

## THE NEWLY ENHANCED U.S. NCAP: A FIRST LOOK AT MODEL YEAR 2011 RATINGS

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### ABSTRACT

In 2008, the National Highway Traffic Safety Administration (NHTSA) published a notice detailing changes to its New Car Assessment Program (NCAP), a consumer information program that tests and rates vehicles for safety using an easily recognizable 5-star rating system. In recent years, more vehicles were achieving 4- and 5-stars, which led the agency to recognize the need for a tougher rating system that, in keeping with the program's goal, would encourage continuous advancement of vehicle safety through market forces. With the availability of improved test devices and a better understanding of occupant injuries and crash conditions, the agency was able to develop a more stringent set of criteria for its safety ratings program. The agency began applying this criteria and disseminating the new safety ratings to consumers starting with model year (MY) 2011 vehicles.

This paper details changes made to the crashworthiness tests conducted under the NCAP program and provides analyses of crash test results for MY 2011 vehicles tested during the 2010 calendar year. More specifically, this paper shows that the average star ratings assigned to MY 2011 vehicles are lower than those from recent model years. Despite lower star ratings, based on the MY 2011 rating system and comparing to the extent possible data from previous model years, MY 2011 vehicles on a whole are offering consumers lower injury risks (a higher level of crash protection) than the baseline injury risk used within the new rating system. Driver injury results from MY 2007-2010 Frontal NCAP tests will be directly compared to those from MY 2011 NCAP tests. A comparative analysis of injury data and ratings from vehicles known to be compliant with the upgraded Federal Motor Vehicle Safety Standard (FMVSS) No. 214, "Side impact protection," to those that have not yet been redesigned to meet this upgrade, will also be shown. While some vehicle manufacturers have made changes to comply with the upgraded side impact standard, additional protection for certain body regions may still be needed. The analyses show that while many vehicles are achieving high ratings

under the new rating system, others still need to improve their crashworthiness protection.

For ease of discussion, the vehicle rating system that applies to MY 2011 vehicles and beyond (NHTSA 2008a) is referred to as the "new" rating system. The system that applies to MY 1990-2010 vehicles (DOT 2007) is referred to as the "old" rating system.

It is important to note that while this paper makes injury data comparisons between 2011 and previous model year vehicles, the actual star ratings calculated under the new and old systems should not be compared.

### FRONTAL NCAP – RIGID BARRIER TEST

In this section, an overview of the new rating program will be discussed. Driver and passenger injury readings and star ratings from MY 2011 will be presented and compared. In addition, driver injury results from MY 2007-2010 vehicles tested under the old NCAP program will be evaluated under the new rating system and compared to those from MY 2011 vehicles tested under the new program.

#### An Overview of the New Frontal Ratings

Under the new rating system, NHTSA maintains the same speed and type of frontal test (35 mph (56.3 km/h) rigid barrier) as it conducted under the NCAP program since 1979. However, instead of using a 50th percentile male Hybrid III dummy in the front passenger seating position in the test, a 5th percentile female Hybrid III dummy is now seated in that position. The agency's frontal crash ratings were also revised and are now based on different (and more stringent) injury criteria than the previous rating system. Head, neck, chest, and femur injury are assessed under the new rating system. The combined probability of injury to both the driver and passenger in frontal NCAP is comprised of these four body regions. Additionally, the risk curves (with the exception of femur) are based on the chance of an Abbreviated Injury Scale (AIS) 3+ injury rather than an AIS 4+ injury as used under the old system. Detailed information regarding baseline injury risk,

injury risk curves and frontal star rating assignments can be found in the appendices of NHTSA’s “Final decision” notice (2008a).

**Comparing Driver and Passenger Injury Readings from MY 2011 Vehicles in Frontal Tests**

It was of interest to see how the driver and right front passenger in MY 2011 frontal NCAP performed, both with respect to one another and with respect to the baseline injury risk. When comparing injury results between the two, however, several factors have to be considered. For one, 50<sup>th</sup> percentile male and 5<sup>th</sup> percentile female dummies occupied the driver and right front passenger seating positions, respectively, and represent occupants of different sizes. In addition, these dummies are seated differently in frontal NCAP tests (NHTSA 2010a). Furthermore, the restraint conditions for these two seating positions cannot be compared, in part due (but not limited) to different air bag sizes and deployment strategies. Nevertheless, it was of interest to compare the probabilities of injuries recorded and star ratings assigned for the driver and right front passenger tested under the new MY 2011 program. Table 1 shows the results of this comparison.

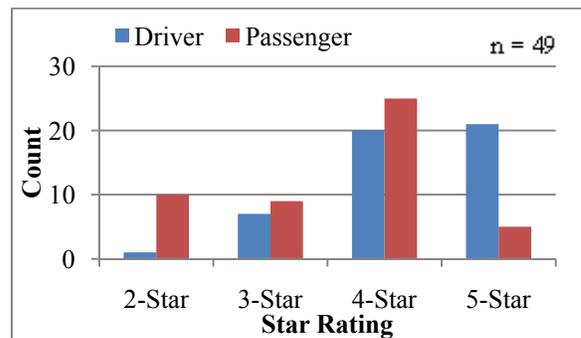
**Table 1. Driver and Right Front Passenger Results from MY 2011 Vehicles in Frontal Tests**

Occupant	Average		Min.	Max.
	P (AIS 3+) (%)	Star Rating	P (AIS 3+) (%)	P (AIS 3+) (%)
<b>Driver (n=49)</b>	11.7	4.24	7.2	20.4
<b>Passenger (n=49)</b>	15.3	3.48	8.8	28.4

The risk of combined injury for the 50<sup>th</sup> percentile male driver is lower than the risk of injury for the 5<sup>th</sup> percentile female right front passenger. The difference shows statistical significance at a probability of 0.05. The combined injury risk for the driver in frontal NCAP tests is lower than the new program’s baseline injury risk figure of 15 percent (2008a). In addition, the right front passenger now achieves an average combined injury risk of 15 percent, which is nearly identical to the baseline risk.

In terms of star ratings, the average driver rating from MY 2011 vehicles tested under the new frontal NCAP program was 4.24. For model years 2007-

2010 frontal NCAP data, using the old rating system, the average driver star rating was 4.71. The average star rating for the 5<sup>th</sup> percentile female right front passenger from MY 2011 vehicles tested under the new program was 3.48. The average star rating for the 50<sup>th</sup> percentile male dummy that formerly occupied the right front passenger seating position under the old rating system was 4.68. The star ratings for both the driver and right front passenger from MY 2011 vehicles tested under the new program ranged from 2 to 5 stars. There were no one-star ratings assigned to either occupant in MY 2011 vehicles. The decrease in average star ratings for the driver and right front passenger in MY 2011 tests compared to MY 2007 - 2010 was due to the new, more stringent rating system. Figure 1 shows a breakdown of the star ratings assigned to MY 2011 vehicles tested under the new frontal NCAP program.



**Figure 1. The driver and right front passenger frontal star ratings from MY 2011 vehicles.**

It was also of interest to examine the average probabilities of injury for each occupant to the four individual body regions. Table 2 contains this information.

**Table 2. Average Occupant AIS 3+ Injury Probabilities (%) from MY 2011 Vehicles in Frontal Tests**

Occupant	Head	Neck	Chest	Femur
<b>Driver (n=49)</b>	0.5	6.9	3.1	1.7
<b>Passenger (n=49)</b>	1.5	10.3	2.1	2.2

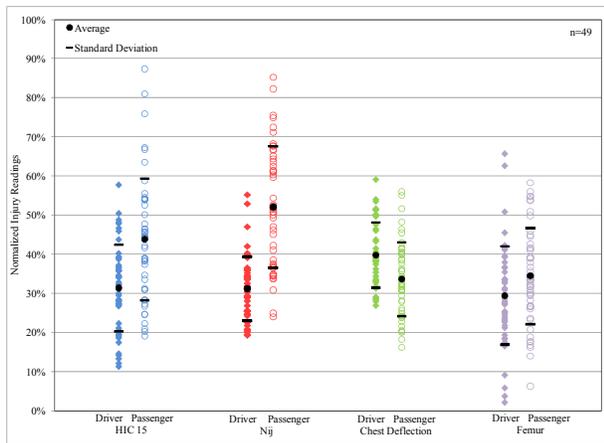
Both the driver and right front passenger exhibit similarly low probabilities of injury to the head, chest, and femur. The large variation seen between the two occupants is in the elevated probability of neck injury, more specifically Nij.

Another approach in comparing the differences between the driver and right front passenger dummy

responses was taken by normalizing each injury reading to its appropriate Injury Assessment Reference Value (IARV), which can be found in FMVSS No. 208 (sections S.6 and S.15, respectively). The results of this comparison are summarized in Table 3 and Figure 2 below.

**Table 3.**  
**Normalized MY 2011 Driver and Passenger Injury Readings (% of IARVs) in Frontal Tests**

	HIC <sub>15</sub>	Nij	Chest Deflection	Femur
<b>Driver IARV</b>	700	1	63 mm	10000 N
<b>Driver Average</b>	31.3	31.2	39.7	29.4
<b>Passenger IARV</b>	700	1	52 mm	6800 N
<b>Passenger Average</b>	43.8	52.1	33.6	34.4



**Figure 2. Normalized driver and passenger injury readings from MY 2011 vehicles in frontal tests.**

Data for the driver and right front passenger shows similar averages and ranges of injury to the chest and femur with respect to their IARVs. However, the right front passenger head and neck injury readings are much higher on average with respect to their IARV than the corresponding driver injury readings. The standard deviations of these two readings for the right front passenger are also much higher than for the driver, suggesting a larger range of protection to the head and neck being afforded to the right front passenger across the MY 2011 vehicle fleet. This is also aligned with similar observations concerning the range of combined probability of injury for the right

front passenger, which was similarly less homogenous than for the driver.

### Comparing Driver Injury Readings in Recent Model Years

Although the additional injury readings included in the new frontal ratings were not previously used to determine vehicle star ratings, NCAP has consistently collected this data since it began using the Hybrid III 50<sup>th</sup> percentile dummy in MY 1995 vehicles. Since the 50<sup>th</sup> percentile male driver is common between the old and new frontal NCAP programs, the injury responses generated under each can be directly compared. When NHTSA developed the baseline injury risk for the new NCAP rating system, it calculated the combined probability of driver injury as if the new rating system had been applied since MY 1995 (2008a). When the agency analyzed historical NCAP data from model years 1995-2007, it found a steadily decreasing trend in driver injury probability. It was of interest to extend that analysis to include recent NCAP data from model years 2008-2010 obtained under the old program and compare it with MY 2011 data obtained from the new program.

Data from the old program was limited to model years 2007-2010, since 2007 was the model year the agency used to derive the baseline injury risk. Data from the new program is limited to MY 2011 vehicles that were tested and quality control reviewed by the time of this publication.

Similar to the historical trend, the average combined probability of driver injury (shown in Table 4) continued to decrease in recent model years.

**Table 4.**  
**Combined Driver AIS 3+ Injury Probability (%) from MY 2007-2011 Vehicles in Frontal Tests**

Model Year	Average	Minimum	Maximum
<b>2007</b>	14.6	8.9	37.9
<b>2008</b>	14.7	8.7	24.4
<b>2009</b>	14.1	9.8	22.6
<b>2010</b>	12.3	8.0	20.0
<b>2011</b>	11.7	7.2	20.4

Of particular interest is the similarity in the average injury probability for MY 2010 and MY 2011. The range of combined injury probability has also decreased since 2007. Not only are vehicles continuing to offer occupants higher levels of frontal crash protection, the fleet is also becoming more homogenous in the level of protection it is offering.

It was of further interest to determine if certain injury probabilities had decreased or if all four body regions in question had decreased simultaneously. Table 5 shows the results of this analysis.

**Table 5.**  
**Average Driver AIS 3+ Injury Probabilities (%)**  
**from MY 2007-2011 Vehicles in Frontal Tests**

Model Year	Head	Neck	Chest	Femur
2007	0.8	6.9	4.3	3.3
2008	1.2	7.0	4.3	3.0
2009	0.9	6.7	5.0	1.9
2010	0.8	7.0	3.4	1.7
2011	0.5	6.9	3.1	1.7

The data shows that the probability of driver chest and femur injury has decreased while the probability of neck injury has stayed fairly constant. The 2011 MY drivers also experienced the lowest probability of head injury since 2007. Chest injury probabilities from model years 2010 and 2011 are similar while those from model years 2007-2009 are more alike. The probability of femur injury was similar from model years 2007 and 2008 and quite different from model years 2009-2011.

### **SIDE NCAP - MOVING DEFORMABLE BARRIER TEST**

In this section, the new side NCAP moving deformable barrier (MDB) test will be discussed. Driver and passenger injury readings and star ratings from MY 2011 will be presented and compared. Results from vehicles that are certified to comply with FMVSS No. 214, S7.2, "Side Impact Protection, MDB Test with Advanced Test Dummies," will be compared to results from those vehicles that are certified to FMVSS No. 214, S7.1, "Side Impact Protection, MDB Test with SID." An in-depth look at the driver and rear passenger occupants and their main sources of injury will be discussed. Finally, vehicles that have both old and new side NCAP MDB ratings will be examined and their corresponding ratings will be compared.

#### **An Overview of the New Side MDB Ratings**

The new side MDB test is conducted similarly to the one conducted under the old program. The test speed is maintained at 38.5 mph (61.9 km/h) and the crabbed angle remains at 27°; however, rather than positioning two 50<sup>th</sup> percentile male Hybrid III SID

dummies in the driver and left rear passenger seats, a 50<sup>th</sup> percentile male ES-2re dummy occupies the driver seating position and a 5<sup>th</sup> percentile female SID-IIs dummy occupies the left rear passenger seating position. Under the old program, star ratings for the side MDB test were based solely on injury to the dummies' chests. The new, more stringent side MDB ratings are based on head, chest, abdomen, and pelvis readings for the driver dummy and head and pelvis readings for the rear passenger dummy. The combined probability of injury for each dummy is comprised of these respective body regions. Similar to the frontal NCAP test, risk curves for the new side barrier test (with the exception of the pelvis for the SID-IIs dummy) are based on the chance of incurring an AIS 3+ injury rather than an AIS 4+ injury, as was the case under the old program. The appendices of NHTSA's "Final decision" notice (2008a) provide detailed information regarding baseline injury risk, injury risk curves, and the side MDB star ratings.

### **Comparing Driver and Passenger Injury Readings from MY 2011 Vehicles in Side MDB Tests**

Many factors influence injury readings for the driver and rear passenger dummies in the side MDB tests. Typically, restraint conditions vary for these two positions, particularly in terms of advanced seat belt devices such as pretensioners and the presence of torso or torso/pelvis side air bag protection (common for the front seat, but not for the rear). In addition, the seating procedures for the driver and rear passenger dummies are different (NHTSA 2010b). Regardless, it was of interest to compare the average probabilities of injury and resultant star ratings for the driver and rear passenger dummies for the 48 MY 2011 vehicles subjected to NCAP's side MDB test. Note that there are only 45 ratings total for the rear passenger due to lack of rear seating in three vehicles. The results of this comparison are shown in Table 6.

**Table 6.**  
**Driver and Rear Passenger Results from MY 2011**  
**Vehicles in Side MDB Tests**

Occupant	Average		Min.	Max.
	p (AIS 3+) (%)	Star Rating	p (AIS 3+) (%)	p (AIS 3+) (%)
<b>Driver (n=48)</b>	10.4	4.40	2.1	45.2
<b>Rear Passenger (n=45)</b>	9.3	4.31	0.3	36.8

The average risk of combined injury for the 50<sup>th</sup> percentile male driver dummy is slightly higher than for the 5<sup>th</sup> percentile female rear passenger dummy. One reason for this could be that the rear passenger probabilities are limited to head and pelvis injuries. Currently, thoracic and abdominal rib deflections for the 5<sup>th</sup> percentile female rear passenger dummy are monitored, but they are not incorporated into FMVSS No. 214 or NCAP star rating calculations. A footnote is posted beneath a vehicle's ratings on [www.Safecar.gov](http://www.Safecar.gov) to alert consumers of instances in which readings for the thoracic and/or abdominal ribs exceed associated IARVs. Similarly, NCAP uses a Safety Concern symbol to note instances in which a lower spine acceleration reading exceeds the performance requirements set forth in FMVSS No. 214.

Average star ratings for the driver and left rear passenger dummies in the 48 MY 2011 vehicles (with rear passenger ratings reduced by three as previously described) were 4.40 and 4.31, respectively. The star ratings for the driver ranged from 1 to 5 stars and the star ratings for the rear passenger ranged from 2 to 5 stars.

Table 7 shows average injury probabilities for body regions used to calculate the star ratings for the driver and rear passenger. When comparing injury risk for the head and pelvis, it is shown that the rear passenger has a greater risk of injury to these regions on average than the driver. The results from Tables 6 and 7 indicate that the chest and abdomen are predominantly influencing the combined injury probabilities for the driver, and therefore, the driver side MDB star ratings. The average probabilities of AIS 3+ injury to the chest and abdomen for the driver are relatively high compared with those to the head and pelvis. The data also suggests that pelvis injury is influencing the star rating for the rear passenger dummy.

**Table 7.**  
**Average Occupant AIS 3+ Injury Probabilities (%) from MY 2011 Vehicles in Side MDB Tests**

Occupant	Head	Chest	Abdomen	Pelvis
Driver	0.1	7.7	2.5	0.6
Passenger	1.0	N/A	N/A	8.5

**Driver and Rear Passenger Results for Vehicles Certified to FMVSS No. 214, S7.1 vs. S7.2**

As shown in Table 6, average injury probabilities for both the 50<sup>th</sup> percentile male driver and 5<sup>th</sup> percentile female passenger dummies fall below the original 15

percent baseline risk for side impact crashes. In NHTSA's "Final decision" notice (2008a), the agency analyzed driver and rear passenger data from seven MY 2004-2005 side barrier tests conducted with the ES-2re and SID-IIIs dummies to support the upgrade of FMVSS No. 214. It should be noted that, with the exception of test speed, the new FMVSS No. 214 side impact barrier test is nearly identical to NCAP's new side impact barrier test. The test speed for the compliance side MDB test is 33.5 mph (53.0 km/h), whereas it is 38.5 mph (61.9 km/h) for the new side NCAP MDB test. The average risk of injury for the driver and rear passenger dummies in that test series was 9 percent and 12 percent, respectively (NHTSA 2008a). Recall that the MY 2011 test data in Table 6 shows a similar average risk of injury for the driver dummy (10.4 percent) and a reduced average risk of injury for the rear passenger dummy (9.3 percent) when compared to the MY 2004-2005 test data. Considering the MY 2011 side impact barrier test data was collected from tests conducted at a higher speed, it is possible that vehicle manufacturers have introduced countermeasures in recent years to lower the risk of injury to the rear occupant.

Average injury risk for the driver and/or rear passenger dummies for vehicles that have been certified to the new FMVSS No. 214 side impact barrier test (S7.2) was compared to those that have not (S7.1). The data set for vehicles that meet the new requirements (n = 20 driver, 19 passenger) consisted only of passenger cars and SUVs. Therefore, the second data set consisting of those vehicles that did not certify to the new requirements (n = 28) was reduced to include only passenger cars and SUVs (n = 21). Note that the data set for rear passenger ratings for vehicles that meet the new requirements has been decreased by one due to the lack of a rear seating position in one vehicle.

As shown in Tables 8 and 9, average injury risk for vehicles certified to the new side impact barrier test requirements is lower than for vehicles that have not yet been redesigned to meet the new standard. This difference is statistically significant at a probability of 0.05 for both the driver and rear passenger dummies, whose injury risks decrease to 7.6 percent and 5.6 percent, respectively, in those vehicles that have been redesigned. Injury risk for the rear passenger decreased by more than half for vehicles certified to the new test requirements.

**Table 8.**  
**Driver Results from MY 2011 Vehicles in Side MDB Tests**

	Average		Min.	Max.
	P (AIS 3+) (%)	Star Rating	P (AIS 3+) (%)	P (AIS 3+) (%)
<b>Not Certified to FMVSS No. 214, S7.2 (n=21)</b>	14.5	3.95	3.8	45.2
<b>Certified to FMVSS No. 214, S7.2 (n=20)</b>	7.6	4.70	2.1	19.1

**Table 9.**  
**Rear Passenger Results from MY 2011 Vehicles in Side MDB Tests**

	Average		Min.	Max.
	P (AIS 3+) (%)	Star Rating	P (AIS 3+) (%)	P (AIS 3+) (%)
<b>Not Certified to FMVSS No. 214, S7.2 (n=21)</b>	14.4	3.76	0.3	36.8
<b>Certified to FMVSS No. 214, S7.2 (n=19)</b>	5.6	4.74	0.8	17.2

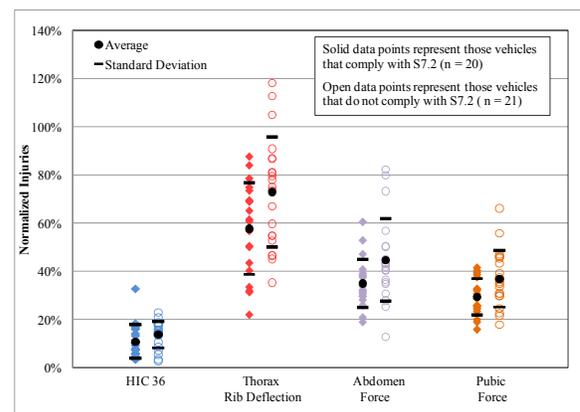
Although the minimum values of risk observed for the driver and rear passenger are fairly similar for vehicles that have certified to FMVSS No. 214, S7.2 (2.1 percent and 0.8 percent, respectively) compared to those that have not (3.8 percent and 0.3 percent, respectively), the maximum values are widely different. The maximum risk of injury for the driver dummy in vehicles that have been certified to meet FMVSS No. 214, S7.2 was 19 percent, whereas it was more than double (45 percent) for vehicles that have not yet been redesigned. For the rear passenger dummy, the maximum injury risk for vehicles certifying to FMVSS No. 214, S7.2 was 17 percent, whereas it was 37 percent for vehicles that have not yet been certified to meet the new standard.

The marked decrease in injury risk for vehicles that have been certified to comply with FMVSS No. 214,

S7.2 corresponded to an increase in average star ratings for both dummies. Average star ratings for the driver and rear passenger dummies increased from 3.95 and 3.76 to 4.70 and 4.74, respectively. Star ratings ranged from 1 to 5 stars for the driver dummy and from 2 to 5 stars for the rear passenger dummy for those vehicles which were not certified to FMVSS No. 214, S7.2. For vehicles which were certified to FMVSS No. 214, S7.2, the star ratings ranged from 3 to 5 stars for both dummies.

### A Closer Look at Driver Results in Side MDB Test

Injury data from the 48 MY 2011 test vehicles was once again divided into two categories: one for vehicles that have not yet been certified to FMVSS 214, S7.2 and the other for vehicles that have been certified to the new standard. As before, the data set for those vehicles that have not yet complied with FMVSS No. 214, S7.2 was reduced to include comparable vehicle types. All injury readings collected for the driver dummy were normalized to associated IARVs (specified in the FMVSS No. 214 final rule) and are shown in Figure 2, along with the average and standard deviation. As mentioned previously, resultant lower spine acceleration has not been incorporated into either FMVSS No. 214 or side NCAP test for the ES-2re dummy. Consequently, this injury criterion will not be included in this analysis.



**Figure 3. The normalized side MDB driver injury readings for MY 2011 vehicles certified to the new and old FMVSS No. 214.**

Figure 3 and Table 10 show improved performance across all body regions for the ES-2re driver dummy in those vehicles certified to FMVSS No. 214, S7.2 (n = 20) compared to those vehicles certified to FMVSS No. S7.1 (n = 21). As shown, not only was the average injury lower for each body region, but in

general, with the exception of the head, the standard deviation was reduced as well. For those vehicles certified to FMVSS No. 214, S7.2, Table 10 shows comparable reductions (of approximately 20 percent) in normalized injury readings for all four body regions.

**Table 10.**  
**Average Normalized Driver Injury Readings (% of IARVs) from MY 2011 Vehicles in Side MDB Tests**

	<b>HIC<sub>36</sub></b>	<b>Thor. Rib Defl.</b>	<b>Comb. Abd. Force</b>	<b>Pubic Force</b>
<b>IARV</b>	1000	44 mm	2500 N	6000 N
<b>Not Certified to FMVSS No. 214, S7.2 (n=21)</b>	13.8	72.9	44.8	37.0
<b>Certified to FMVSS No. 214, S7.2 (n=20)</b>	10.9	57.7	35.0	29.6
<b>% Reduction</b>	21.0	20.9	21.9	20.0

The reduction in injury readings for those vehicles certified to FMVSS No. 214, S7.2 translates to a significant reduction in injury probability. As shown in Table 11, the average injury probability recorded for three of the four body regions (chest, abdomen, and pelvis) was reduced by approximately half compared to the respective average injury probabilities recorded for those vehicles that have not yet been redesigned. As mentioned previously, however, it is the thoracic and abdominal injuries that are influencing side MDB ratings for the driver occupant. This is true for the vehicle dataset as a whole, and as shown in Table 11, it is also true for each of the two reduced datasets individually. Although abdominal and pelvic injuries might still be reduced further, as average normalized injuries recorded for those vehicles complied with FMVSS No. 214, S7.2 remain at 35 percent and 30 percent of the associated IARVs, respectively, manufacturers choosing to target the thoracic region may see the largest difference in ratings. The average probability of injury recorded for the thoracic region, 5.6 percent, remains the highest for the four body regions. Additionally, as was shown in Figure 3 and Table 10, normalized injury for the thorax was 58 percent of the IARV.

HIC<sub>36</sub> readings are already low, as evidenced by the 0.1 percent average probability and average injury readings falling at 11 percent of the IARV.

Therefore, it may be unlikely that further improvement for this body region can be achieved. Furthermore, because of the nature of the associated risk curve, a reduction in head injury will likely not result in a higher driver star rating in the side NCAP MDB test. As shown in Tables 10 and 11, for those vehicles that certify to FMVSS No. 214, S7.2, even a reduction in head injury of 21 percent does not translate to a meaningful difference in probability of injury. Accordingly, the star rating for this occupant would not be affected. The same can be said for abdomen and pelvic injuries. Although average readings for the abdomen and pelvis in FMVSS No. 214, S7.2 compliant vehicles were 35 percent and 30 percent of the associated IARVs, respectively, Table 11 shows that these average normalized readings translate to a very low probability of injury for the two body regions.

**Table 11.**  
**Average Driver AIS 3+ Injury Probabilities (%) from MY 2011 Vehicles in Side MDB Tests**

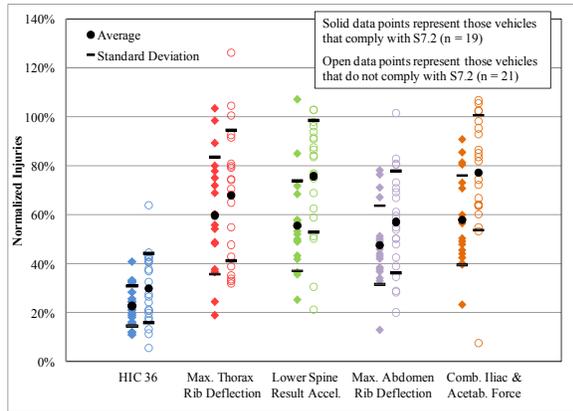
	<b>Head</b>	<b>Chest</b>	<b>Abdomen</b>	<b>Pelvis</b>
<b>Not Certified to FMVSS No. 214, S7.2 (n=21)</b>	0.1	10.6	3.8	0.8
<b>Certified to FMVSS No. 214, S7.2 (n=20)</b>	0.1	5.6	1.8	0.4
<b>% Reduction</b>	0.0	47.2	52.6	50.0

#### **A Closer Look at Rear Passenger Results in Side MDB Tests**

Injury readings for the SID-II's rear passenger dummy in the side MDB test were also normalized for the two data sets studied for the ES-2re driver dummy. Normalized readings for each data set are shown in Figure 4, along with the related averages and standard deviations. Average values are also presented in Table 12.

As mentioned previously, injury criteria related to thoracic and abdominal rib deflection for the SID-II's dummy has not yet been incorporated into either FMVSS No. 214 or side NCAP ratings. However, the agency acknowledged in the FMVSS No. 214 final rule that “thoracic and abdominal rib deflections are a critical part of the [SID-II's] dummy.” Furthermore, the agency contended that it “may undertake future rulemaking to propose to limit thoracic and abdominal rib deflections measured by the SID-II's in the FMVSS No. 214 MDB and pole tests.” As IARVs for each of these criteria have been established, these injury criteria will be included in

this analysis. Resultant lower spine acceleration will also be analyzed because, even though this criterion has not yet been adopted into the side NCAP rating scheme for the SID-II's dummy, the agency has established related performance limits that have been incorporated into FMVSS No. 214.



**Figure 4. The normalized side MDB rear passenger injury readings from MY 2011 vehicles certified to the new and old FMVSS No. 214.**

Similar to Figure 3, Figure 4 shows improved performance for the SID-II's dummy across all body regions for those vehicles certified to comply with FMVSS No. 214, S7.2 (n = 19) as compared to FMVSS No. 214, S7.1 (n = 21). Average readings were lower for each body region, and associated standard deviations were also reduced.

**Table 12. Average Normalized Rear Passenger Injury Readings (% of IARVs) from MY 2011 Vehicles in Side MDB Tests**

	HIC <sub>36</sub>	Thor. Rib Defl.	Abd. Rib Defl.	Lower Spine Accel.	Comb. Pelvic Force
<b>IARVs</b>	1000	38 mm	45 mm	82 G	5525 N
<b>Not Certified to FMVSS No. 214, S7.2 (n=21)</b>	30.1	67.9	57.1	75.7	77.3
<b>Certified to FMVSS No. 214, S7.2 (n=19)</b>	22.8	59.7	47.7	55.5	57.9
<b>% Reduction</b>	24.3	12.1	16.5	26.7	25.1

Table 12 shows that reductions in average injury readings were most apparent for the head (24 percent), lower spine (27 percent), and pelvis (25

percent). Average thoracic rib and abdominal rib deflections decreased by a lesser extent, 12 percent and 17 percent, respectively.

The reduction in injury readings for those vehicles that are certified to comply with FMVSS No. 214, S7.2 translates to a noticeable reduction in injury probability. Table 13 shows the average AIS 3+ injury probability recorded for the head and pelvis in those vehicles that are certified to FMVSS No. 214, S7.2 and those that are not. The star rating for the rear passenger is currently determined by the probability of injury to these two body regions. As shown, it is the pelvis, not the head, which influenced the rating for the rear occupant. This was true for the vehicle dataset as a whole, as was shown in Table 7, and is also true for each of the two reduced data sets. Average injury probabilities for those vehicles that complied with FMVSS No. 214, S7.2 were reduced by more than 60 percent compared to the respective average injury probabilities recorded for those vehicles that have not yet been redesigned.

**Table 13. Average Rear Passenger AIS 3+ Injury Probabilities (%) from MY 2011 Vehicles in Side MDB Tests**

	Head	Pelvis
<b>Not Certified to FMVSS No. 214, S7.2 (n=21)</b>	1.6	13.1
<b>Certified to FMVSS No. 214, S7.2 (n=19)</b>	0.5	5.1
<b>% Reduction</b>	68.9	61.1

In MY 2011 vehicles that were certified to comply with FMVSS No. 214, S7.2, average head injury readings were recorded at 23 percent of the related IARV, and average injury readings for the pelvis remain at 58 percent of the IARV (Table 12). The average probability of injury for the pelvis, 5.1 percent, remains the higher of the two body regions. Because of the nature of the risk curve, any reduction in head injury will translate to little improvement in the star rating for the rear passenger dummy since the average probability of injury for this body region, 0.5 percent, is already relatively low.

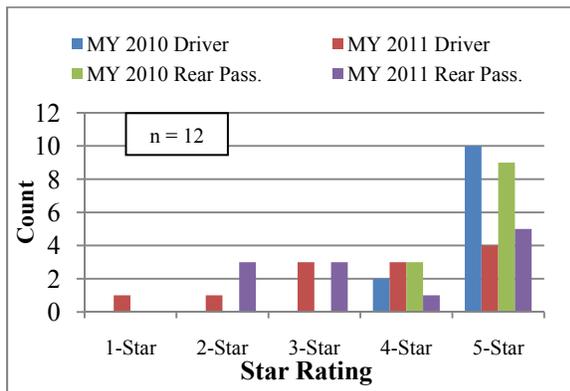
**Comparing Side MDB Star Ratings Obtained from the New Program to Those Obtained from the Old Program**

Vehicle models that do not receive structural or restraint redesigns that would affect side impact performance are considered carryover models from

one year to the next. Although carryover models would not typically be retested for the newer model year, due to the major enhancements to the NCAP program, ratings for those models did not carry over in MY 2011. As the new side impact barrier test remained virtually unchanged under the new program, with the exception of the test dummies and collected injury criteria, it was of interest to see if side impact barrier ratings assigned under the new program were lower, on average, than those assigned under the old program for the same vehicle model.

To ensure the most accurate comparison, vehicles for this analysis were limited to those models (n = 13) that were considered carryovers from MY 2010 and were not yet redesigned to meet FMVSS No. 214, S7.2. Furthermore, the carryover data set was further limited to only passenger cars and SUVs (n = 12). Vehicles certified as complying with FMVSS No. 214, S7.2 were excluded because, as has been shown, it is likely that they have already been redesigned with necessary countermeasures that could skew the results. For this study, it was desired to have a more direct, one-to-one comparison to reveal the effect of the new rating system on assigned star ratings.

As shown in Figure 5, for the 12 carryover models that were tested under the old program (MY 2010 vehicles) and again under the new program (MY 2011 vehicles), the star ratings were lower, on average, for both the driver and rear passenger under the new program. In fact, as shown in Table 14, driver ratings were at least one star lower in 8 of the 12 vehicles, and rear passenger ratings were lower in all but five vehicles. Only one vehicle achieved a higher star rating under the new program.



**Figure 5. The driver and rear passenger star ratings from both MY 2010 and 2011 carryover vehicles not certified to FMVSS No. 214, S7.2.**

**Table 14. Change in Driver and Rear Passenger Star Ratings for MY 2011 Carryover Vehicles Not Certified to FMVSS No. 214, S7.2**

	Down 3 Stars	Down 2 Stars	Down 1 Star	Same Star	Up 1 Star
# 2011 Driver Ratings	1	4	3	4	0
# 2011 Rear Pass. Ratings	2	3	2	4	1

As shown in Table 15, for this limited data set of 12 carryover vehicles, the average risk of injury for the driver and rear passenger was 17 percent and 15 percent, respectively, and the overall combined average was 15.6 percent, which is nearly identical to the baseline injury risk used in NCAP’s new rating system, 15 percent. Recall that, in Tables 8 and 9, respectively, it was shown that the average injury risk for the driver and rear passenger decreased to 8 percent and 6 percent, respectively, for those vehicles (n = 20 driver, 19 passenger) that have been certified to FMVSS No. 214, S7.2. This suggests that newly redesigned vehicles are offering consumers a level of protection that exceeds the baseline injury risk level under the new rating system.

**Table 15. Driver, Rear Passenger, and Combined Average Injury Probabilities for Carryover Models in Side MDB Tests (n=12)**

	Average p(AIS 3+) (%)
<b>Driver</b>	16.6
<b>Rear Passenger</b>	14.6
<b>Combined</b>	15.6

Although it was mentioned earlier that average star ratings were higher for vehicles that have been certified to FMVSS No. 214, S7.2 compared to those that have not, it was also of interest to see what percentage of redesigned vehicles were receiving the highest ratings. As shown in Table 16 below, 75 percent of vehicles certified to comply with FMVSS No. 214, S7.2 received a 5-star rating for the driver and/or rear passenger. This is a sharp increase compared to the 33 percent (4 out of 12) of drivers and 42 percent (5 out of 12) of rear passengers in the carryover data set (n = 12) that received 5-star ratings for MY 2011 as illustrated in Figure 5.

**Table 16.**  
**Driver and Rear Passenger Star Ratings from MY 2011 Vehicles Certified to FMVSS No. 214, S7.2**

Stars	# 2011 Driver Ratings	% of Driver Ratings	# 2011 Rear Pass. Ratings	% of Rear Pass. Ratings
5	15	75	15	75
4	4	20	3	15
3	1	5	1	5
2	0	0	0	0
1	0	0	0	0
N/A	0	0	1	5

**SIDE NCAP - THE SIDE POLE TEST**

Driver injury readings from NCAP’s new side pole test will be presented in this section. Results from vehicles that are certified to comply with FMVSS No. 214, S9, “Side Impact Protection, Vehicle-To-Pole Requirements,” will be compared to results from those vehicles that do not yet meet these requirements. The main sources of injury for the driver occupant will also be revealed and a breakdown of side pole star ratings will be shown.

**An Overview of the New Side Pole Ratings**

The side pole test is a new addition to the NCAP test series as well as to FMVSS No. 214. For this test, a 5<sup>th</sup> percentile female SID-IIs dummy occupies the driver seat; there is no dummy in the rear seat. A vehicle, crabbed at 75°, is towed into a 25 cm diameter rigid pole at a speed of 20 mph (32.2 km/h). This test is meant to simulate a vehicle impacting a narrow, tall fixed object such as a tree or utility pole. The dummy’s head is aligned with the pole such that, at impact, the head’s center of gravity (CG) is aligned with the vertical centerline of the pole. Similar to the SID-IIs dummy in the rear seat for the side MDB test, the SID-IIs driver pole rating is based only on the combined risk of injury to the head and pelvis. Again, risk curves for the SID-IIs dummy in the side pole test are based on the chance of incurring an AIS 3+ injury to the head and AIS 2+ injury to the pelvis. Information pertaining to baseline injury risk, injury risk curves, and the side pole star ratings can be found in the appendices of NHTSA’s “Final decision” notice (2008a).

**Driver Injury Readings from MY 2011 Vehicles in Side Pole Tests**

Because of localized loading, intrusion is a major factor in injury readings measured in NCAP’s side pole test. As the side pole rating is based solely on combined injury to the head and pelvis, it is essential that vehicles have sufficient countermeasures to protect these body regions. Since the 5<sup>th</sup> percentile female SID-IIs driver dummy in the side NCAP pole test sits in a different, more forward position than the 50<sup>th</sup> percentile male ES-2re driver dummy in the side NCAP MDB test, side curtain air bags must be designed to offer protection to both occupants for each of the two testing scenarios. Side torso air bags that are not also designed to provide pelvis protection may not afford the driver dummy enough protection to attain a high side pole rating.

Table 17 shows the average probabilities of injury and resultant star ratings for the driver dummy in the 48 MY 2011 vehicles subjected to NCAP’s side pole test. As shown, the average combined injury probability for the driver dummy was 13 percent, which falls below the original overall 15 percent baseline risk for side impact crashes. The average star rating was 4.15 and the range was from 1 to 5 stars.

**Table 17.**  
**Driver Results from MY 2011 Vehicles in Side Pole Tests**

	Average		Min.	Max.
	P (AIS 3+) (%)	Star Rating	P (AIS 3+) (%)	P (AIS 3+) (%)
<b>Driver (n=48)</b>	12.9	4.15	1.6	65.1

Average injury probabilities for the two body regions (head and pelvis) used to calculate the star rating for the driver dummy in the side pole test are shown in Table 18. As the average probability of AIS 3+ injury to the pelvis is relatively high compared to that for the head, it can be inferred that pelvic injury is influencing the star rating for the driver dummy.

**Table 18.**  
**Average Driver AIS 3+ Injury Probabilities (%) from MY 2011 Vehicles in Side Pole Tests**

	Head	Pelvis
<b>Driver (n=48)</b>	2.3	11.0

It should be noted that the average injury risk for the head (2 percent) and pelvis (11 percent) for the SID-IIs driver dummy in the side pole tests was greater than it was for the 50<sup>th</sup> percentile male driver dummy in the side barrier test (average risks of 0.1 percent and 0.6 percent, respectively). Localized intrusion, side air bag designs, and occupant size may be contributing factors to the higher readings seen for the side pole test.

**Driver Results for Vehicles Certified and Not Certified to FMVSS No. 214, S9**

The agency conducted seven MY 2004-2005 side pole tests with the SID-IIs dummy to support the upgrade of FMVSS No. 214. As mentioned in NHTSA’s “Final decision” notice (2008a), the average injury risk for this test series was 57 percent. This is in sharp contrast to the 13 percent average injury risk found for the driver dummy in the 48 MY 2011 vehicles included in this study. It should be noted that there were no significant differences between the current side NCAP pole test protocol and the one used for the FMVSS No. 214 test series. This suggests that, in recent years, manufacturers have implemented or improved countermeasures for side pole crashes which provide additional protection for the small occupant. Therefore, similar to the side MDB test, it was of interest to see if the average risk of injury for the driver dummy in the side pole test was considerably lower for those vehicles that have been certified to the new FMVSS No. 214 requirements (S9) compared to those that have not. Injury readings for the 48 MY 2011 test vehicles studied were once again divided into two groups: one for those vehicles that were certified to FMVSS No. 214, S9 (n = 20), and one for those that were not (n = 28). As was done for the previous analyses, the data set for those vehicles that were not yet certified to the new standard was reduced to include only passenger cars and SUVs (n = 21).

Table 19 shows that the average injury risk for the 20 vehicles certified to the new pole test requirements is substantially less (7.2 percent) than for the 21 vehicles that have not yet been certified to the new requirements (17 percent). This difference is statistically significant at a probability of 0.05. Accordingly, the average injury risk recorded for the compliant vehicle set falls below the original overall baseline risk of 15 percent for side impact crashes. It should also be noted that although the minimum risk values were fairly comparable for the two data sets, the maximum values varied considerably. The maximum combined injury risk for those vehicles that do not yet certify to the new requirements was 65

percent. This value is nearly four times the maximum risk recorded for those vehicles that have been redesigned. For those vehicles that have certified to the new pole test requirements, the maximum combined risk of head and pelvis injury was 16 percent. Furthermore, the maximum risk for those vehicles that were certified to comply with the new standard is actually less than the average risk for those vehicles that were not.

**Table 19.  
Driver Results from MY 2011 Vehicles in Side Pole Tests**

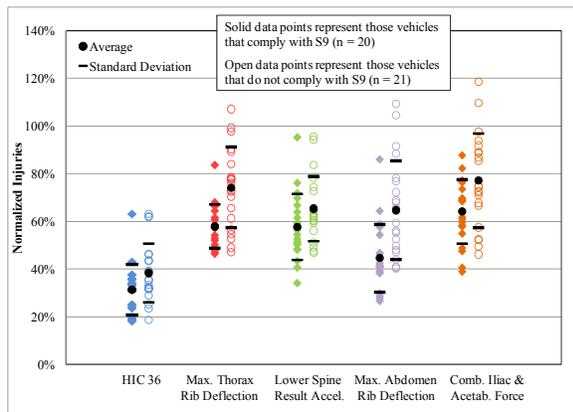
	Average		Min.	Max.
	P (AIS 3+) (%)	Star Rating	P (AIS 3+) (%)	P (AIS 3+) (%)
<b>Not Certified to FMVSS No. 214, S9 (n=21)</b>	17.0	3.68	2.7	65.1
<b>Certified to FMVSS No. 214, S9 (n=20)</b>	7.2	4.80	1.6	15.8

The significant decrease in average injury risk for those vehicles that meet the new side pole test requirements resulted in an increase in the average star rating for the driver dummy. The average star rating for the driver dummy in those vehicles (n = 20) that have been certified to the new requirements was 4.80 stars. This is compared to 3.68 stars for those vehicles (n = 21) that have not yet certified to the new requirements. This means that the average driver star rating for vehicles certifying to the new standard is one star higher than the average driver rating for vehicles that have not yet been designed to meet these new requirements. Star ratings ranged from 3 to 5 stars for those vehicles that were certified to the new standard, and from 1 to 5 stars for those that were not.

**A Closer Look at Driver Results in Side Pole Tests**

Injury readings collected by the SID-IIs driver dummy in NCAP’s side pole test were normalized to related IARVs for each of the two vehicle data sets. Figure 6 shows normalized readings for each group, along with the related averages and standard deviations. Average values are also presented in Table 20.

As was previously mentioned in relation to the SID-IIs rear passenger dummy in the side MDB test, injury criteria for thoracic and abdominal rib deflection have not yet been incorporated into either FMVSS No. 214 or side NCAP ratings. That said, as mentioned previously, performance thresholds have been established for each of these criteria; therefore, they will be included in this analysis. Resultant lower spine acceleration will also be part of the discussion. Although this criterion is not currently part of the side pole rating for the driver occupant, the agency has established an IARV for this criterion that has been adopted into FMVSS No. 214, S9.



**Figure 6. The normalized side pole driver injury readings from MY 2011 vehicles that are certified to the new FMVSS No. 214 pole test and those that are not.**

As was the case for the driver and rear passenger dummies in the side MDB test, vehicles that have certified to comply with the new FMVSS No. 214 pole requirements (n = 20) showed improved performance in the pole test for all body regions compared to those that have not (n = 21). For those vehicles certifying to the side pole test requirements, Figure 6 shows that average readings for the SID-IIs driver dummy decreased for each body region. With the exception of lower spine acceleration, associated standard deviations were also reduced. The standard deviation for lower spine acceleration remained essentially constant for those vehicles certifying to the new requirements.

Table 20 shows that contrary to what was observed for the rear passenger SID-IIs dummy in the side MDB test, the most prominent reductions in average injury readings for the SID-IIs driver dummy in the side pole test were seen in the thoracic and abdominal ribs. Injuries to these two body regions were reduced

by 22 percent and 31 percent, respectively. Notable reductions in average injury readings were also seen for the head (18 percent) and pelvis (17 percent). This was as expected since these two injury criteria make up the side pole rating for the driver dummy. Lower spine injury readings were reduced by the least amount, 12 percent.

**Table 20. Average Normalized Driver Injury Readings (% of IARVs) from MY 2011 Vehicles in Side Pole Tests**

	HIC <sub>36</sub>	Thor. Rib Defl.	Abd. Rib Defl.	Lower Spine Accel.	Comb. Pelvic Force
<b>IARV</b>	1000	38 mm	45 mm	82 G	5525 N
<b>Not Certified to FMVSS No. 214, S9 (n=21)</b>	38.4	74.3	64.7	65.4	77.2
<b>Certified to FMVSS No. 214, S9 (n=20)</b>	31.4	58.0	44.7	57.7	64.1
<b>% Reduction</b>	18.2	21.9	30.9	11.8	17.0

Reductions in average readings for the head, thorax, and pelvis (18 percent, 22 percent, and 17 percent, respectively) were fairly comparable to the reductions seen for the same body regions for the driver dummy in the side MDB test (21 percent, 21 percent, and 20 percent, respectively). Injury reductions for the abdomen showed noticeable differences between the two tests, however. The driver dummy saw a greater reduction in average abdominal injuries (31 percent) in the side pole test compared to the side MDB test (22 percent). As mentioned previously, intrusion, side air bag designs, and occupant size may contribute to the variation in the severity of injuries recorded for particular body regions in each test.

As shown in Table 21, the reduction in injury readings for those vehicles that are certified to comply with the new side pole test requirements translates to a noticeable reduction in injury probability for the two body regions (head and pelvis) that determine the driver’s side pole rating. The average probability of head injury was reduced by 48 percent for those vehicles meeting the new side

pole test requirements, and the average probability of pelvis injury was reduced by 61 percent. Similar to what was observed in the rear passenger dummy in the side MDB test, it is pelvis injury that is influencing the side pole rating for the driver dummy. This was true for all 48 vehicles, and is also true for each of the smaller data sets.

**Table 21.**  
**Average MY 2011 Driver AIS 3+ Injury Probabilities (%) in Side Pole Tests**

	Head	Pelvis
<b>Not Certified to FMVSS No. 214, S9 (n=21)</b>	2.9	14.7
<b>Certified to FMVSS No. 214, S9 (n=20)</b>	1.5	5.8
<b>% Reduction</b>	48.3	60.5

Average HIC<sub>36</sub> readings were recorded at 31 percent of the related IARV for those vehicles that complied with FMVSS No. 214, S9. This suggests that the average probability of head injury (1.5 percent) may still be reduced. However, manufacturers looking to improve the star rating for the driver dummy may focus on pelvis readings instead. The average pelvic force reading for vehicles certified to FMVSS No. 214, S9 were recorded at 64 percent of the IARV and the corresponding probability of injury was 5.8 percent. Similar to that discussed in earlier analyses, because the average probability of head injury for the driver dummy is already low, even a rather large reduction in head injury will not translate to a meaningful difference in related probability of head injury. This is due to the nature of the associated risk curve. Consequently, the star rating for the driver dummy would also be unaffected.

### Side Pole Star Ratings Received Under the New Program

In Table 19, it was shown that the average injury risk for the driver decreased to 7 percent for those vehicles (n = 20) that have certified to FMVSS No. 214, S9. Therefore, similar to that observed for the side barrier test, newly redesigned vehicles appear to afford consumers a level of protection for the side pole test that exceeds the average injury risk level under the new rating system. On average, star ratings for vehicles certified to FMVSS No. 214, S9 were also shown to be notably higher than those for vehicles that have not yet been certified to the new standard. The following analysis will expand upon the earlier work to show the percentage of vehicles

that receive the highest ratings for the driver dummy in the side pole test.

As shown in Table 22 below, 85 percent of vehicles that are certified to FMVSS No. 214, S9 received a 5-star driver rating and 10 percent received a 4-star rating. These percentages contrast sharply with those in the data set that consists of only those vehicles that have not yet been redesigned to comply with FMVSS No. 214, S9. For this second group of vehicles, only 46 percent received a 5-star rating and 18 percent received a 4-star rating.

**Table 22.**  
**Driver Star Ratings from MY 2011 Vehicles Certified and Not Certified to FMVSS No. 214, S9**

		5-Star	4-Star	3-Star	2-Star	1-Star
<b>All Vehicles (n = 48)</b>	<b>Count</b>	30	7	2	6	3
	<b>%</b>	62	15	4	13	6
<b>Not Certified to 214, S9 (n = 28)</b>	<b>Count</b>	13	5	1	6	3
	<b>%</b>	46	18	4	21	11
<b>Certified to 214, S9 (n = 20)</b>	<b>Count</b>	17	2	1	0	0
	<b>%</b>	85	10	5	0	0

It is interesting to note that an identical percentage of vehicles (95 percent) that certified to FMVSS No. 214, S9 and achieved either a 5-star or 4-star side pole rating for the driver also certified to FMVSS No. 214, S7.2 and achieved a 5-star or 4-star side barrier rating for this occupant.

### CONCLUSIONS

Although MY 2011 vehicles tested under the new NCAP program generally received lower star ratings than those tested under the old program, the new model year vehicles offered a level of crash protection not seen in previous model year vehicle fleets.

In general, results confirm that the baseline injury risk of 15 percent is higher than the level of injury risk in MY 2011 vehicles tested under the new program. Vehicle manufacturers have, for the most part, responded to the challenge to improve their vehicles' crashworthiness. The following summarizes the major conclusions made from these analyses of MY 2011 vehicles tested under the new program.

For the frontal NCAP program:

1. The average combined injury probability for the 50<sup>th</sup> percentile male driver dummy from MY 2007 to MY 2011 has decreased.
2. Based on the range of combined injury probabilities and observed percentage of IARVs for the driver from MY 2011 vehicles tested under the new program, the new model year vehicle fleet appears to offer a better, more homogenous level of frontal injury protection than in previous model year vehicle fleets.
3. Based on the range of combined injury probabilities and observed percentages of IARVs from MY 2011 vehicles tested under the new program, those vehicles seem to offer better frontal crash protection for the driver than for the front passenger.
4. The average star rating for the driver in MY 2011 vehicles was 4-stars, while the average rating for the right front passenger was 3-stars. There were no 1-star ratings assigned to either position in MY 2011 vehicles tested under the new program.

For the side NCAP program:

1. The average star rating for driver and rear passenger dummies in vehicles certifying to the new side MDB requirements was 5-stars. It was 4-stars for those vehicles that have not yet certified to the new requirements.
2. For the side MDB test, thoracic and abdominal injuries were found to have the largest influence on star ratings for the driver dummy, while pelvic injuries were shown to have the greatest impact on star ratings for the rear passenger dummy.
3. Reductions in average injury values for the driver dummy in the side MDB test were fairly comparable for all body regions. Reductions in average injury values for the rear passenger SID-II dummy in the side MDB test were most apparent for the head, lower spine, and pelvis.
4. For carryover models, the new side NCAP rating system proved to be more stringent than the old side NCAP rating system for both the driver and rear passenger dummies in the side MDB test.
5. The average star rating for the driver dummy in vehicles certifying to the new side pole test requirements was 5 stars; it was 4 stars for those vehicles that did not certify to the new requirements.

6. Pelvic force was found to have the largest influence on the side pole star rating for the driver dummy.
7. The most prominent reductions in average injury values for the driver dummy in the side pole test were for the thoracic and abdominal ribs.
8. Combined injury risks for the 50<sup>th</sup> percentile male driver dummy in the side MDB test and for the 5<sup>th</sup> percentile female driver in the side pole test were similar.
9. For the side MDB and side pole tests, the overall average risk of injury for the dummies in vehicles redesigned to meet the new FMVSS No. 214 requirements was reduced by half or more compared to those vehicles that have not yet been redesigned.

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