THE ENHANCED U.S. NCAP: FIVE YEARS LATER

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ABSTRACT

The U.S. New Car Assessment Program (NCAP) encourages vehicle manufacturers to make safety improvements to their vehicles through its award-winning consumer information-based 5-Star Safety Ratings Program. Occupant injury readings have decreased and star ratings have generally improved since the program was enhanced in the 2011 Model Year (MY). This paper summarizes vehicle crash test results for the five MYs since the program was last upgraded to demonstrate how quickly vehicles have been redesigned to achieve high ratings under the more stringent requirements. As a result, most vehicles are achieving 4- or 5-star ratings. Though there are still vehicles the agency has tested that do not achieve the highest ratings, the performance of the majority of vehicles tested under the enhanced program is excellent. This sets the stage for the agency to begin exploring the possibility of making additional changes to the current program to spur even further vehicle safety improvements through market forces and consumer demand. The NCAP's crash test data (specifically, occupant injury data) and star ratings derived from those data will be used throughout this study. Occupant performance from the first year of the enhanced program will be compared to more recent results. A comparative analysis of paired data for vehicles that have been tested and retested under the enhanced NCAP will also be shown. These analyses will serve to demonstrate the effectiveness of the program in encouraging vehicle manufacturers to make immediate design changes that improve the occupant protection afforded by their vehicles.

LIMITATIONS OF THIS STUDY

The crash test data included in this study spans MYs 2011 to 2015; however, MY 2015 data is limited as testing was not completed in time for all results to be included in this publication. Also, the study is limited by the vehicles the NCAP selected each MY for testing. Though these tests encompass results from over 85% of the vehicles (by projected sales volume) in the U.S. fleet each MY they do not represent the composition of the entire fleet (NHTSA 2013d). Therefore, the authors do not make any further projections about overall fleet safety. Furthermore, this study also does not include an analysis of how the probabilities of injury risk measured in NCAP tests relate to the reduction of real-world injuries and fatalities.

HISTORY OF THE U.S. NCAP

The National Highway Traffic Safety Administration (NHTSA) established the NCAP in 1978 in response to Title II of the Motor Vehicle Information and Cost Savings Act of 1972. At the time, the agency only assessed vehicles for their occupant protection in frontal impacts. Though stars were not used at the time, it has been estimated that less than 30% of those tested vehicles would have been able to achieve the highest possible ratings (4 or 5 stars) for the driver (2008a). After several years and the addition of a side moving deformable barrier (MDB) impact crash test for MY 1997 vehicles, and a rollover resistance test in MY 2001, the NCAP began soliciting comments for a program overhaul in 2007 (2007a). The agency began testing and rating vehicles under an enhanced program (NHTSA 2008a) in 2010 beginning with MY 2011 vehicles. Under the enhanced program, the agency continues to conduct a 35 mph (56 km/h) vehicle frontal impact rigid barrier test and a 38.5 mph (62 km/h) MDB side impact vehicle test, but now uses newer side-impact test dummies compared to the previous program. The enhanced program now also includes a 20 mph (32 km/h) vehicle side impact pole test. For each test type, injury data from each occupant is

collected from different body regions and is incorporated into a single combined probability of injury. An occupant's combined probability of injury is divided by a baseline risk of injury and the resulting relative risk score, or RRS, is converted to a star rating for that occupant. The results of all three crash tests are then merged with the results from a rollover resistance test, which remained unchanged from the previous version of the program, in order to provide consumers with a single, combined vehicle rating known as the Overall Vehicle Score (OVS) (NHTSA 2008a).

The agency examined the performance of vehicles tested soon after the enhanced program was initially launched and was encouraged that those results showed lower levels of injury when compared to the performance of vehicles tested under the previous version of the program (Park 2011). After five MYs, the agency believes that sufficient data has been collected to adequately assess occupant performance in modern vehicles under the NCAP. This paper will present the results of this analysis.

Since the rollover resistance test remained the same under the enhanced program and this paper focuses only on crashworthiness results, the authors will not explore the results of that testing mode over the past five MYs. Likewise, since rollover results are needed to calculate the OVS, this paper will not discuss how that particular metric has changed. Each section below will briefly describe the test setup and protocol for each crash test mode before describing the results of the study. If desired, additional procedural details can be obtained from the individual test protocols (NHTSA 2013a, b, and c), and more detailed information pertaining to the injury risk curves and ratings system can be found in the appendices of the "Final decision" notice (NHTSA 2008a).

METHODOLOGY OF ANALYSES

The purpose of this study was to determine the effectiveness of the program over the five MYs since the enhancements were implemented, primarily by comparing crash test data from previous versions of make models selected and tested in the program with those of a later version. To accomplish this, NCAP test data was analyzed in two ways.

First, for each test mode, aggregate crash test results from the beginning of the enhanced NCAP were compared to the most recent data collected. Unpaired t-tests were conducted to determine whether occupant injury probability and star ratings from MY 2011vehicles were different from those collected for MY 2014-2015 vehicles. The last two years of test data were combined to ensure sufficient data points for analysis since the full set of 2015 data was not available at the time of publication. For ease of discussion, this analysis will be referred to as the unpaired analysis. Both star ratings and the occupant combined injury probabilities were analyzed because it was thought that the two could show different nuances in the data.

Second, vehicles that were tested more than once from the 2011 to 2015 MYs were identified and isolated to perform a similar analysis. At the beginning of each MY, the NCAP solicits information about light vehicle production from each vehicle manufacturer. In these requests, manufacturers are given the opportunity to inform the agency about the vehicles they plan to produce in the next MY. Some vehicle designs are considered identical from one MY to the next. When this is the case, the NCAP is able to "carry over" a given set of vehicle ratings to the next MY. In other cases, design changes are made that only affect the performance of a vehicle in one test mode. For example, changes may be made to the design of a frontal air bag which could result in retesting the vehicle for the frontal rigid barrier test, but not for the side impact test modes.

The authors examined data from the "first" and "last" times a make and model was tested under the enhanced NCAP and, using paired t-tests, tried to determine whether design changes between those two versions resulted in measurable improvements in the crash protection afforded to the vehicle occupants. Some vehicles may have been tested more than twice over this time period, such that other test data fell in the interim – either after the "first" test or before the "last" test. In these cases, manufacturers may have incorporated one or more interstitial design changes in vehicles that were not necessarily successful in achieving better star ratings, which resulted in retesting those vehicles several times during the course of the enhanced program. For ease of calculation and discussion, the authors decided to exclude this interim data and focus only on the first and last tests from the past five MYs. By selecting the latest version tested, it was expected that manufacturers' best efforts to date would be captured. This second

analysis will be referred to as the paired analysis. Test results from the first time a given vehicle model was tested under the enhanced program were compared to those from the most recent time that vehicle was retested.

In addition, data was analyzed based on changes to the ratings assigned, which may or may not be represented by the same vehicle make and model from year to year. This is due to several factors. For instance, vehicle manufacturers may change and/or rebrand particular vehicle names from one year to the next. A vehicle model may also be referred to as something new from a marketing perspective, but in actuality, it is identical to a model that was previously produced. In addition, vehicles that a manufacturer claims are corporate twins in one MY may not be designated as such in subsequent years.

Lastly, some vehicles demonstrated an increase in risk of occupant injuries (or a subsequent decrease in star ratings) after a redesign. No additional effort was made to determine how or why these vehicles performed more poorly after a redesign.

RESULTS

Frontal NCAP – Rigid Barrier Test

The NCAP's frontal star ratings are based on the performance of two Hybrid III dummies installed in the first row of a vehicle. The driver is a 50th percentile male and the right front passenger is a 5th percentile female. For this test, the vehicle impacts a rigid wall at 35 mph (56 km/h) (NHTSA 2013a). Readings from the dummies' heads, necks, chests, and legs are used to calculate combined probabilities of AIS3+ injury, which are then divided by a baseline risk of injury and converted to star ratings (NHTSA 2008a). For ease of discussion, this paper will primarily focus on the probabilities of injuries recorded by the test dummies and the star ratings assigned to them, and will not explain the calculations involved, as these are presented in detail in the 2008 "Final decision" notice (2008a).

A summary of the average probabilities of injury and star ratings over the years for the driver and front passenger dummies in the frontal NCAP test may also be found in the Appendix in Tables A1-A4.

Comparison of unpaired vehicle data – 2011 versus 2014/2015 (unpaired analysis) The average combined injury probabilities and star ratings for the driver dummy did not change much from MY 2011 to MY 2014/2015. There was no statistical difference found at the 95% confidence interval as evidenced by the P-value between the MY 2011 and MY 2014/2015 data sets when considering the occupants' combined injury probabilities and star ratings. However, differences between MY 2011 and MY 2014/2015 average combined injury probabilities and star ratings for the right front passenger were found to be statistically significant at the 95% confidence interval. The combined injury probabilities showed a significant decrease, and consequently, the star rating significantly increased. Table 1 details the results of this analysis.

Table 1.
Results of Frontal NCAP Unpaired Analysis

	Frontal NCAP Driver				**Frontal NCAP Front Passenger**			
	Comb. Injury Prob.		***Star Rating***		***Comb. Injury Prob.***		***Star Rating***	
Data Set	**2011**	**2014/15**	**2011**	**2014/15**	**2011**	**2014/15**	**First Test**	**Last Test**
t-stat	0.928		0.386		4.219		4.532	
Two tailed P-value	0.355		0.700		< 0.0001		< 0.0001	
Mean	0.117	0.111	4.28	4.33	0.151	0.117	3.55	4.24
Standard Deviation	0.036	0.036	0.81	0.73	0.051	0.042	0.92	0.82
N	64	66	64	66	64	66	64	66

Comparison of paired vehicle data – 2011 versus most recent test (paired analysis) While driver performance in frontal NCAP has not improved significantly on average from MY 2011, the paired analysis shows that when manufacturers make changes to specific vehicles, significant improvements are seen in both combined injury probabilities and star ratings. These differences were significant at the 95% confidence level. Likewise, differences in the most updated vehicles' right front passenger combined injury probabilities and star ratings were

also statistically significant at the 95% confidence level. Both the driver and right front passenger dummies' combined injury probabilities showed a significant decrease, and consequently, the star ratings significantly increased. Table 2 illustrates the results for this analysis.

Table 2.
Results of Frontal NCAP Paired Analysis

	Frontal NCAP Driver				**Frontal NCAP Front Passenger**			
	Comb. Injury Prob.		***Star Rating***		***Comb. Injury Prob.***		***Star Rating***	
Data Set	**First Test**	**Last Test**	**First Test**	**Last Test**	**First Test**	**Last Test**	**First Test**	**Last Test**
t-stat	4.443		3.244		7.889		7.496	
Two tailed P-value	< 0.0001		0.0018		< 0.0001		< 0.0001	
Mean	0.121	0.103	4.19	4.49	0.158	0.118	3.41	4.18
Standard Deviation	0.040	0.023	0.84	0.58	0.054	0.038	0.93	0.71
N	73		73		73		73	

Side NCAP – MDB Test

The side MDB NCAP test is conducted by towing an MDB into the driver's side of a stationary vehicle crabbed at a 27 degree angle at 38.5 mph (62 km/h) (NHTSA 2013b). An ES-2re 50th percentile male dummy is seated in the driver's seat, and a 5th percentile female SID-IIs dummy is seated in the rear seat behind the driver. Readings from the driver dummies' heads, chests, abdomens, and pelvises, and the rear passenger dummies' heads and pelvises, are used to calculate combined probabilities of AIS3+ injury, which are then divided by a baseline risk of injury and converted to star ratings (NHTSA 2008a).

A summary of the average injury probabilities over the years for the driver and rear passenger dummies in the side MDB test may be found in the Appendix in Tables A5-A8.

Comparison of unpaired vehicle data – 2011 versus 2014/2015 (unpaired analysis) As shown in Table 3, the differences between both the star ratings and the combined injury probabilities in the 2011 data and the 2014/2015 data were found to be statistically significant at the 95% confidence interval for both dummies in the side MDB test. Both the driver and rear passenger dummies' combined injury probabilities showed a significant decrease, and consequently, the star ratings significantly increased. Five-star ratings dominate the 2014/2015 data set; 89% of driver ratings and 96% of rear passenger ratings were five stars. These figures can be compared to 67% of driver ratings and 68% of rear passenger ratings that achieved five stars in the 2011 data set.

Table 3.
Results of Side MDB NCAP Unpaired Analysis

	Side MDB NCAP Driver				**Side MDB NCAP Rear Passenger**			
	Comb. Injury Prob.		***Star Rating***		***Comb. Injury Prob.***		***Star Rating***	
Data Set	**2011**	**2014/15**	**2011**	**2014/15**	**2011**	**2014/15**	**2011**	**2014/15**
t-stat	3.820		3.518		3.353		3.585	
Two tailed P-value	0.0002		0.0006		0.0010		0.0005	
Mean	0.099	0.057	4.44	4.87	0.087	0.047	4.37	4.88
Standard Deviation	0.088	0.034	0.96	0.41	0.089	0.051	1.04	0.59
N	64	75	64	75	62	75	62	75

Comparison of paired vehicle data – 2011 versus most recent test (paired analysis) For the paired analysis, Table 4 shows the differences between the combined injury probabilities and star ratings in the two sets of data ("first" test versus "last" test) were found to be significant at the 95% confidence interval. Both the driver and rear

passenger dummies' combined injury probabilities showed a significant decrease, and consequently, the star ratings significantly increased.

Table 4.
Results of Side MDB NCAP Paired Analysis

	Side MDB NCAP Driver				**Side MDB NCAP Rear Passenger**			
	Comb. Injury Prob.		***Star Rating***		***Comb. Injury Prob.***		***Star Rating***	
Data Set	**First Test**	**Last Test**	**First Test**	**Last Test**	**First Test**	**Last Test**	**First Test**	**Last Test**
t-stat	3.884		4.323		4.073		3.915	
Two tailed P-value	0.0002		< 0.0001		0.0001		0.0002	
Mean	0.093	0.062	4.38	4.79	0.093	0.046	4.32	4.86
Standard Deviation	0.083	0.052	0.91	0.58	0.095	0.048	1.10	0.51
N	72		72		72		72	

Side NCAP – Pole Test

The side impact pole test, which was new to the NCAP beginning with the enhanced program, is conducted by towing a test vehicle angled at 75 degrees sideways at 20 mph (32 km/h) into an 8 in. (20 cm) diameter rigid pole (NHTSA 2013c). To assess the maximum injury potential in this type of crash, the test protocol requires that the pole be aligned with the center of gravity (CG) of the SID-IIs 5th percentile female driver dummy's head. Readings from the dummies' heads and pelvises are used to calculate combined probabilities of AIS3+ injury, which are then divided by a baseline risk of injury and converted to star ratings (NHTSA 2008a).

A summary of the average injury probabilities and star ratings over the years for the driver dummy in the side pole test may be found in the Appendix as Tables A9 and A10.

Comparison of unpaired vehicle data – 2011 versus 2014/2015 (unpaired analysis) The driver dummy in the side NCAP pole test has seen a large increase in average star ratings since the beginning of the enhanced program in 2011. Both the dummy and the crash test type were completely new beginning with that MY. Despite the obvious increase in pole test driver star ratings over the past few years, a t-test to determine significance was performed comparing the first MY of data to the most recent. The results of this analysis proved statistical significance for the decrease in the combined probability of injury and for the increase in the star rating at the 95% confidence level.

Table 5.
Results of Side Pole NCAP Unpaired Analysis

	Side Pole NCAP Driver			
	Comb. Injury Prob.		***Star Rating***	
Data Set	**2011**	**2014/15**	**2011**	**2014/15**
t-stat	4.229		4.448	
Two tailed P-value	< 0.0001		< 0.0001	
Mean	0.137	0.063	4.10	4.84
Standard Deviation	0.145	0.034	1.35	0.44
N	62	74	62	74

Comparison of paired vehicle data – 2011 versus most recent test (paired analysis) For the paired analysis, the data shows that manufacturers' efforts to improve performance were extremely successful. The t-test analysis shows that between the "first" and "last" vehicle tests, the reduction in probability of injury and the increase in star ratings are both significant at the 95% confidence level. The driver dummies' combined injury probabilities showed a significant decrease, and consequently, the star rating significantly increased.

Table 6.
Results of Side Pole NCAP Paired Analysis

	Side Pole NCAP Driver			
	Comb. Injury Prob.		*Star Rating*	
Data Set	**First Test**	**Last Test**	**First Test**	**Last Test**
t-stat	4.518		5.688	
Two tailed P-value	< 0.0001		< 0.0001	
Mean	0.181	0.065	3.79	4.81
Standard Deviation	0.216	0.033	1.46	0.43
N	70		70	

DISCUSSION

Percentages listed in the below analyses are derived from the data found in the Appendix.

Unpaired Analysis

It is expected that the driver data in the frontal NCAP test would not show significance when comparing the MY 2011 data to the most recent years' data because the dummy type and seating method remained the same in the enhanced program even though the method used to assess the driver dummy's injuries was changed. The 50th percentile Hybrid III dummy has been a fixture as the driver in the frontal NCAP test since 1986 (1995). These circumstances may have given manufacturers a head start in developing design strategies for vehicles tested under the requirements of the enhanced program.

When the enhanced program began (MY 2011), the right front occupant in the frontal crash test had a larger proportion of two- and three-star ratings than the frontal driver did; nearly 38% of right front passenger ratings were less than four stars as opposed to 16% of driver ratings. By MY 2014/2015, these percentages had decreased to 12% for the front passenger and 9% for the driver. The occupants that showed the greatest improvement since the enhanced program began in terms of average star ratings were the Hybrid III 5th percentile female in the right front passenger seat of the frontal test and the 5th percentile SID-IIs driver in the pole test. Since the enhanced program's inception, these occupants experienced a 19% and 18% increase in average star ratings, respectively. The use of 5th percentile female dummies was new to the NCAP in MY 2011. The pole test configuration itself was also completely new. Manufacturers have developed countermeasures to reduce injury risk in these crashes. For instance, the combined probability of injury for the 5th percentile female in the pole test has been reduced by more than half (54%) since MY 2011. For the side MDB test, the probability of injury in the 5th percentile female SID-IIs, seated in the rear seat, reduced by half – more or less (47%), and star ratings increased by 12% on average.

The 50th percentile male ES-2re dummy was also new for the enhanced program. Similar to the results of the SID-IIs in the side MDB test, the ES-2re dummy showed a marked decrease in the combined probability of injury (42%) with only a moderate increase in average star ratings (10%).

The NCAP also tests vehicles beyond the requirements of the Federal Motor Vehicle Safety Standards (FMVSSs), and this is accomplished in several ways. For instance, the NCAP tests vehicles that are beyond the weight requirements set forth in various FMVSSs. This allows the program to select and test vehicles with up to a 10,000 lb (4,536 kg) Gross Vehicle Weight Rating (GVWR) to ensure that some popular consumer vehicles are subject to full-scale crash testing when they may not have been otherwise. Hence, the NCAP test results of certain vehicles may highlight the need for further refinements perhaps in the restraint systems to achieve better NCAP performance. For instance, side air bags, particularly chest and pelvis air bags, are now seen more often in larger vehicles. Note that risk of head injury in the side MDB test is very low and has been, at least since the enhanced program's inception (Table A5). Prior to the enhanced program, side curtain air bags were not necessarily needed to achieve top ratings for these vehicles, but the addition of the side pole test has challenged manufacturers to include safety equipment for head and chest protection on vehicles, including those with GVWRs that exceed FMVSSs. In the MYs during which the enhanced program was formally announced (MY 2009), no vehicles with GVWR between 8,500 lb and 10,000 lb (3,856 kg to 4,536 kg) offered side air bags to protect the occupant's chest or pelvis, and only 38% of these

models offered head protection. Now, many more vehicle models in the MY 2015 heavy vehicle fleet offer side air bags, and all models offer head protection, with 47% of them having head air bags as standard equipment. Additionally, 73% of models offer chest and/or pelvis protection as either optional or standard equipment.

Paired Analysis

Injury probabilities and star ratings examined in the paired analysis showed promising results for all occupants in the NCAP's crash tests.

While the average combined injury probability for the frontal crash test driver decreased by only 5% in the unpaired analysis, it decreased by 15% when looking at the paired vehicle tests; the decrease was sufficient to achieve statistical significance. Accordingly, the average star ratings for the frontal crash test driver increased by 1% in the unpaired analysis versus an increase of 7% in the paired analysis. The frontal crash test passenger's combined injury probability decreased by 25% and the star ratings increased by 23% in the paired study. This provides evidence that manufacturers are responding to frontal NCAP crash test results and further support the hypothesis that manufacturers are making specific design changes to improve occupant performance in vehicles with lower NCAP star ratings even when the larger population of frontal NCAP vehicles shows generally good performance.

The side pole test driver in this paired analysis experienced the largest decrease (64%) in average combined probability of injury of any occupant in either analysis and a 27% increase in average star ratings, an average of greater than one whole star, which was the largest of any occupant's average star rating increase. In fact, a large number of pole test ratings increased by three (n=10, 14%) and even four (n=6, 9%) stars after redesign. In the same analysis, the driver in the side MDB test experienced a 33% reduction in average combined injury probability. The reductions in both MDB and pole test driver combined injury probabilities demonstrate that the driver's position in side impact tests is becoming safer for both the 50th percentile male and the 5th percentile female. Also, it appears countermeasures can be put in place to improve injury readings for both the 50th percentile male and the 5th percentile female. The rear passenger in the MDB test paired data set saw a decrease in average combined injury probability of 51% and star ratings increased 13%. No ratings increased by four stars, but unlike in the pole test, none of the rear passenger ratings were one-star initially, so a four-star increase would be unattainable. Of the ten vehicles in which the rear passenger received a two-star rating, eight vehicles were modified in the later version and achieved five-star ratings.

Though the specific details of a given vehicle's design changes are considered confidential information, there are some general trends in restraint and structural changes the authors can note that have occurred during the past five years of the enhanced program. To improve their vehicles' frontal crash performance, manufacturers made air bag design and deployment refinements, and modifications to advanced seat belt features such as load limiters and pretensioners. Manufacturers have also made front-end changes to better manage crash energy. Regarding the side impact crash mode, the presence of the 5th percentile female SID-IIs in the rear seat of each MDB test seems to have encouraged manufacturers to equip more rear seating positions with side torso air bags or larger torso-abdomen-pelvis (TAP) air bags. This equipment was not often seen prior to the enhanced program. Manufacturers have also opted to install TAP air bags in many front row seats to maximize vehicle performance in both side impact tests. Structural improvements to the side sills, pillars, and door trims have also been made to reduce intrusion into the occupant compartment and/or provide a load path through the vehicle, particularly for the pole test. Chamber locations in curtain air bags have been modified to protect both the 50th percentile male and the 5th percentile female in side crash scenarios.

Four of the vehicles included in the paired analysis had GVWRs between 8,500 lb and 10,000 lb (3,856 kg to 4,536 kg). In all four cases, the combined probabilities of injury substantially improved for the pole test between the first and last test. Three driver occupants experienced high head injury probabilities during the first test. In these cases, injury probabilities appeared to be later improved, in part by the addition of side curtain air bags. The fourth case involved a driver whose pelvic injury probability was high. Side torso air bags were added to this vehicle, among other improvements, and its star rating increased dramatically.

Occupant protection performance in vehicle crash tests is complex. There is no single way to reach a five-star rating, and vehicle manufacturers employ a variety of techniques to achieve the top ratings. In addition, manufacturers must take into account other factors such as vehicle weight, style, and comfort. However, because of improvements made to vehicles, most manufacturers were successful in their efforts to decrease probability of injury and therefore

increase star ratings. The paired analysis suggests that, in the majority of cases, when manufacturers choose to implement design changes, occupant safety is enhanced.

CONCLUSIONS

Two methods of analysis were used to compare changes to occupant injury risk under the enhanced NCAP. An unpaired analysis was undertaken to generally assess the state of injury risk and vehicle ratings in both the first MY of the enhanced program and the most recent MYs, 2014 and 2015. A paired analysis was then run to investigate whether vehicle redesigns were successful in reducing injury risk. All differences were statistically evaluated using t-tests, and for these analyses, significance is defined using a 95% confidence interval.

Driver data in the frontal NCAP test does not show a significant difference overall when comparing MY 2011 to 2014/2015. Likely, manufacturers had already had a head start in designing strategies to protect this occupant in this test mode, as the dummy, seating procedure, and test itself did not change under the enhanced program. However, when considering the paired analysis, driver results from the first and last tests of a vehicle, when one was retested, showed that injury risk was significantly decreased and star ratings significantly increased.

Passenger data in the frontal NCAP test, as well as driver and passenger data from the side impact tests (MDB and pole), show significant decreases in injury risk and, subsequently, significant increases in star rating. This is true for both the unpaired and paired analyses and suggests that manufacturers are successfully responding to the enhanced NCAP crash tests.

Vehicles with GVWRs between 8,500 lb to 10,000 lb (3,856 kg to 4,536 kg) are, in general, being fitted with additional safety equipment in recent MYs. The additions protect body regions which are evaluated in the enhanced NCAP's crash tests, particularly those in the side pole test. When side impact safety equipment was added to the four heavier vehicles included in the paired study, side pole star ratings increased substantially.

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APPENDIX

Table A1.
Frontal NCAP Driver Average Probability of Injury Readings and Number of Star Ratings by Model Year

	2011	2012	2013	2014	2015	2014/2015 Combined	All Years
Number of Ratings	64	69	57	42	24	66	256
Average Probability of Head Injury	0.005	0.005	0.006	0.008	0.006	0.008	0.006
Average Probability of Neck Injury	0.069	0.069	0.071	0.070	0.070	0.070	0.070
Average Probability of Chest Injury	0.029	0.032	0.021	0.026	0.024	0.025	0.027
Average Probability of Leg Injury	0.018	0.015	0.012	0.013	0.010	0.012	0.014
Average Occupant Combined Injury Probability	0.117	0.116	0.106	0.113	0.107	0.111	0.113
Average Star Rating	4.28	4.30	4.44	4.29	4.42	4.33	4.34

Table A2.
Frontal NCAP Driver Star Ratings by Model Year

	2 Star Rating		3 Star Rating		4 Star Rating		5 Star Rating		Total
Model Year	**Count**	**% Total**	**Count**	**% Total**	**Count**	**% Total**	**Count**	**% Total**	
2011	2	3.13%	8	12.50%	24	37.50%	30	46.88%	64
2012	2	2.90%	4	5.80%	34	49.28%	29	42.03%	69
2013	1	1.75%	5	8.77%	19	33.33%	32	56.14%	57
2014	1	2.38%	4	9.52%	19	45.24%	18	42.86%	42
2015	1	4.17%	0	0.00%	11	45.83%	12	50.00%	24
2014/2015 Combined	2	3.03%	4	6.06%	30	45.45%	30	45.45%	66
Total	**7**	**2.73%**	**21**	**8.20%**	**107**	**41.80%**	**121**	**47.27%**	**256**

Table A3.
Frontal NCAP Front Passenger Average Probability of Injury Readings and Number of Star Ratings by Model Year

	2011	2012	2013	2014	2015	2014/2015 Combined	All Years
Number of Ratings	64	69	57	42	24	66	256
Average Probability of Head Injury	0.015	0.013	0.012	0.008	0.011	0.009	0.012
Average Probability of Neck Injury	0.104	0.094	0.088	0.082	0.081	0.082	0.092
Average Probability of Chest Injury	0.018	0.016	0.014	0.014	0.018	0.015	0.016
Average Probability of Leg Injury	0.022	0.022	0.014	0.015	0.013	0.015	0.018
Average Occupant Combined Injury Probability	0.151	0.140	0.124	0.116	0.119	0.117	0.133
Average Star Rating	3.55	3.71	4.05	4.24	4.25	4.24	3.88

Table A4.
Frontal NCAP Front Passenger Star Ratings by Model Year

	2 Star Rating		3 Star Rating		4 Star Rating		5 Star Rating		Total
Model Year	**Count**	**% Total**	**Count**	**% Total**	**Count**	**% Total**	**Count**	**% Total**	
2011	12	18.75%	12	18.75%	33	51.56%	7	10.94%	64
2012	4	5.80%	21	30.43%	35	50.72%	9	13.04%	69
2013	2	3.51%	9	15.79%	30	52.63%	16	28.07%	57
2014	3	7.14%	2	4.76%	19	45.24%	18	42.86%	42
2015	1	4.17%	2	8.33%	11	45.83%	10	41.67%	24
2014/2015 Combined	4	6.06%	4	6.06%	30	45.45%	28	42.42%	66
Total	**22**	**8.59%**	**46**	**17.97%**	**128**	**50.00%**	**60**	**23.44%**	**256**

Table A5.
Side MDB NCAP Driver Average Probability of Injury Readings and Number of Star Ratings by Model Year

	2011	**2012**	**2013**	**2014**	**2015**	**2014/2015 Combined**	**All Years**
Number of Ratings	64	66	52	46	29	75	257
Average Probability of Head Injury	0.001	0.001	0.001	0.001	0.000	0.001	0.001
Average Probability of Chest Injury	0.070	0.059	0.040	0.040	0.040	0.040	0.052
Average Probability of Abdomen Injury	0.027	0.023	0.018	0.014	0.013	0.014	0.020
Average Probability of Pelvis Injury	0.006	0.005	0.004	0.003	0.003	0.003	0.004
Average Occupant Combined Injury Probability	0.099	0.085	0.062	0.058	0.055	0.057	0.076
Average Star Rating	4.44	4.56	4.81	4.87	4.86	4.87	4.67

Table A6.
Side MDB NCAP Driver Star Ratings by Model Year

	1 Star Rating		2 Star Rating		3 Star Rating		4 Star Rating		5 Star Rating		Total
Model Year	**Count**	**% Total**	**Count**	**% Total**	**Count**	**% Total**	**Count**	**% Total**	**Count**	**% Total**	
2011	1	1.56%	3	4.69%	6	9.38%	11	17.19%	43	67.19%	64
2012	0	0.00%	2	3.03%	7	10.61%	9	13.64%	48	72.73%	66
2013	0	0.00%	0	0.00%	1	1.92%	8	15.38%	43	82.69%	52
2014	0	0.00%	0	0.00%	1	2.17%	4	8.70%	41	89.13%	46
2015	0	0.00%	0	0.00%	1	3.45%	2	6.90%	26	89.66%	29
2014/2015 Combined	0	0.00%	0	0.00%	2	2.67%	6	8.00%	67	89.33%	75
Total	**1**	**0.39%**	**5**	**1.95%**	**16**	**6.23%**	**34**	**13.23%**	**201**	**78.21%**	**257**

Table A7.
Side MDB NCAP Rear Passenger Average Probability of Injury Readings and Number of Star Ratings by Model Year

	2011	2012	2013	2014	2015	2014/2015 Combined	All Years
Number of Ratings	62	66	51	46	29	75	254
Average Probability of Head Injury	0.009	0.021	0.007	0.009	0.005	0.007	0.011
Average Probability of Pelvis Injury	0.079	0.073	0.041	0.044	0.033	0.040	0.058
Average Occupant Combined Injury Probability	0.087	0.092	0.047	0.052	0.038	0.047	0.068
Average Star Rating	4.37	4.38	4.86	4.80	5.00	4.88	4.62

Table A8.
Side MDB NCAP Rear Passenger Star Ratings by Model Year

	1 Star Rating		2 Star Rating		3 Star Rating		4 Star Rating		5 Star Rating		Total
Model Year	**Count**	**% Total**	**Count**	**% Total**	**Count**	**% Total**	**Count**	**% Total**	**Count**	**% Total**	
2011	0	0.00%	7	11.29%	5	8.06%	8	12.90%	42	67.74%	62
2012	1	1.52%	6	9.09%	5	7.58%	9	13.64%	45	68.18%	66
2013	0	0.00%	1	1.96%	1	1.96%	2	3.92%	47	92.16%	51
2014	0	0.00%	3	6.52%	0	0.00%	0	0.00%	43	93.48%	46
2015	0	0.00%	0	0.00%	0	0.00%	0	0.00%	29	100.00%	29
2014/2015 Combined	0	0.00%	3	4.00%	0	0.00%	0	0.00%	72	96.00%	75
Total	**1**	**0.39%**	**17**	**6.69%**	**11**	**4.33%**	**19**	**7.48%**	**206**	**81.10%**	**254**

Table A9.
Side Pole NCAP Driver Average Probability of Injury Readings and Number of Star Ratings by Model Year

	2011	2012	2013	2014	2015	2014/2015 Combined	All Years
Number of Ratings	62	64	48	46	28	74	248
Average Probability of Head Injury	0.024	0.064	0.036	0.015	0.012	0.014	0.034
Average Probability of Pelvis Injury	0.117	0.082	0.064	0.048	0.054	0.050	0.078
Average Occupant Combined Injury Probability	0.137	0.136	0.098	0.062	0.065	0.063	0.107
Average Star Rating	4.10	4.23	4.52	4.85	4.82	4.84	4.44

Table A10.
Side Pole NCAP Driver Star Ratings by Model Year

	1 Star Rating		2 Star Rating		3 Star Rating		4 Star Rating		5 Star Rating		Total
Model Year	**Count**	**% Total**	**Count**	**% Total**	**Count**	**% Total**	**Count**	**% Total**	**Count**	**% Total**	
2011	5	8.06%	7	11.29%	2	3.23%	11	17.74%	37	59.68%	62
2012	4	6.25%	5	7.81%	6	9.38%	6	9.38%	43	67.19%	64
2013	1	2.08%	1	2.08%	3	6.25%	10	20.83%	33	68.75%	48
2014	0	0.00%	0	0.00%	1	2.17%	5	10.87%	40	86.96%	46
2015	0	0.00%	0	0.00%	1	3.57%	3	10.71%	24	85.71%	28
2014/2015 Combined	0	0.00%	0	0.00%	2	2.70%	8	10.81%	64	86.49%	74
Total	**10**	**4.03%**	**13**	**5.24%**	**13**	**5.24%**	**35**	**14.11%**	**177**	**71.37%**	**248**

For the star rating tables, percentages may not total 100 due to rounding.