THE EFFECT OF REDESIGNED AIR BAGS ON FRONTAL USA NCAP

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ABSTRACT

In March 1997, the National Highway Traffic Safety Administration (NHTSA) temporarily amended Federal Motor Vehicle Safety Standard (FMVSS) No. 208 to allow manufacturers more flexibility in the use of less aggressive air bags. Beginning with the 1998 model year (MY), most vehicles produced for sale in the US market were equipped with these redesigned frontal air bags. This paper investigates how the safety ratings as developed in the New Car Assessment Program (NCAP) were affected by the introduction of these air bags.

Results from thirty-three MY 1998 vehicles crash tested for frontal NCAP were compared with the same make and models vehicles that were previously tested in NCAP. The only differences between the MY 1998 vehicles and the earlier vehicles are the redesigned air bags and other restraint system changes (i. e. , safety belt or steering assembly modifications). The head injury criteria (HIC), chest accelerations (chest G's), combined injury probability, and NCAP star ratings are examined for the driver and right front passenger. The neck responses of the driver and right front passenger between two model years also are examined relative to the new neck requirements that were included in the March 1997 amendment to FMVSS No. 208.

The average HIC values were lower for the MY 1998 vehicles. The lower average was primarily due to reductions in HICs that occurred in light truck and vans. Average chest G values were found to be nearly the same for the MY 1998 vehicles, as a group, when compared to the earlier models. Average neck loads were found to be approximately the same except for neck extension. The neck extension moments for the newer air bag vehicles were lower.

INTRODUCTION

Frontal crashes are the most prevalent fatality and severe injury-causing type of crash. Such crashes result in 51 percent of all driver and right front passenger fatalities. Air bags are proven to be effective in reducing fatalities in these types of crashes. NHTSA estimates that, between 1986 and May 1, 1998, air bags have saved over 3,000 drivers and passengers. Based on current levels of effectiveness, air bags will save more than 3,000 lives each year in passenger cars and light trucks when all light vehicles on the road are equipped with dual air bags.[1]

However, real world crash investigations have established that air bags are causing fatalities and injuries in some situations, especially to children and small-stature adults. [2] NHTSA's Special Crash Investigation program has identified 57 crashes in which the deployment of the passenger air bag resulted in fatal injuries to a child — unfortunately many cases were in low speed crashes.

Two adult passengers have also been fatally injured. In addition, 38 drivers are known to have been fatally injured. [1] Based on the 1998 - 1994 National Automotive Sampling System (NASS), a study of frontal collisions found that arm injuries to belt restrained drivers who had an air bag deploy are more likely than for drivers belt restrained without a deploying air bag. [3]

From NHTSA's ongoing study of adults and children who sustained fatal or serious injuries in low-to moderate severity crashes, it is found that the harm to these occupants is due to their close proximity to the air bag when it deployed. The most common reason for their proximity was the failure to use safety belts. In addition, infants in rear-facing child safety seats sustained fatal head or neck injuries from the deploying passenger air bags because they were positioned in the right front seat close to the dashboard. NHTSA continues to emphasize children under 12 years of age and infants in rear-facing child safety seats should not be in the right front seat where an air bag could deploy. By contrast, NHTSA studies concluded that such fatalities are very rare in comparison to the number of vehicles equipped with air bags (about 73 million vehicles had air bags by May 1, 1998).

To assist in reducing these problems, in March 1997, NHTSA temporarily amended FMVSS No. 208 to allow manufacturers more flexibility in the use of less aggressive air bags.[1] This amendment provided an option for manufacturers to use a generic sled test in place of the 48 kmph rigid barrier crash test to certify vehicle compliance with the unbelted 50th percentile male driver and passenger dummies. Based on the agency's research and analysis, the agency concluded that an average reduction in the power of air bag inflators of 20 to 35 percent would reduce the risk of air bag fatalities and injuries to out-of position occupants in lower speed crashes, while the life-saving capabilities of air bags in higher speed crashes may be reduced for unbelted occupants (particularly unbelted passengers). Manufacturers contended that the sled test would make it possible to more rapidly introduce these less aggressive air bags in their vehicles. Subsequently, most of the MY 1998 vehicles were equipped with redesigned air bags.

The objective of this paper is to investigate the effects of these air bag changes on MY 1998 vehicles crash tested for frontal NCAP by comparing with the same make and models vehicles tested in NCAP in previous years. The head injury criteria (HIC), chest accelerations (chest G's), combined injury probability, and NCAP star ratings are examined for the driver and right front passenger. The neck responses of the driver and right front passenger between two model years also are examined relative to the new neck requirements that were included in the March 1997 amendment to FMVSS No. 208.

Frontal USA New Car Assessment Program

In 1979, NHTSA began assessing the occupant protection capabilities of new cars by conducting high speed frontal, barrier crash tests. The primary goals of the USA NCAP is to provide consumers with a measure of the relative safety potential of automobiles and to establish market forces which encourage vehicle manufacturers to design higher levels of safety into their vehicles. The USA NCAP represents the first program ever initiated to provide relative crashworthiness information to consumers on the potential safety performance of passenger vehicles. [4,5,6]

Frontal USA NCAP test speeds and impact locations closely resemble the conditions in a large proportion of actual frontal crashes that result in fatalities or serious injuries. In these controlled crash tests, the levels of potential injury are assessed by measurements taken from two instrumented anthropomorphic test devices (dummies) that simulate 50th percentile adult males. These dummies are located in the front driver and front-right passenger seats and are restrained by the vehicle's safety belts and air bags, if available. [4]

During the crash, measurements are taken from each dummy's head, chest and upper legs. The injury potential to the head is measured by a composite of acceleration values known as the Head Injury Criterion or HIC. The injury potential to the chest is measured by a chest deceleration value known as chest G's. For the upper legs, the injury potential is measured by compressive axial forces on each of the femur bones. [4]

Beginning with the model year 1994 vehicles, the agency adopted a simplified nonnumeric format, the five star rating, for the frontal NCAP results. [6] NHTSA wanted to give the US consumer easily grasped vehicle safety performance information. This nonnumeric format is based on the use of injury risk functions, that relate the Hybrid III dummy measurements to injury probabilities. [7,8] The head and chest injury data are combined into a single rating, reflected by the number of stars with:[6]

☆☆☆☆☆	=	10% or less chance of any serious injury to the head or chest
☆☆☆☆	=	11% to 20% chance of serious injury
☆☆☆	=	21% to 35% chance of serious injury
☆☆	=	36% to 45% chance of serious injury
☆	=	46% or greater chance of serious injury

The relationship of the star rating system to injury probability and to the range of HIC and chest G values is shown in Figure 1.

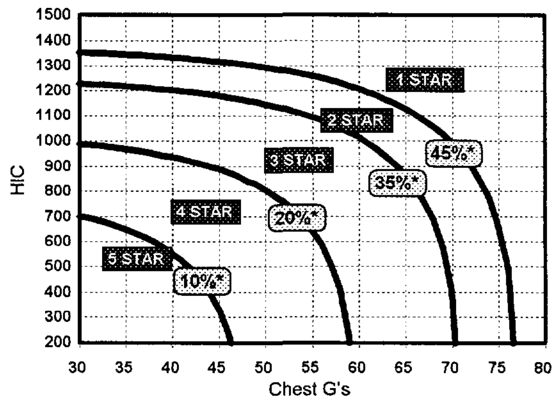

Figure 1. Relationship of the Star Rating and Probability to HIC and Chest G.

Consumers and interested parties may find the agency's safety information (i.e. star rating of vehicles) in several locations. World wide, one can reach the NCAP information on the agency's web site. The NHTSA web site address is www.nhtsa.dot.gov. NHTSA's web site provides a direct link to four other web sites world wide. The link reaches the (1) Insurance Institute for Highway Safety, (2) National Organization for Automotive Safety and Victim's Aid (Japan), (3) NRMA Crash Testing (Australia), and (4) Euro-NCAP (FIA Crash Testing).

RESULT AND DISCUSSION

For MY 1998, crash tests were conducted on fifty passenger cars, light trucks, vans, and sport utility vehicles in the frontal NCAP. In 1997, forty-two vehicles were tested. For this study, thirty-three vehicles have been selected and the pertinent dummy readings and star ratings are included in Table A1 of Appendix A. The thirty-three vehicles consist of different makes and models of twenty passenger cars and thirteen light trucks and vans (LTVs). A primary factor for selecting the vehicles is that the MY 1998 vehicles were reported by the manufacturers to have redesigned, or second generation, air bags for the driver and right front passenger as compared to the same make and model for MY 1997. Selected vehicles had no major structural changes between the two model years.

For the comparison, values of HIC, chest G's, and combined injury probability are examined. In addition, the redesigned air bag effects on the neck response of the 50th percentile Hybrid III dummy are studied (the neck readings for both years are included in Tables A2 and A3 of Appendix A). To examine the differences, the averages, standard deviations and ranges are calculated for the variables listed above for the two model years. The results are given for three vehicle groups: overall (combined passenger cars and LTVs), passenger cars, and LTVs. Calculated averages and standard deviation are tabulated in Table A4 of Appendix A.

Head Injury Criterion

The averages and standard deviations of HIC for the driver and right front passenger are illustrated in Figures 2 and 3. The results indicate that there is little difference for the overall and the passenger car groups for either the driver or right front passenger. However, marginal differences are exhibited for the LTV group, for both the driver and right front passenger. For the LTVs, the average driver HIC for MY 1998 is 137 less than the average HIC for MY 1997 and the average passenger HIC is 61 less for MY 1998. These differences in the LTV group for both driver and right front passenger are still considered to be small.

Figure 4 depicts the absolute difference in HIC value between the two model years. The comparison is made by calculating the difference from MY 1998 to MY 1997 for the same make and model for all thirty-three vehicles. Then, the difference is sorted and plotted in ascending order for driver and right front passenger. Therefore, the driver and passenger values do not occur at the same location in the figure. The decrease in HIC (indicated with negative sign) shows that the HIC value for MY 1998 is lower by the indicated amount. The figure shows that the trends for absolute change for driver and right front passenger are similar.

In Figure 5, HICs of the MY 1998 vehicles are plotted as a function of the HICs of the MY 1997 vehicles for the driver and right front passenger. Three HIC values exceed 1,000 which is the regulatory requirement in the 48 kph test of FMVSS No. 208. The values exceeding 1,000 are indicated with filled markers. Two readings above 1,000 in MY 1997 decreased in HIC value for MY 1998. One reading exceeded 1,000 in MY 1998, but was less than 1,000 in MY 1997. Most of the results are distributed along the 45 degree line and are well below 1,000.

In summary, from these comparisons, the differences in HIC between MY 1997 and MY 1998 vehicles are small. Therefore, it is expected that the level of head injury protection for the normally seated belt-restrained adult will be, at least, maintained in these MY 1998 vehicles.

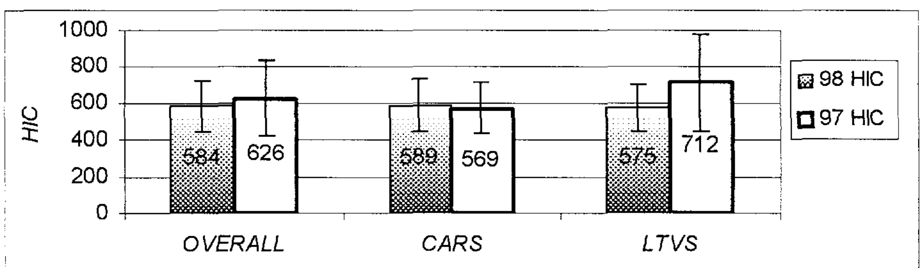

Figure 2. Average HIC values for the driver between MY 1998 and MY 1997.

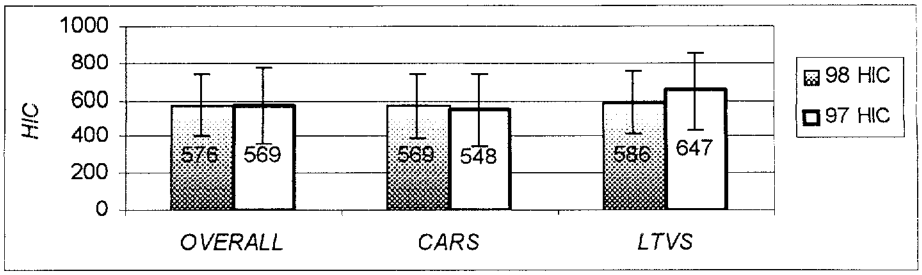

Figure 3. Average HIC values for the right front passenger between MY 1998 and MY 1997.

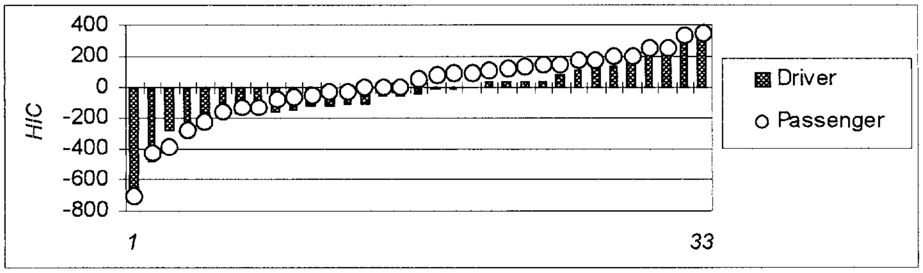

Figure 4. Absolute Difference in HIC between two Model Year vehicles for same vehicle.

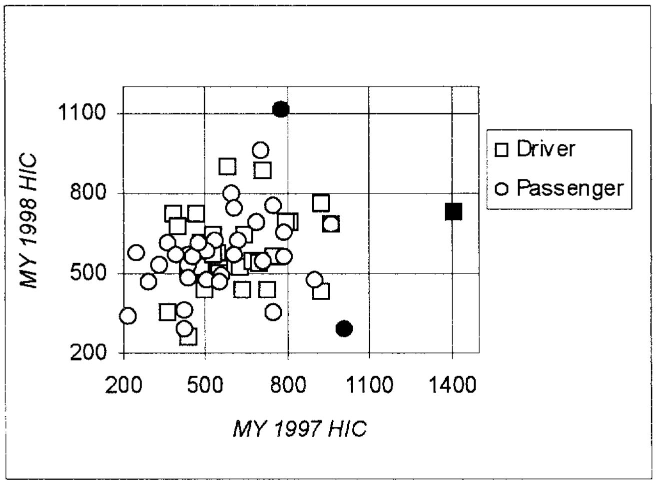

Figure 5. HIC distribution for the driver and right front passenger.

Chest G's (3 msec clip)

The averages and standard deviations of chest G's for the driver and right front passenger are illustrated in Figures 6 and 7. As can be seen, there is no difference in chest G's for the overall, the passenger cars, and the LTV groups for the driver. Similar results are found for the right front seat passenger; there is virtually no difference found in chest G's between the MY 1998 and MY 1997 vehicles.

Figure 8 depicts the absolute difference in chest deceleration values between the two model years. Again, the comparison is made by calculating the difference from MY 1998 to MY 1997 for the same make and model for all thirty-three vehicles. Then, the differences are sorted and plotted in an ascending order.

Figure 9 plots chest G's for MY 1998 as a function of chest G's for MY 1997 to show the overall chest G distribution for the driver and right front passenger. The

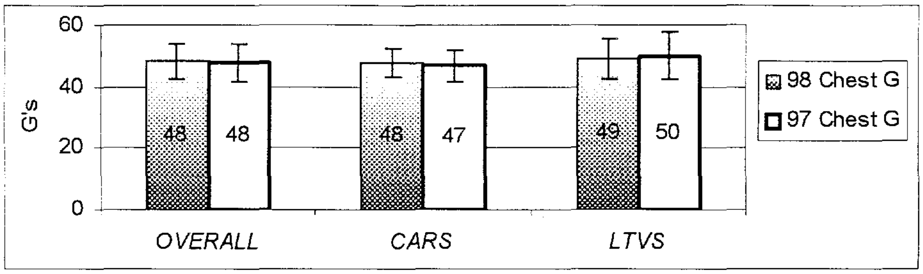

Figure 6. Average chest G's values for the driver between MY 1998 and MY 1997.

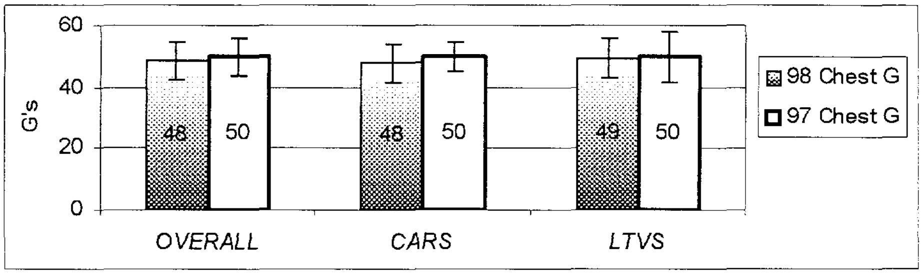

Figure 7. Average chest G's values for the right front passenger between MY 1998 and MY 1997.

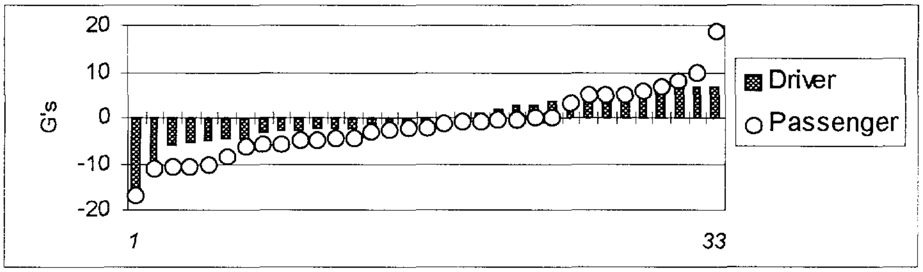

Figure 8. Absolute Difference in chest G's between two Model Year vehicles for same vehicle.

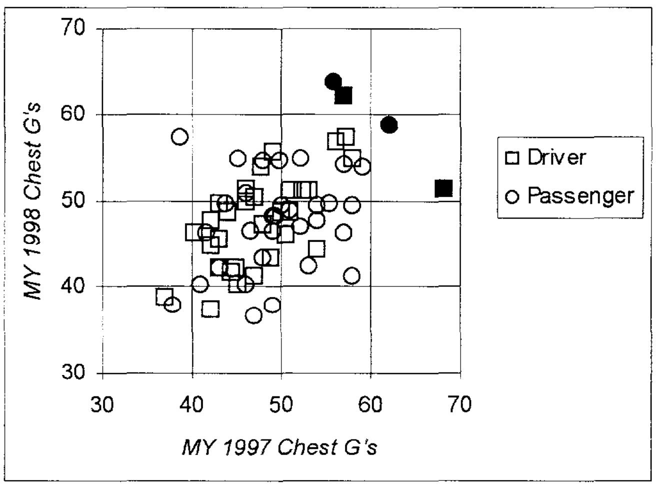

Figure 9. Chest G Distribution for the driver and right front passenger.

filled markers indicate the readings that exceed the 60 G's which is the regulatory requirement in the 48 kph test of FMVSS No. 208. Most of the results are distributed along the 45 degree line and no apparent difference is found. The figure shows that two chest readings that exceed 60 G's in MY 1997 are below 60 G's for MY 1998. Similarly, two chest readings that are below 60 G's in MY 1997 are now above 60 G's for MY 1998.

In summary, there is no difference in average chest G's between model years. Therefore, as for head injury protection, it is expected that the level of chest injury protection for the normally seated belt-restrained adult will be, at least, maintained in these MY 1998 vehicles.

Combined Injury Probability

As discussed before, the NCAP star rating is assessed based on the outcome of the combined injury probability that uses the dummy readings of HIC and chest G values. Figures 10 and 11 depict the comparison of the average combined injury probability for the driver and right front passenger, respectively. In general, in all three groups — overall, passenger cars, and LTVs — the injury probability for MY 1998 is generally lower than MY 1997 for both the driver and right front passenger. One notable change is in the LTV group. Since there is virtually no change in averaged chest G comparison, the difference reflects the slight change in average HIC. Nevertheless, no difference can be noted except for the LTV group.

To further examine the difference, Figure 12 depicts the absolute difference in combined injury probability between two model years for the driver and the right front passenger. Again, the comparison is made by calculating the difference from MY 1998 to MY 1997 for same makes and model for all thirty-three vehicles. Then, the difference is sorted and plotted in ascending order. For the driver, there is little variation for MY 1998 from MY 1997. One notable decrease in injury value is shown at the far left (of figure 12) for driver (lower by 45% for MY 1998). The variation is slightly more for the right front passenger. Nevertheless, most of the variation is less than 10 % for either decreased or increased injury probability values for the driver and the right front passenger. In summary, the trends for combined injury probability for driver and right front passenger are similar.

Since, the comparison of injury probability shows very little difference between MY 1998 and MY 1997, it is of interest to see how this is reflected by the nonnumeric five star rating. Figure 13 shows the difference in star rating results for two model years by plotting the difference. For instance, in the figure, a positive star means that the rating went up for MY 1998. The comparison shows that, for MY 1998, most of the star rating stayed the same or changed by no more than one star - up or down. In fact, 60 percent remained the same, whereas, only two ratings changed by more than one star. Fifteen star ratings increased for 1998 and 13 decreased.

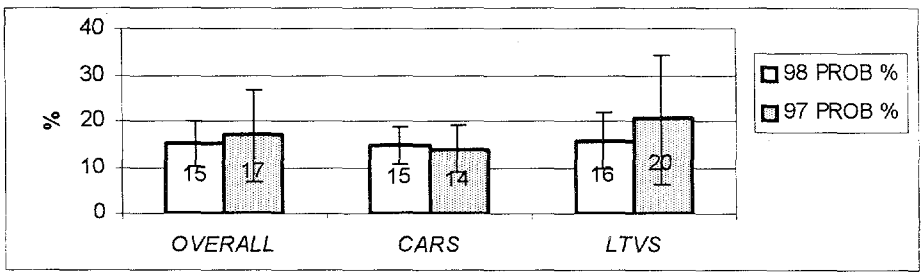

Figure 10. Average Combined Injury Probability values for the driver.

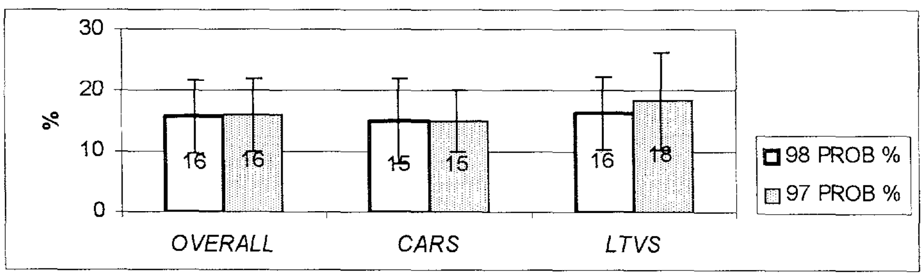

Figure 11. Average Combined Injury Probability values for right front passenger.

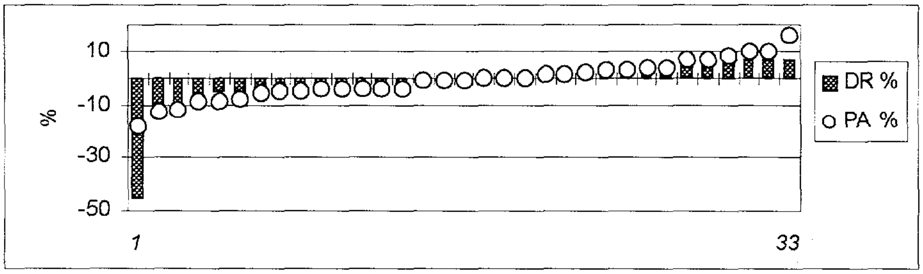

Figure 12. Absolute Difference in Combined Injury Probability between two Model Years.

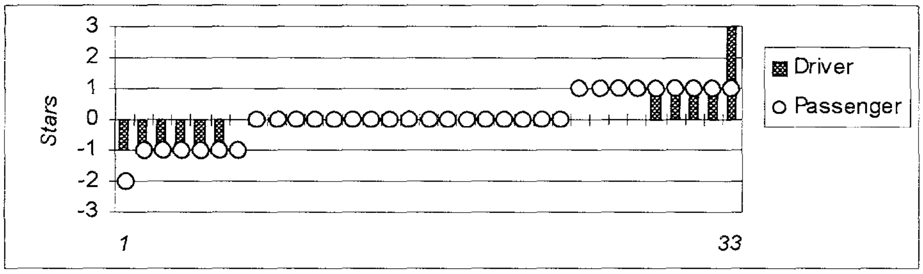

Figure 13. Difference in star rating for MY 1998 and MY 1997.

Neck Injury Criteria Comparison

Neck injury criteria are not used to determine the star rating. However, in the March 1997 temporary amendment to FMVSS No. 208, neck injury criteria were included as additional requirements in the optional sled test. The values for the neck injury criteria are shown in Table 1. With the occurrence of neck injuries associated with small stature adults and children in NHTSA's Special Crash Investigation Study, it is of interest to examine the effect of the redesigned MY 1998 air bags on the neck responses of the 50th percentile male test dummies in the NCAP tests.

Table 1.
Neck Injury Criteria for 50 % Dummy

Loading Mechanism	Neck Injury Criteria	SAE Electronic Filter
Flexion Bending Moment	190 Nm	600
Extension Bending Moment	57 Nm	600
Axial Tension	3300 N	1000
Axial Compression	4000 N	1000
Fore-and-Aft Shear	3100 N	1000

In Figures 14, 15, and 16, plots are shown of the neck force responses of MY 1998 as a function of MY 1997 for fore-and-aft shear, axial tension, and axial compression for both model years. All responses are below the FMVSS No. 208 requirements for both MYs except for the one response in 1998 that exceeds the axial tension criterion.

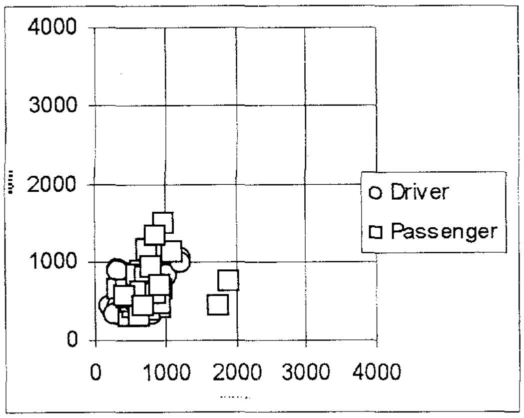

Figure 14. Neck fore-and-aft shear distribution

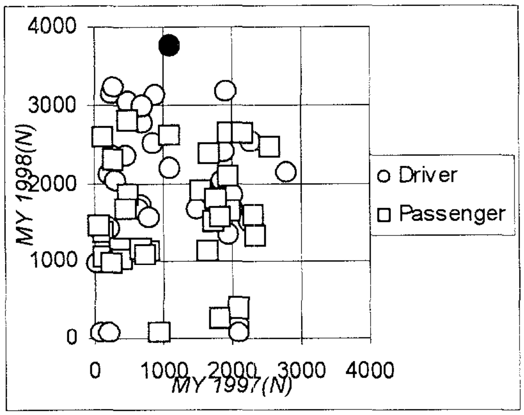

Figure 15. Neck axial Tension distribution

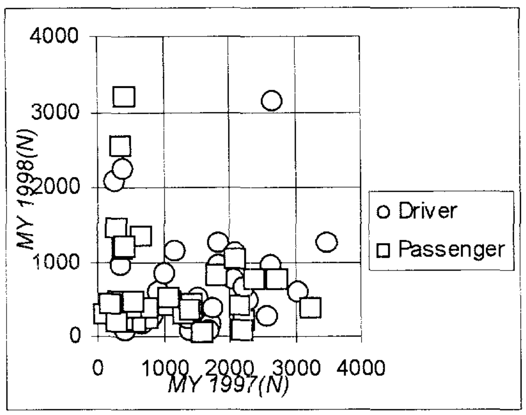

Figure 16. Neck axial Compression distribution

In Figures 17 and 18, plots are shown of the neck bending moments of MY 1998 as a function of MY 1997 for flexion and extension comparisons for the two model years. Here, most of the neck flexion bending moments are well below the FMVSS No. 208 injury criteria. However, for the neck extension bending, several readings exceed the criteria in both the MY 1998 and 1997 vehicles (indicated with filled markers).

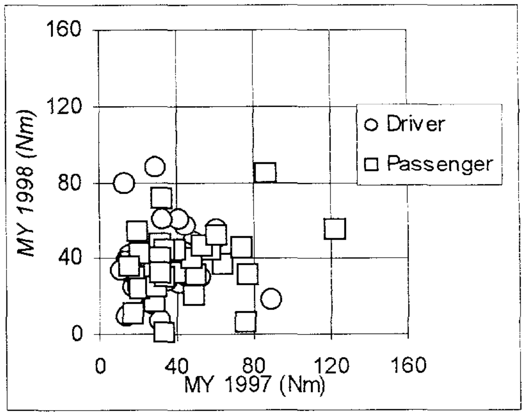

Figure 17. Neck Flexion Bending distribution

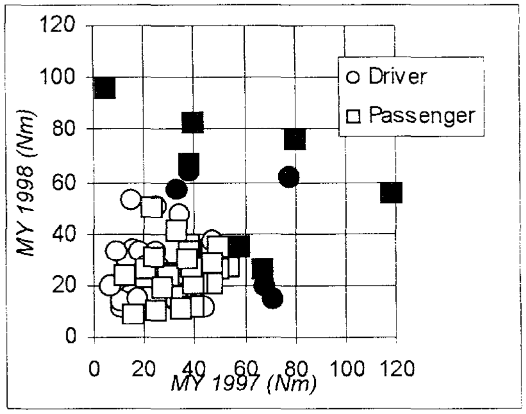

Figure 18. Neck Extension distribution

Figures 19 and 20 show the average neck extension for the driver and right front passenger for all groups. The comparisons show that the averaged readings for MY 1998 are somewhat lower than MY 1997 especially the passenger car group for both the driver and right front passenger. Furthermore, the difference can be discerned more in Figure 21 where it depicts the absolute difference in neck extension values between two model years for the driver and right front passenger. Again, the comparison is made by calculating the difference from MY 1998 to MY 1997 for the same makes and model for all thirty-three vehicles. Then, the difference is sorted and plotted in ascending order. For the driver, the number of neck extension responses that have decreased for the 1998 MY vehicles are about the same as that has increased. However, for the passenger, there are substantially more neck extension responses that have decreased for the 1998 MY vehicles than have increased — 24 of the 33.

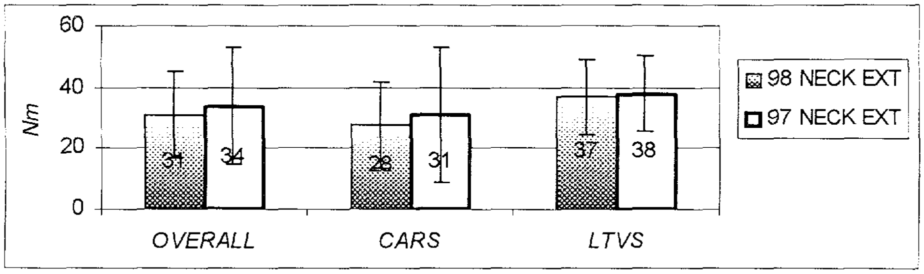

Figure 19. Average Neck Extension values for driver.

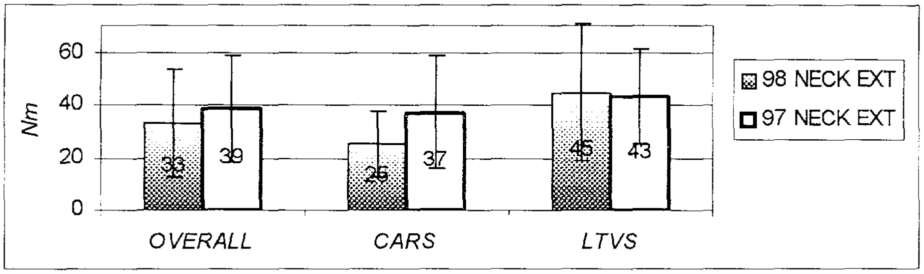

Figure 20. Average Neck Extension values for right front passenger.

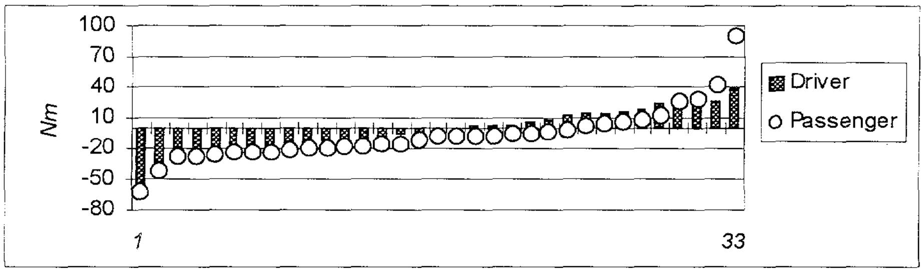

Figure 21. Absolute Difference in Neck Extension between two Model Years.

CONCLUSIONS

Beginning with the 1998 model year (MY), most vehicles produced for sale in the US market were equipped with redesigned frontal air bags. This paper investigates how the safety performance and ratings as developed in the New Car Assessment Program (NCAP) were affected by the introduction of these air bags.

Results from thirty-three MY 1998 vehicles crash tested for frontal NCAP were compared with the same make and models vehicles that were previously tested in NCAP. The only differences between the MY 1998 vehicles and the earlier vehicles are the redesigned air bags and other restraint system changes (i. e. , safety belt or steering assembly modifications). The head injury criteria (HIC), chest accelerations (chest G's), combined injury probability, and NCAP star ratings are examined for the driver and right front passenger. The neck responses of the driver and right front passenger between two model years also are examined relative to the new neck requirements that were included in the March 1997 amendment to FMVSS No. 208.

The average HIC values were lower for the MY 1998 vehicles. The lower averages were primarily due to reductions in HICs that occurred in LTVs. For the LTVs, the average driver HIC for MY 1998 is 575. This is 137 less than the average HIC for MY 1997. Overall only three HIC values exceeded the FMVSS No. 208 requirement of 1,000 — two in the MY 1997 vehicles and one in the MY 1998 vehicle.

Average chest G values were found to be the essentially the same for the MY 1998 vehicles when compared to the earlier models. All average values are between 48 and 50 G's. Two values for each MY exceeded the FMVSS No. 208 requirement of 60 G's.

The similarities in HIC and chest G's were reflected in the combined injury probabilities and the NCAP star ratings. For MY 1998, most of the star rating stayed the same or changed by no more than one star — up or down. In fact, 60 percent remained the same, whereas, only two ratings changed by more than one star.

Average neck loads were found to be approximately the same except for neck extension. The average neck extension moments for the newer air bag vehicles were lower for the passenger car group. For passenger cars, the average driver extension moment for MY 1998 is 28 Nm. This is 3 Nm less than the average extension moment for drivers in the MY 1997 passenger cars. The average passenger extension moment for MY 1998 is 25 Nm. This is 11 Nm less than the average extension moment for passengers in the MY 1997 vehicles.

These data indicate that the introduction of the redesigned air bags in the MY 1998 vehicles had little effect on the safety performance and ratings as measured and developed in NCAP. With average HICs of 584 for drivers, 576 for passengers, average chest G's of 48 for both drivers and passengers, and average neck responses well below those required in FMVSS No. 208, it is expected that the MY 1998 vehicles will provide high levels of protection to restrained occupants in frontal collisions that are represented by the NCAP tests.

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Appendix A.

Table A1.

Head and chest readings and corresponding star rating for frontal New Car Assessment Program. The list below shows thirty-three vehicles chosen from the fifty crash tests conducted as MY1998. The results for MY1997 is either the result from MY1997 NCAP tests or from the prior year test result that carried over as MY1997. A primary factor for selecting the vehicles is that the MY1998 vehicles changed only the air bags for both driver and right front passenger—had no major structural changes.

		Model Year 1998 (Redesigned Air Bags)						Model Year 1997 (Fully Powered Air Bags)					
		Driver			Right Front Passenger			Driver			Right Front Passenger		
Make	Model	*HIC*	*ChestG's*	*Stars*	*HIC*	*Chest G's*	*Stars*	*HIC*	*Chest G's*	*Stars*	*HIC*	*Chest G's*	*Stars*
Chevrolet	*Cavalier 2 Dr*	643	57	3	620	47	4	646	50	4	882	45	4
Chevrolet	*Cavalier 4 Dr*	514	54	4	751	48	4	552	48	4	749	54	3
Chevrolet	*Lumina*	679	48	4	495	40	5	394	42	5	560	46	4
Chevrolet	*Malibu*	691	42	4	473	50	4	810	44	4	546	44	4
Chevrolet	*CK Ext.*	726	46	4	693	57	3	468	40	5	689	39	4
Chevrolet	*Venture*	538	43	4	962	48	3	692	49	4	704	49	4
Dodge	*Dakota*	550	51	4	570	50	4	669	52	4	603	55	4
Dodge	*Ram Ext.*	691	47	4	295	49	4	793	48	4	1004	54	3
Ford	*Contour*	514	42	5	617	49	4	471	43	5	357	58	4
Ford	*Crown Victoria*	602	39	5	335	40	5	499	37	5	218	41	5
Ford	*Escort*	681	55	3	532	64	3	959	58	3	436	56	4
Ford	*Mustang*	436	41	5	364	47	4	493	47	4	419	52	4
Ford	*Taurus*	577	49	4	486	51	4	541	44	4	438	46	4
Ford	*Expedition*	544	45	4	569	42	4	693	42	4	393	43	5
Ford	*Explorer*	567	56	4	558	55	4	525	49	4	448	48	4
Ford	*F-150*	497	42	5	615	46	4	548	45	4	474	42	5
Ford	*Ranger*	442	51	4	545	43	4	724	53	4	711	53	4
Ford	*Windstar*	353	37	5	471	38	5	363	42	5	294	38	5
Honda	*Civic 4Dr*	619	50	4	531	55	4	480	46	4	329	45	5
Isuzu	*Rodeo*	650	62	3	561	54	4	528	57	4	782	59	3
Nissan	*Altima*	887	51	3	1119	55	2	710	51	4	777	52	4
Nissan	*Maxima*	565	49	4	654	54	4	747	50	4	783	57	3
Nissan	*Sentra*	898	49	3	797	49	4	583	51	4	599	50	4
Saturn	*SL*	435	40	5	585	44	4	633	45	4	506	48	4
Subaru	*Legacy*	525	51	4	623	49	4	482	46	4	532	51	4
Toyota	*Avalon*	504	50	4	577	37	5	517	47	4	243	47	5
Toyota	*Camry*	525	46	4	480	38	5	625	51	4	501	49	4
Toyota	*Corolla*	722	44	4	566	47	4	384	54	4	433	49	4
Toyota	*ES300*	512	50	4	478	48	4	432	43	5	902	49	3
Toyota	*4-Runner*	760	57	3	743	59	3	920	56	3	601	62	3
Toyota	*RAV-4*	434	49	4	355	46	4	919	51	3	747	57	3
Toyota	*Tacoma Ext.*	731	51	4	683	55	3	1411	68	1	962	50	3
Volvo	*S70*	259	46	5	294	41	5	434	43	5	421	58	4

Table A2.

Hybrid III dummy neck readings from frontal New Car Assessment Program for model year 1998. Blank spaces indicate no data.

		Model Year 1998									
		DRIVER					RIGHT FRONT PASSENGER				
Make	Model	Shear (N)	Tension (N)	Comp (N)	Flex (Nm)	Exten (Nm)	Shear (N)	Tension (N)	Comp (N)	Flex (Nm)	Exten (Nm)
Chevrolet	*Cavalier 2 dr*	1053	1671	85	46	20	414	1137	181	30	27
Chevrolet	*Cavalier 4 dr*	840	2112	406	27	34	692	1054	444	32	23
Chevrolet	*Lumina*	440	2362	175	16	33	670	982	221	48	11
Chevrolet	*Malibu*	1011	1350	849	55	62	549	1516	214	35	24
Chevrolet	*CK Ext.*	358	2190	279	30	37	1171	2378	457	45	83
Chevrolet	*Venture*	912	2982	600	10	28	1339	2652	1212	1	76
Dodge	*Dakota*	550	3040	963	35	64	944	1814	194	45	35
Dodge	*Ram Ext.*	516	2528	760	8	36	1508	2608	525	36	96
Ford	*Contour*	338	89	178	49	12	666	1367	65	72	9
Ford	*Crown Victoria*	397	3174	600	43	17	902	1908	376	54	26
Ford	*Escort*	786	81	2241	25	51	667	1315	3207	7	12
Ford	*Mustang*	389	1728	513	32	14	776	1855	392	33	56
Ford	*Taurus*	415	3148	370	31	28		1307		45	19
Ford	*Expedition*	559	1843	392	61	25	318	1569	430	25	33
Ford	*Explorer*	924	3237	488	41	57	644	2314	820	47	21
Ford	*F-150*	438	2770	1113	40	34	480	2156	1048	31	27
Ford	*Ranger*	338	2045	654	30	29	617	1095	778	52	29
Ford	*Windstar*	620	993	241	50	20	452	1454	82	33	30
Honda	*Civic 4dr*	354	2140	1157	28	30	1138	92	524	85	24
Isuzu	*Rodeo*	609	2536	962	44	35	590	1597	1452	40	67
Nissan	*Altima*	616	187	2069	26	32	643	398	2559	38	10
Nissan	*Maxima*	338	1502	156	25	23	682	2459	459	11	36
Nissan	*Sentra*	651	2399	344	40	26	817	2097	315	24	21
Saturn	*SL*	721	1662	262	88	15	860	2643	396	42	35
Subaru	*Legacy*	672	1761	206	39	28	503	1632	1332	33	50
Toyota	*Avalon*	650	2034	291	36	14	427	1133	242	21	18
Toyota	*Camry*	608	78	1258	18	53	320	256	1182	17	25
Toyota	*Corolla*	863	2349	957	79	33	433	1168	478	37	26
Toyota	*ES300*	697	1435	85	58	12	528	1028	420	30	16
Toyota	*4-Runner*	752	3749	3156	61	48	542	2797	408	40	21
Toyota	*RAV-4*	485	1564	270	41	33	704	1660	361	46	41
Toyota	*Tacoma Ext.*	912	3124	1268	34	33	446	2610	774	55	26
Volvo	*S70*	530	1679	86	35	15	394	1161	305	32	31

Table A3.

Hybrid III dummy neck readings from frontal New Car Assessment Program for model year 1997. Blank spaces indicate no data.

		Model Year 1997									
		DRIVER					RIGHT FRONT PASSENGER				
Make	Model	Shear (N)	Tension (N)	Comp (N)	Flex (Nm)	Exten (Nm)	Shear (N)	Tension (N)	Comp (N)	Flex (Nm)	Exten (Nm)
Chevrolet	*Cavalier 2 dr*	1221	1480	415	32	68	922	1651	560	33	54
Chevrolet	*Cavalier 4 dr*	1015	197	1575	41	16	825	131	1436	77	21
Chevrolet	*Lumina*	200	264	1700	27	9	434	255	2213	31	35
Chevrolet	*Malibu*	1227	1945	1007	60	78	453	1733	395	28	30
Chevrolet	*Ck Ext.*	650	1100	1426	45	47	754	1666	550	39	40
Chevrolet	*Venture*	339	710	3033	14	52	851	2162	408	33	80
Dodge	*Dakota*	480	480	2630	24	38	800	1750	300	34	58
Dodge	*Ram Ext.*	666	843	2058	31	39	987	125	1092	15	5
Ford	*Contour*	796	215	1500	49	44	340	133	1600	32	16
Ford	*Crown Victoria*	391	1912	933	19	15	645	1559	749	19	50
Ford	*Escort*		2102	372	17	25	934	2320	400	76	40
Ford	*Mustang*	427	661	1520	33	11	1886	476	3247	39	118
Ford	*Taurus*	564	230	1733	24	21	684			57	27
Ford	*Expedition*	740	1999	685	32	37	617	1804	203	29	38
Ford	*Explorer*	320	278	2294	15	33	656	281	1800	53	40
Ford	*F-150*	333	700	2096	24	51	930		2101	34	39
Ford	*Ranger*	253	293	2237	52	37	846	718	2393	60	47
Ford	*Windstar*	436	42	1352	59	7	668	48	2176	31	37
Honda	*Civic 4dr*	425	2797	1175	35	13	1097	925	1086	86	12
Isuzu	*Rodeo*	584	2270	352	43	55	417	2299	286	31	38
Nissan	*Altima*	541	2076	240	21	43	449	2087	347	16	25
Nissan	*Maxima*	464	2250	678	19	37	815	2541	332	17	38
Nissan	*Sentra*	489	1867	214	27	45	709	1937	80	20	47
Saturn	*SL*	853	2013	813	29	71	589	1950	500	20	50
Subaru	*Legacy*	380	1816	449	14	26	499	1962	656	31	23
Toyota	*Avalon*	323	1850	364	41	33	796	776	772	49	39
Toyota	*Camry*	643	91	1827	89	15	472	1822	367	28	32
Toyota	*Corolla*	406	448	1851	13	18	545	364	1124	64	21
Toyota	*ES300*	426	199	1412	44	11	618	400	1095	19	33
Toyota	*4-Runner*	582	1082	2670	41	34	606	479	2152	48	41
Toyota	*RAV-4*	474	785	2579	28	25	911	468	1402	74	33
Toyota	*Tacoma Ext.*	354	886	3453	11	39	1742	1078	2722	122	67
Volvo	*S70*		628	1692	46	17	763	661	1286	50	24

Table A4.

Average, standard deviation, and range of dummy readings for the frontal New Car Assessment Program for model year 1998 and model year 1997. These calculations are made from the Table A1 based on the compared thirty-three vehicles.

			OVERALL				CARS				LTVS			
		Criteria	AVG	STD	MAX	MIN	AVG	STD	MAX	MIN	AVG	STD	MAX	MIN
MY 1998	Dr	HIC	584	139	898	259	589	149	898	259	575	128	760	353
		Chest G	48	6	62	37	48	5	57	39	49	7	62	37
		Prob %	15	5	27	7	15	4	23	9	16	6	27	7
		Shear	616	210	1053	338	618	219	1053	338	613	204	924	338
		Tension	1986	956	3749	78	1647	929	3174	78	2508	762	3749	993
		Comp	710	689	3156	85	614	635	2241	85	857	768	3156	241
		Flexion	39	18	88	8	40	19	88	16	37	16	61	8
		Extension	31	14	64	12	28	14	62	12	37	12	64	20
	Pa	HIC	576	173	1119	294	569	180	1119	294	586	169	962	295
		Chest G	48	6	64	37	48	7	64	37	49	6	59	38
		Prob %	16	6	36	8	15	7	36	8	16	6	25	8
		Shear	682	286	1508	318	636	206	1138	320	750	374	1508	318
		Tension	1612	710	2797	92	1325	661	2643	92	2054	551	2797	1095
		Comp	683	685	3207	65	701	837	3207	65	657	403	1452	82
		Flexion	37	17	85	1	36	19	85	7	38	14	55	1
		Extension	33	21	96	9	25	12	56	9	45	26	96	21
MY 1997	Dr	HIC	626	212	1411	363	569	148	959	384	712	268	1411	363
		Chest G	48	6	68	37	47	5	58	37	50	8	68	40
		Prob %	17	10	64	8	14	5	31	8	20	14	64	9
		Shear	548	255	1227	200	600	302	1227	200	478	155	740	253
		Tension	1106	818	2797	42	1252	901	2797	91	882	640	2270	42
		Comp	1465	867	3453	214	1074	591	1851	214	2067	897	3453	352
		Flexion	33	17	89	11	34	18	89	13	32	15	59	11
		Extension	34	18	78	7	31	21	78	9	38	13	55	7
	Pa	HIC	569	200	1004	218	518	181	902	218	647	210	1004	294
		Chest G	50	6	62	38	50	5	58	41	50	8	62	38
		Prob %	16	6	30	7	15	5	24	7	18	8	30	7
		Shear	765	329	1886	340	724	337	1886	340	830	317	1742	417
		Tension	1179	811	2541	48	1246	819	2541	131	1073	823	2299	48
		Comp	1102	844	3247	80	960	770	3247	80	1353	922	2722	203
		Flexion	42	14	122	15	40	22	86	16	46	27	122	15
		Extension	39	21	118	5	37	22	118	12	43	18	80	5