 0.14 | 0.5 | 0.39 | 0.01 |
| Repeat on wooden blocks | 2 | 0.01 | 0.12 | 0.13 | 0.5 | 0.40 | 0.00 |
| Baseline on metal seat | 4 | 0.01 | 0.08 | 0.13 | 0.8 | 0.41 | 0.13 |
| Repeat on metal seat | 6 | 0.01 | 0.10 | 0.14 | 0.7 | 0.42 | 0.14 |
| 2 inches rear | 7 | 0.02 | 0.16 | 0.11 | 0.4 | 0.20 | 0.01 |
| 2 inches forward | 8 | 0.03 | 0.17 | 0.26 | 0.9 | 0.50 | 0.02 |
| 2 inches up | 9 | 0.01 | 0.09 | 0.15 | 0.6 | 0.34 | 0.06 |
| 2 inches down | 10 | 0.04 | 0.19 | 0.19 | 0.9 | 0.61 | 0.06 |
| 2 inches right | 11 | 0.02 | 0.12 | 0.17 | 0.7 | 0.42 | 0.06 |
| 2 inches left | 12 | 0.01 | 0.13 | 0.12 | 0.7 | 0.42 | 0.04 |

**Table 4.4**
**Honda Odyssey Passenger Side.**

| **Dummy**: 6YO<br>**LRD Position**: 2<br>**Bag Mode**: Low (130 ms delay) | **Test Number** | **Injury values normalized to IARV** | | | | | |
|---|---|---|---|---|---|---|---|
| | | **15ms HIC** | **3ms Clip** | **Chest Def.** | **NIJ** | **Neck Tension** | **Neck Comp.** |
| Baseline | 13 | 0.01 | 0.12 | 0.06 | 0.3 | 0.03 | 0.41 |
| Repeat | 14 | 0.01 | 0.12 | 0.01 | 0.3 | 0.07 | 0.44 |
| 2" left | 15 | 0.00 | 0.09 | 0.03 | 0.5 | 0.07 | 0.23 |
| 4" left | 17 | 0.00 | 0.09 | 0.01 | 0.5 | 0.01 | 0.29 |
| 2" right | 18 | 0.00 | 0.10 | 0.02 | 0.3 | 0.04 | 0.23 |
| 2" rear | 19 | 0.06 | 0.08 | 0.02 | 0.3 | 0.12 | 0.23 |
| 4" rear | 20 | 0.01 | 0.12 | 0.56 | 0.3 | 0.16 | 0.40 |
| Top of head at A/B Center (Baseline+ 4” up) | 21 | 0.80 | 0.27 | 0.35 | 1.1 | 1.01 | 0.04 |
| Top of head at ab/center + 2" left | 22 | No data | 0.15 | 0.13 | 0.6 | 0.47 | 0.05 |
| Top of head at ab/center + 2" right | 23 | 0.38 | 0.22 | 0.17 | 0.6 | 0.81 | 0.07 |
| Baseline + 2” down | 24 | 0.00 | 0.08 | 0.40 | 0.3 | 0.04 | 0.31 |

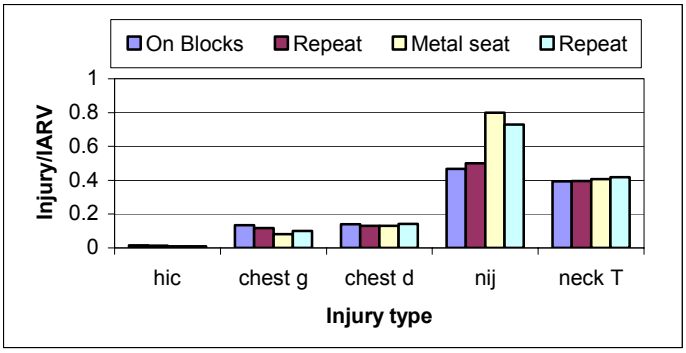


**Figure 4.6 Windstar Driver 5th F repeatability.**

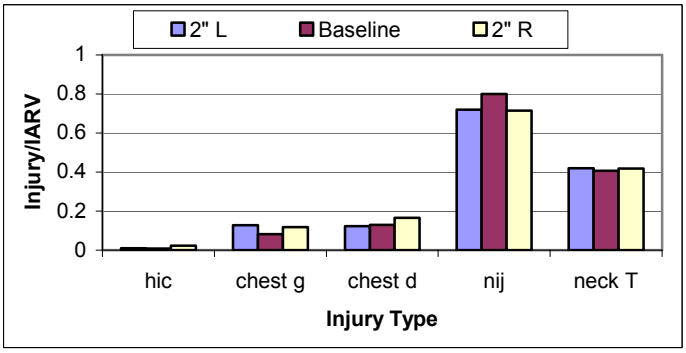


**Figure 4.7 Windstar Driver 5th F lateral shift.**

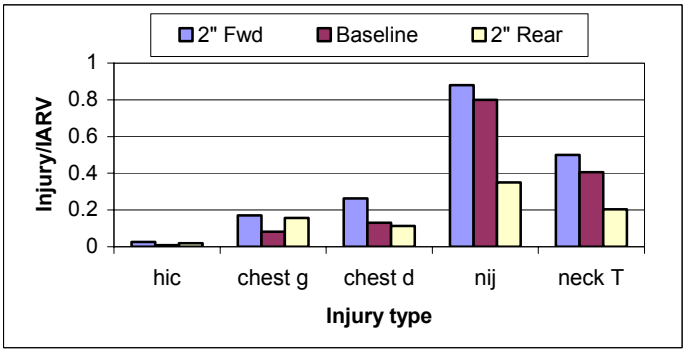


**Figure 4.8 Windstar Driver 5th F longitudinal shift.**

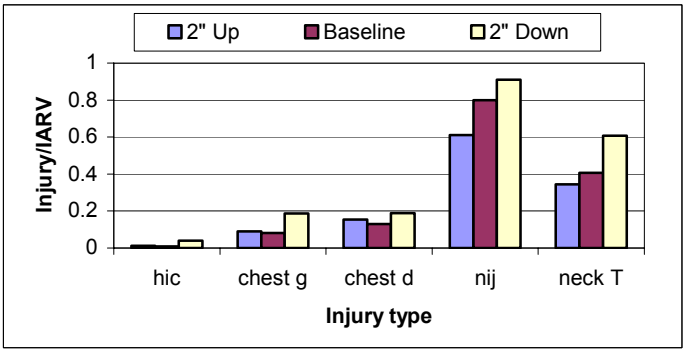


**Figure 4.9 Windstar Driver 5th F vertical shift.**

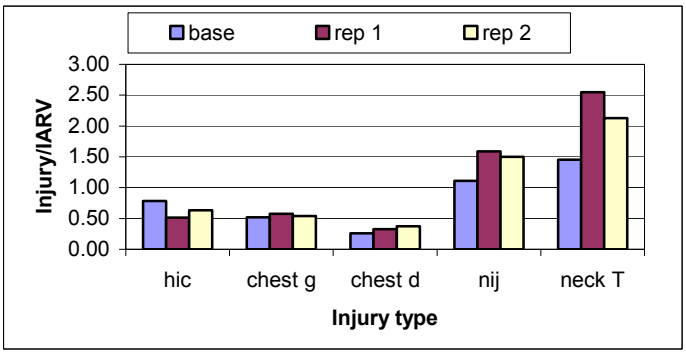


**Figure 4.10 Windstar Passenger 6YO repeatability.**

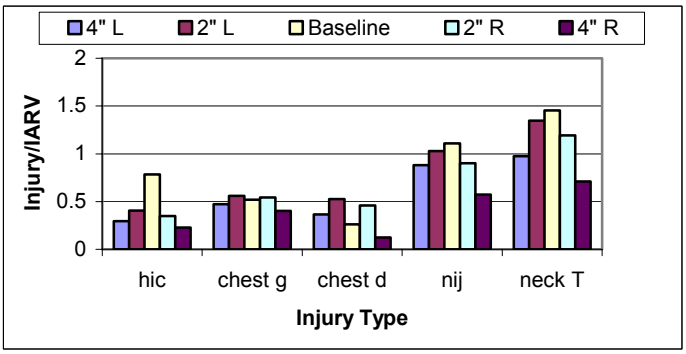


**Figure 4.11 Windstar Passenger 6YO lateral shift.**

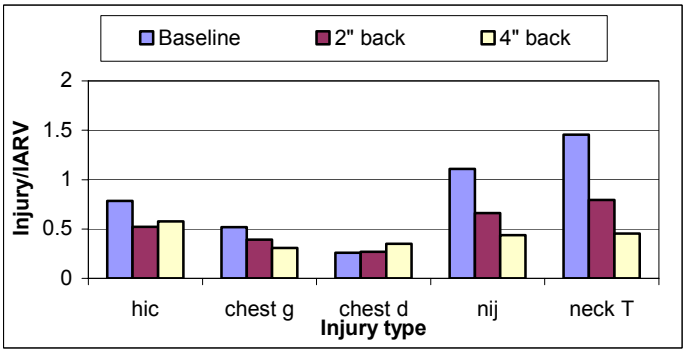


**Figure 4.12 Windstar Passenger 6YO longitudinal shift.**

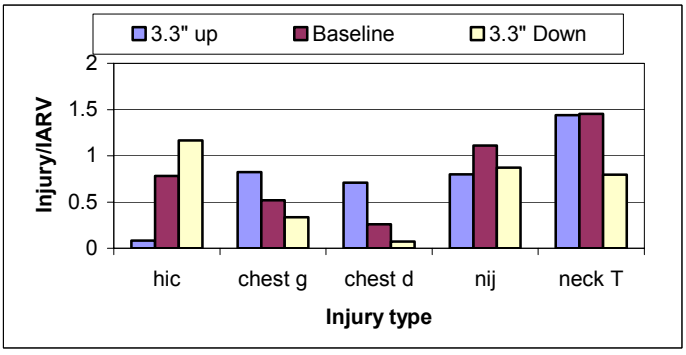


**Figure 4.13 Windstar Passenger 6YO vertical shift.**

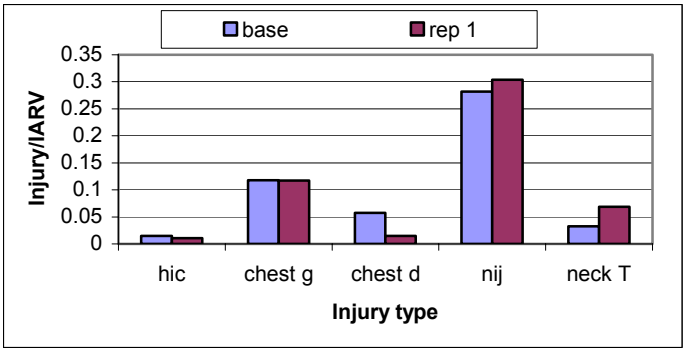


**Figure 4.14 Odyssey Passenger 6YO repeatability.**

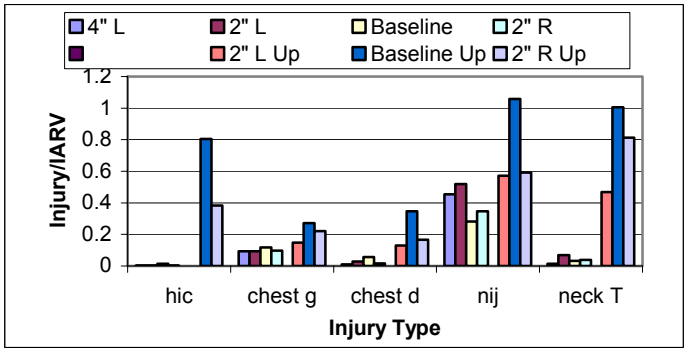


**Figure 4.15 Odyssey Passenger 6YO lateral shift.**

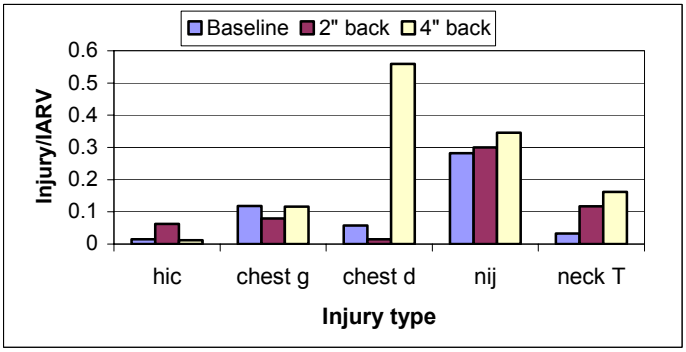


**Figure 4.16 Odyssey Passenger 6YO longitudinal shift.**

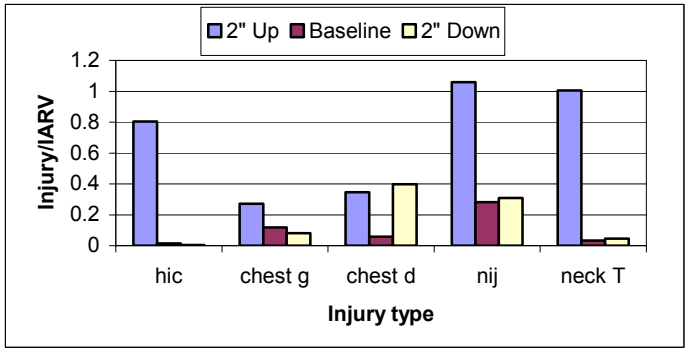


**Figure 4.17 Odyssey Passenger 6YO vertical shift.**

### 5.1 Methods

Thirty-six vehicles were purchased from dealer lots close to the test facilities. Vehicles with advanced air bag technology such as dual or multi-stage inflators were specifically considered for this test program. The Saturn Vue was the only single stage air-bag inflator that was tested. The Saturn Vue was chosen due to it being a new production vehicle for the model year tested. Vehicle body type and vehicle sales volume were considered when constructing the final test matrix. The vehicles were tested in accordance with procedures outlined in FMVSS No. 208 Sections 14, 15 and 17, except that the combination of dummy size, seat belt use, and test speed was varied for these research tests. Pre-test measurements quantified distance between various occupant body parts to vehicle interior components (i.e. chest-to-steering wheel). The vehicles were placed on a test track and accelerated to the prescribed test speed. The test vehicles struck a rigid barrier with the long axis of the vehicle perpendicular to the barrier face. The barrier engaged the entire front of the vehicle (no offset). Test speeds were either 48 or 56 kmph with a 50th M dummy and a 95th M Hybrid III dummy. The 56 kmph tests were performed only on the belted 95th dummy. The test speeds were 40 or 56 kmph for the 5th percentile female Hybrid III dummy. The 40 kmph were unbelted tests and the 56 kmph were belted tests for the 5th percentile female.

The IARVs for in-position occupants can be found in Table 5.3. The tests with the 50th M and the 5th F chest, head, neck and femur were evaluated using the IARVs for the FMVSS No. 208 advanced air bag rule. The 95th M chest, head, neck and femur were evaluated using IARV's developed by NHTSA's Office of Biomechanics Research Center.

**Table 5.3**
**Injury Assessment Reference Values.**

| | | IARV | | |
|---|---|---|---|---|
| Injury Criteria | Units | 5th Female | 50th Male | 95th Male |
| HIC 15 | - | 700 | 700 | 700 |
| $N_{ij}$ | - | 1 | 1 | 1 |
| Neck Tension | Newtons | 2620 | 4170 | 5030 |
| Neck Compression | Newtons | 2520 | 4000 | 4830 |
| Chest Acceleration | g | 60 | 60 | 55 |
| Chest Deflection | Millimeters | 52 | 63 | 70 |
| Femur Force | Newtons | 6805 | 10008 | 12700 |

Transfer paint was applied to parts of the dummy and vehicle interior, leaving witness marks from which occupant contacts could be evaluated post-crash. Fifteen or more high-speed cameras documented vehicle and occupant kinematics during the event.

### 5.2 Results for 50th and 95th Male

The HIC15 responses were all below the thresholds for injury with exception of two tests (see Appendix A, Tables A1 & A2). For the 50th M all drivers and passengers were below the threshold for injury. For the 95th percentile male, the passenger in the unbelted 48 kmph Saturn Vue test and the driver in the belted 56 kmph Chevrolet Avalanche test exceeded the injury criteria.

The $N_{ij}$ responses were all below the thresholds for injury with exception of two tests. For the 50th M all driver and passenger injury measures were below the threshold for injury. For the 95th M, the passenger dummy in the unbelted 48 kmph Saturn Vue test and the driver dummy in the unbelted 48 kmph Toyota Corolla test exceeded the injury criteria

Both the 50th M and 95th M were below the injury threshold for neck tension and neck compression in all tests.

For chest acceleration all dummy measures were below the injury threshold except in three tests. The 50th M exceeded the injury limit in one test and the 95th percentile male exceeded the injury limit in two separate tests. The 50th M passenger in the 48 kmph unbelted Jeep Liberty test exceeded the chest acceleration injury criteria (See Figure 5.1). Both the 95th M driver and passenger in the 48 kmph unbelted Saturn Vue test exceeded the chest acceleration injury criteria. The 95th percentile driver in the 56 kmph belted Chevrolet Avalanche test exceeded the chest acceleration injury criteria (See Figure 5.2).

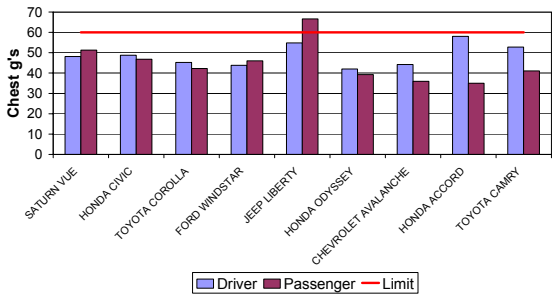


**Figure 5.1 50th Percentile Male - Chest g's.**

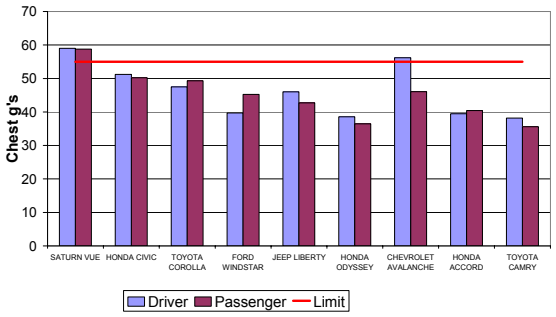


**Figure 5.2 95th Percentile Male – Chest g's.**

For chest displacement all occupants were below the injury threshold except in one test. The 50th M driver in the 48 kmph unbelted Honda Civic test exceeded the chest displacement injury criteria

All 50th M and 95th M driver and passenger responses in each test were below the injury threshold for femur load.

### 5.3 Results for 5th Female

The HIC15 responses were all below the thresholds for injury (see Appendix A, Tables A1 & A2

The $N_{ij}$ responses were all below the thresholds for injury with exception of two tests. For the unbelted 40 kmph tests the passenger in the Toyota Corolla test exceeded the injury criteria (See Figure 5.3). For the 56 kmph belted tests the passenger in the Chevrolet Avalanche test exceeded the injury criteria (See Figure 5.4).

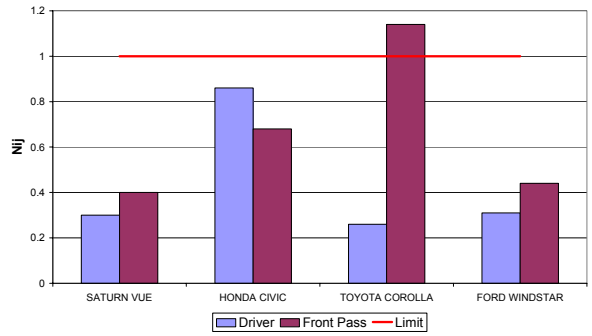


**Figure 5.3. Unbelted 5th Percentile Female – $N_{ij}$.**

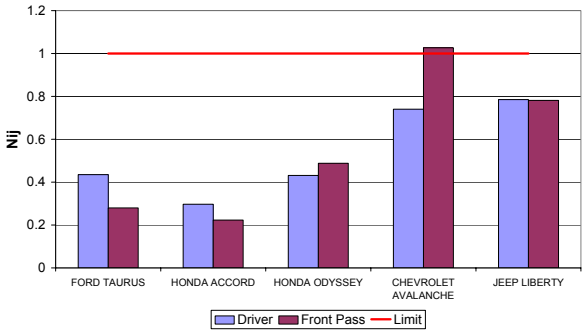


**Figure 5.4 Belted 5th Percentile Female – $N_{ij}$.**

The 5th percentile female dummy was below the injury threshold for neck tension and neck compression in both the unbelted 40 kmph tests and the belted 56 kmph tests.

For chest acceleration all dummy measures were below the injury threshold in all unbelted 40 kmph tests and all belted 56 kmph tests.

For chest displacement all 5th percentile dummy drivers and passengers were below the injury threshold except in one test. The driver in the 40 kmph unbelted Honda Civic test exceeded the chest displacement injury criteria (See Figures 5.5).

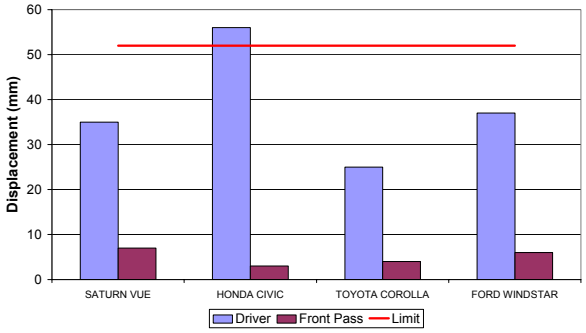


**Figure 5.5 Unbelted 5th Percentile Female – Chest Displacement.**

All 5th percentile female drivers and passengers responses for both the 40 kmph tests and the 56 kmph tests were below the injury threshold for femur load.

### 5.4 Observations

The restraint systems in these crash tests did a good job of mitigating head injury for the 5th female and the 50th M; however, it is not surprising that the air bag alone was not sufficient to mitigate head injury in the 95th male unbelted tests. Even with the aid of being belted along with an air bag, the 95th M exceeded the IARV for the head in one 56 kmph test.

The 5th female exceeded $N_{ij}$ injury criteria in an unbelted 40 kmph and a belted 56 kmph test.

Figure 5.6 shows the 50th M driver during the crash event for the Honda Civic test #4613. It appears that the bag was high, which may account for the abdomen contact with the steering wheel. This contact can be seen in Figure 5.7. This could be the reason that the Civic in this test exceeded chest displacement.


**Figure 5.6 Test #4613 - 50th Male Driver in Honda Civic.**

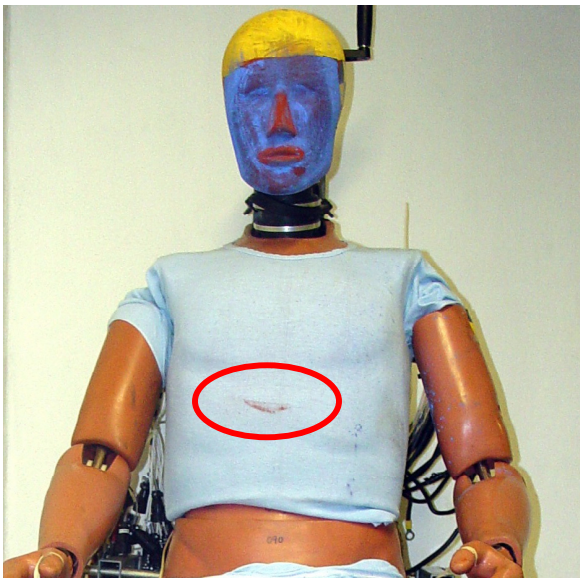

**Figure 5.7 50th Driver Post Crash Abdomen Contact Photo From Test #4613.**

Figure 5.8 shows the 95th male driver during the crash event for the Toyota Corolla test #4577. The 95th M dummy exceeded $N_{ij}$ in this test. Figures 5.8 shows how either the bag or head contact with the header pushed the head backwards. The driver head contact can be seen in Figure 5.9. These could be the reason for failing $N_{ij}$ criteria for this test.

**Figure 5.8 Test #4577 95th Driver in Toyota Corolla.**

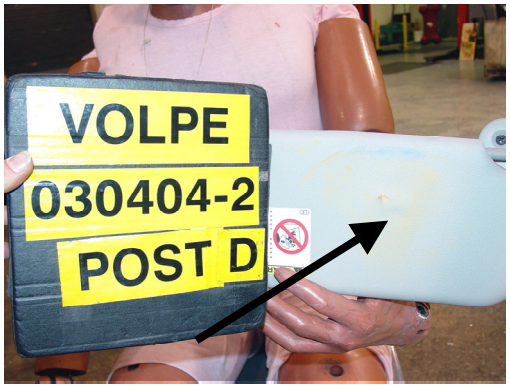


**Figure 5.9 95th Driver Post Crash Head Contact Photo From Test #4577.**

Figure 5.10 shows the 95th male driver in the Saturn Vue test #4702., in which the dummy exceeded chest acceleration criterion. After film analysis, it is believed that the 95th male driver rode through the air bag during this test. Figure 5.10 shows the dummy in its full forward position. Figure 5.11 shows how the bag did not restrain the dummy and allowed head contact with the windshield.


**Figure 5.10 95th Driver Saturn VueTest #4702.**


**Figure 5.11 Post Test 95th Driver Head Contact in Saturn Vue Test #4702.**

Figure 5.12 shows the 95th male passenger in the unbelted Saturn Vue test #4714, in which the dummy exceeded chest acceleration, HIC and $N_{ij}$ criteria. After film analysis, and as seen in Figures 5.12 and 5.13, the 95th male passenger contacted the header, thus restricting the head from moving forward with the torso, causing excessive neck extension.

**Figure 5.12 95th Passenger Saturn Vue Test #4714.**


**Figure 5.13 Post Test 95th Passenger Head Contact in Saturn Vue Test # 4702.**

## 6.0 SUMMARY

Research into performance of air bags is ongoing at NHTSA. Data from this research has been presented in the past [1][3][4]. This paper provides an update on the status of that effort, specifically, tests using dummies of different sizes not currently in FMVSS No. 208 (10YO, 95th M) and at test conditions not currently in the standard. Limited numbers of tests were conducted at OOP locations near those in FMVSS No. 208. Any additional research will be reported in future publications of technical reports or conference papers.

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2. Beuse, N. et al, "Performance of the 5th Percentile Dummy In a 56 KMPH (35 MPH) Frontal Barrier Crash", NHTSA Docket 2001-10687-12

3. Maltese, M. et al, "Vehicle Performance In Full-Frontal Crash Tests with Small Female And Mid-Sized male Occupants", Paper # 414, 18th ESV.

4. Prasad et al, "Injury Risks From Advanced Air Bags In Frontal Static Out-Of-Position Tests", Paper # 427, 18th ESV.

5. Stammen, Jason, "Hybrid III 10 Year Old Dummy (HIII-10C) Injury Criteria Development", NHTSA report in progress

.

## APPENDIX A, Table A1 – Crash Test Results – Driver

| Dummy and Vehicle Information | | | | | Injury Criteria | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Make | Model | Year | Test # | HIC 15 | Nij ver. 10 | Neck Tension (N) | Neck Comp (N) | Chest g's | Chest Disp (mm) | Max Femur (N) |
| | | | | **IARV 5th** | **700** | **1.00** | **2620** | **2520** | **60** | **52** | **6800** |
| **5th Female Unbelted 40 kmph** | SATURN | VUE | 2002 | 4579 | 55.0 | 0.3 | 654.0 | 341.0 | 31.0 | 35.0 | 4200.0 |
| | HONDA | CIVIC | 2002 | 4830 | 108.0 | 0.9 | 1555.0 | 360.0 | 39.4 | 56.0 | 2931.0 |
| | TOYOTA | COROLLA | 2002 | 4829 | 93.0 | 0.3 | 772.0 | 56.0 | 36.7 | 25.0 | 2282.0 |
| | FORD | WINDSTAR | 2002 | 4828 | 95.0 | 0.3 | 579.0 | 78.0 | 37.9 | 37.0 | 2405.0 |
| | | | | | | | | | | | |
| **5th Female Belted 56 kmph** | FORD | TAURUS | 2004 | 5143 | 152.2 | 0.4 | 1433.8 | 286.3 | 37.5 | 29.1 | 1135.1 |
| | HONDA | ACCORD | 2004 | 5145 | 279.9 | 0.3 | 914.9 | 161.3 | 32.1 | 26.0 | 4605.2 |
| | HONDA | ODYSSEY | 2004 | 5144 | 56.8 | 0.4 | 917.6 | 141.5 | 32.4 | 24.4 | 5522.4 |
| | CHEVROLET | AVALANCHE | 2004 | 5210 | 579.5 | 0.7 | 1727.7 | 555.0 | 58.6 | 44.4 | 1820.0 |
| | JEEP | LIBERTY | 2004 | 5211 | 232.4 | 0.8 | 1755.3 | 721.2 | 44.8 | 31.1 | 3073.4 |
| | | | | | | | | | | | |
| | | | | **IARV 50th** | **700** | **1.00** | **4170** | **4000** | **60** | **63** | **10008** |
| **50th Male Unbelted 48 kmph** | SATURN | VUE | 2002 | 4714 | 86.8 | 0.3 | 1230.5 | 397.6 | 48.1 | 54.4 | 7103.5 |
| | HONDA | CIVIC | 2002 | 4613 | 92.1 | 0.3 | 1297.7 | 146.6 | 48.8 | 65.0 | 6835.3 |
| | TOYOTA | COROLLA | 2003 | 4578 | 216.9 | 0.3 | 753.7 | 255.6 | 45.2 | 32.4 | 4569.6 |
| | FORD | WINDSTAR | 2002 | 4556 | 99.8 | 0.2 | 1589.4 | 117.7 | 43.8 | 36.3 | 5422.7 |
| | JEEP | LIBERTY | 2004 | 5158 | 306.7 | 0.3 | 604.5 | 1201.6 | 54.8 | 41.6 | 7662.0 |
| | HONDA | ODYSSEY | 2004 | 5212 | 57.7 | 0.3 | 1371.7 | 94.7 | 42.0 | 48.2 | 7547.4 |
| | CHEVROLET | AVALANCHE | 2004 | 5213 | 193.3 | 0.3 | 1599.2 | 1489.1 | 44.2 | 47.5 | 6459.4 |
| | HONDA | ACCORD | 2004 | 5215 | 293.6 | 0.3 | 1383.2 | 71.3 | 58.1 | 54.5 | 5376.5 |
| | TOYOTA | CAMRY | 2004 | 5216 | 116.5 | 0.3 | 1650.1 | 200.7 | 52.8 | 33.1 | 6588.9 |
| | | | | | | | | | | | |
| | | | | **IARV 95th** | **700** | **1.00** | **5030** | **4830** | **55** | **70** | **12700** |
| **95th Male Unbelted 48 kmph** | SATURN | VUE | 2002 | 4702 | 279.0 | 0.3 | 2044.0 | 333.9 | 59.0 | 56.8 | 7035.4 |
| | HONDA | CIVIC | 2002 | 4659 | 180.5 | 0.3 | 1924.2 | 654.7 | 51.3 | 61.6 | 9259.6 |
| | TOYOTA | COROLLA | 2003 | 4577 | 562.8 | 1.0 | 1167.3 | 3940.5 | 47.5 | 25.5 | 7127.9 |
| | FORD | WINDSTAR | 2002 | 4568 | 213.9 | 0.3 | 1175.2 | 2202.8 | 39.7 | 45.2 | 5756.4 |
| | | | | | | | | | | | |
| **95th Male Belted 56kph** | HONDA | ODYSSEY | 2004 | 5136 | 186.7 | 0.2 | 1176.5 | 63.6 | 38.6 | 27.3 | 3196.4 |
| | JEEP | LIBERTY | 2004 | 5137 | 575.2 | 0.3 | 2087.7 | 349.5 | 46.0 | 32.5 | 4631.8 |
| | TOYOTA | CAMRY | 2004 | 5138 | 381.7 | 0.5 | 1075.7 | 260.6 | 38.2 | 29.3 | 6041.9 |
| | HONDA | ACCORD | 2004 | 5139 | 589.0 | 0.2 | 1087.4 | 591.1 | 39.5 | 36.1 | 3118.6 |
| | CHEVROLET | AVALANCHE | 2004 | 5140 | 802.8 | 0.5 | 2960.5 | 772.2 | 56.2 | 24.4 | 8455.7 |

Note: Green shaded cells represent injury value between 0-80% of IARV
Yellow shaded cells represent injury value between 80-100% of IARV inclusive
Red shaded cells represent injury value greater than 100% of IARV

## APPENDIX A, Table A2 – Crash Test Results – Passenger

| Dummy and Vehicle Information | | | | | Injury Criteria | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Make | Model | Year | Test # | HIC 15 | Nij ver. 10 | Neck Tension (N) | Neck Comp (N) | Chest g's | Chest Disp (mm) | Max Femur (N) |
| | | | | **IARV 5th** | **700** | **1.00** | **2620** | **2520** | **60** | **52** | **6800** |
| **5th Female Unbelted 40 kmph** | SATURN | VUE | 2002 | 4579 | 96.0 | 0.4 | 560.0 | 1048.0 | 28.0 | 7.0 | 4040.0 |
| | HONDA | CIVIC | 2002 | 4830 | 98.0 | 0.7 | 393.0 | 1030.0 | 33.7 | 3.0 | 5481.0 |
| | TOYOTA | COROLLA | 2002 | 4829 | 175.0 | 1.1 | 2339.0 | 263.0 | 36.8 | 4.0 | 2736.0 |
| | FORD | WINDSTAR | 2002 | 4828 | 360.0 | 0.4 | 838.0 | 901.0 | 38.8 | 6.0 | 4004.0 |
| **5th Female Belted 56 kmph** | FORD | TAURUS | 2004 | 5143 | 289.9 | 0.3 | 409.7 | 271.7 | 42.0 | 19.1 | 1597.6 |
| | HONDA | ACCORD | 2004 | 5145 | 181.5 | 0.2 | 738.0 | 295.7 | 38.3 | 28.8 | 3773.8 |
| | HONDA | ODYSSEY | 2004 | 5144 | 233.2 | 0.5 | 918.9 | 131.3 | 38.1 | 14.5 | 4207.8 |
| | CHEVROLET | AVALANCHE | 2004 | 5210 | 483.9 | 1.0 | 1770.2 | 230.5 | 53.6 | 14.9 | 3360.0 |
| | JEEP | LIBERTY | 2004 | 5211 | 527.1 | 0.8 | 1369.4 | 823.3 | 42.8 | 24.2 | 3586.3 |
| | | | | **IARV 50th** | **700** | **1.00** | **4170** | **4000** | **60** | **63** | **10008** |
| **50th Unbelted 48 kmph** | SATURN | VUE | 2002 | 4702 | 319.4 | 0.38 | 1779.0 | 359.5 | 51.3 | 12.5 | 7014.4 |
| | HONDA | CIVIC | 2002 | 4659 | 196.3 | 0.52 | 544.4 | 1765.2 | 46.8 | 15.6 | 6466.9 |
| | TOYOTA | COROLLA | 2003 | 4577 | 230.1 | 0.35 | 788.2 | 1185.5 | 42.2 | 14.3 | 5301.6 |
| | FORD | WINDSTAR | 2002 | 4568 | 473.6 | 0.57 | 1312.5 | 2934.2 | 46.1 | 14.7 | 5303.8 |
| | JEEP | LIBERTY | 2004 | 5158 | 523.2 | 0.58 | 1342.5 | 830.3 | 66.6 | 12.0 | 8065.1 |
| | HONDA | ODYSSEY | 2004 | 5212 | 160.6 | 0.29 | 415.9 | 976.5 | 39.3 | 9.8 | 5377.0 |
| | CHEVROLET | AVALANCHE | 2004 | 5213 | 124.3 | 0.36 | 1632.3 | 233.6 | 35.9 | 9.0 | 6689.6 |
| | HONDA | ACCORD | 2004 | 5215 | 97.4 | 0.27 | 615.4 | 577.4 | 35.0 | 11.4 | 6864.4 |
| | TOYOTA | CAMRY | 2004 | 5216 | 138.1 | 0.36 | 559.5 | 692.7 | 41.1 | 14.7 | 5084.3 |
| | | | | **IARV 95th** | **700** | **1.00** | **5030** | **4830** | **55** | **70** | **12700** |
| **95th Unbelted 48 kmph** | SATURN | VUE | 2002 | 4714 | 853.7 | 1.1 | 1835.7 | 2656.4 | 58.8 | 18.6 | 10025.5 |
| | HONDA | CIVIC | 2002 | 4613 | 222.4 | 0.6 | 2533.0 | 1634.2 | 50.2 | ND | 11500.5 |
| | TOYOTA | COROLLA | 2003 | 4578 | 668.2 | 0.4 | 732.6 | 2554.5 | 49.3 | 11.0 | 8900.2 |
| | FORD | WINDSTAR | 2002 | 4556 | 349.3 | 0.2 | 1118.9 | 814.6 | 45.3 | 22.8 | 7719.0 |
| **95th Belted 56kph** | HONDA | ODYSSEY | 2004 | 5136 | 222.1 | ND | 1071.5 | 718.6 | 36.5 | 26.2 | 5316.6 |
| | JEEP | LIBERTY | 2004 | 5137 | 513.1 | 0.4 | 1906.1 | 161.2 | 42.7 | 28.1 | 6888.3 |
| | TOYOTA | CAMRY | 2004 | 5138 | 242.3 | 0.2 | 1191.4 | 186.5 | 35.6 | 27.0 | 1596.3 |
| | HONDA | ACCORD | 2004 | 5139 | 272.0 | 0.2 | 771.0 | 213.4 | 40.4 | 38.9 | 3683.4 |
| | CHEVROLET | AVALANCHE | 2004 | 5140 | 587.2 | 0.4 | 2189.0 | 252.7 | 46.1 | 34.5 | 5792.1 |

Note: Green shaded cells represent injury value between 0-80% of IARV
Yellow shaded cells represent injury value between 80-100% of IARV inclusive
Red shaded cells represent injury value greater than 100% of IARV