EVALUATION OF THE EFFECT OF AIR BAGS IN MULTI-YEAR LIGHT TRUCK NCAP TESTS

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ABSTRACT

The New Car Assessment Program (NCAP) has evaluated the crashworthiness of numerous vehicles since 1979. Each year selected models were frontally crashed at 35 mph into a fixed barrier. Due to increased interest by the public in vehicle safety as part of their car-buying decisions, NHTSA has recently undertaken an expanded program of consumer information on vehicle safety issues. As part of this program, an analysis was performed to determine the effectiveness of light truck driver air bags to reduce the risk of severe injury as measured by the head and chest injury responses of selected NCAP tests. The light trucks tested most frequently were analyzed to obtain reliable estimates of air bag effectiveness. The vehicles were tested with all the restraints available on that model, which in the case of the early years were safety belts, and in the latter years were a combination of safety belts and air bags.

Analysis of NCAP data for multi-tested vehicle models for the period 1979 through 2000 indicated a significant reduction of 56% for light trucks in the risk of severe trauma for drivers in air bag equipped vehicles.

INTRODUCTION

The New Car Assessment Program (NCAP) has evaluated the crashworthiness of numerous vehicles since 1979. Each year selected models were frontally crashed at 35 mph into a fixed barrier. This paper examines the effectiveness of air bags in preventing severe injury to drivers for passenger light trucks that were tested multiple times over the past twenty years.

METHODOLOGY

The NCAP test vehicles carried two fully restrained front-seat dummies that contained instruments measuring the simulated head injury (HIC) and chest injury (chest G) sustained in the crash test. The higher the HIC and chest G scores the more likely a severe injury would occur in an actual frontal fixed-object crash.

The NCAP vehicles were chosen from those models that are new, potentially popular, redesigned with structural changes, or have improved safety equipment, such as an air bag. The vehicles were bought from new car dealers' lots and were not supplied by the manufacturer. Only one of each model was tested.

The multi-tested vehicles maintained a consistent body platform over the NCAP testing period. The HIC and chest G scores for the driver-side dummy for vehicles tested with only safety belts were compared to the scores for the same vehicles tested with both safety belts and a driver-side air bag. The selected multi-tested vehicles had at least two 'belts-only' tests along with at least two 'belts+bag' tests. These selected vehicle groups represented nearly all vehicles that satisfied the multi-testing requirements.

Two types of dummies have been used in the NCAP frontal crash tests. The original 50th percentile anthropomorphic test device was designated the Hybrid II dummy. An updated, state-of-the-art design dummy called the Hybrid III was phased in recently to provide more detailed crash injury data. A comparative evaluation performed by a Ford Motor Company engineer [1] of the response for these two dummy devices in 35 mph barrier crash test indicated that the Hybrid III driver dummy would have a 17% higher HIC and a 9% greater chest G than the Hybrid II driver dummy when both dummies were tested with belt-restraint systems. The HIC response for both driver dummy types tested with air bag and belt restraints was essentially the same, while the Hybrid III driver dummy had a 22% higher chest injury response than the Hybrid II driver dummy.

A 1990 SAE paper [2] related the risk of severe (MAIS$\geq$4) head and chest injury to the HIC and chest G scores. The probability of severe head injury is given by the equation

$$P_{Head} = [1+Exp(5.02 - 0.00351 \times HIC)]^{-1}$$

The risk of incurring a severe chest injury is obtained from the equation

$$P_{Chest} = [1+Exp(5.55-0.0693 \times \text{chest G})]^{-1}$$

If the risks of severe head and chest injury are considered statistically independent, the equation

$$(P_{Combined}) = P_{Head} + P_{Chest} - P_{Head} \times P_{Chest}$$

relates the combined risk of severe head or chest driver injury to the separate chest and head injury risks.

The effectiveness of the driver air bag to prevent severe injury to the driver dummy for each vehicle is obtained by computing the percent reduction in the average combined severe injury risk for the air bag tests as compared to the tests with only safety belts. A negative effectiveness represents an increase in severe injury risk.

ANALYSIS

All the tested vehicles had driver dummies restrained by lap and shoulder belts. In order to standardize the crash test comparison, the NCAP test results with the Hybrid II dummy were adjusted to reflect the response expected from Hybrid III dummy based on the Prasad comparative evaluation.

Specifically, the Hybrid II driver dummy HIC was increased 17% while the chest G was raised 9% for crash tests with belt-restraint systems. For NCAP tests using the Hybrid II driver dummy restrained by both an air bag and belts the chest G result was increased by 22% to conform to the expected Hybrid III driver dummy chest injury response. All of the light truck groups tested from 1994 to the present used the

Hybrid III driver dummy.

The estimated effectiveness of air bags in reducing the risk of severe injury for light truck drivers is shown in Appendix A. The ten selected light trucks included pickups (PU), vans (VAN), and multi-purpose vehicles (MPV). The range of estimated severe injury effectiveness ranged from about 24% to 78% with an average of 55.5% for the ten multi-tested light truck groups.

Two recent NHTSA Final Economic Assessments, [3, 4] also related the risk of severe (MAIS $\geq$ 4) head and chest injury to the HIC and chest G scores. The probability of severe head injury is given by the equation

$$P_{Head} = [\ 1+ \text{Exp}\ ((4.9\text{-}200/HIC)\text{-}0.00351 \times HIC)]^{-1}$$

The risk of incurring a severe chest injury is obtained from the equation

$$P_{chest} = [1+\text{Exp}\ (4.3425\text{-}0.063 \times \text{chest G}]^{-1}$$

The estimated light truck effectiveness using the FEA risk equations was 41%. The difference in effectiveness using the Viano risk equations is primarily due to differences in the chest injury risk produced by the two methods.

CONCLUSION

The results from vehicles tested frequently by NCAP with varying driver restraint systems clearly show the benefit of air bags in reducing injury severity in severe frontal crashes. The estimated air bag severe injury effectiveness was 56% for light trucks.

There have been improvements in structural design/materials and energy-absorbing belt systems over the twenty years of NCAP crash tests. However, it would be unlikely for these improve-ments by themselves to have accounted for the reduction in severe injury risk that occurred throughout the light truck NCAP tests since the introduction of driver air bags.

REFERENCES

1. Prasad, P., “Comparative Evaluation of the Dynamic Responses of the Hybrid II and Hybrid III Dummies,” Proceedings of the 34th Strapp Car Crash Conference, SAE Paper 902318, Warrendale, PA, November 1990.

2. Viano, D.C., and Arepally, S., “Assessing the Safety Performance of Occupant Restraint Systems”, Proceedings of the 34th Stapp Car Crash Conference, SAE Paper 902328, Warrendale, PA, November 1990.

3. Final Economic Assessment, FMVSS No 201, Upper Interior Head Protection, Office of Regulatory Analysis, Plan and Policy, NHTSA, June 1995 Docket No. 92-28 Notice 4.

4. Final Economic Assessment, FMVSS No. 208, Advanced Airbags, Office of Regulatory Analysis, Plans and Policy, NHTSA, May 2000, Docket No.99-6407-143.

APPENDIX A

LIGHT TRUCKS MULTI-YEAR NCAP TESTS

MAKE/ MODEL/ STYLE GROUP	MODEL YEAR	TRUCK TYPE	DRIVER PROTECTION	HYBRID III DRIVER HIC	HYBRID III DRIVER CHEST	% DRIVER SEVERE HEAD INJURY RISK	% DRIVER SEVERE CHEST INJURY RISK	% DRIVER SEVERE INJURY RISK	AIR BAG SEVERE INJURY EFFECTIVE-NESS
1 Ford F-150 2WD Pickup	1984	PU	Manual Belts	1594	52	64.0	12.5	68.5	
	1988	PU	Manual Belts	1257	61	35.3	21.0	48.9	
	1992	PU	Manual Belts	1006	52	18.4	12.5	28.6	
	1994	PU	Air bag + Belts	446	41	3.1	6.2	9.1	
	1997	PU	Air bag + Belts	548	45	4.3	8.1	12.1	
	1998	PU	Air bag + Belts	497	42	3.6	6.7	10.1	
	1999	PU	Air bag + Belts	517	46	3.9	8.6	12.2	77.7
2 Chrysler Town & Country/ Dodge Caravan/ Plymouth Voyager 2WD Van	1984	Van	Manual Belts	1138	48	26.4	9.8	33.6	
	1987	Van	Manual Belts	1057	47	21.2	9.2	28.5	
	1992	Van	Air bag + Belts	407	61	2.7	21.0	23.2	
	1994	Van	Air bag + Belts	514	51	3.9	11.8	15.2	
	1997	Van	Air bag + Belts	773	51	9.1	11.8	19.7	
	1998	Van	Air bag + Belts	870	53	12.3	13.3	23.9	
	2000	Van	Air bag + Belts	772	49	9.0	10.4	18.5	35.2

MAKE/ MODEL/ STYLE GROUP	MODEL YEAR	TRUCK TYPE	DRIVER PROTECTION	HYBRID III DRIVER HIC	HYBRID III DRIVER CHEST G	% DRIVER SEVERE HEAD INJURY RISK	% DRIVER SEVERE CHEST INJURY RISK	% DRIVER SEVERE INJURY RISK	AIR BAG SEVERE INJURY EFFECTIVE-NESS
3 Ford Ranger 2WD Pickup	1987	PU	Manual Belts	1143	57	26.7	16.8	39.0	
	1992	PU	Manual Belts	1181	52	29.4	12.5	38.2	
	1993	PU	Manual Belts	1110	57	24.5	16.8	37.2	
	1995	PU	Air bag + Belts	508	50	3.8	11.1	14.4	
	1997	PU	Air bag + Belts	724	53	7.7	13.3	20.0	
	1998	PU	Air bag + Belts	442	51	3.0	11.8	14.4	57.4
4 Jeep Cherokee 4WD 4-Door	1989	MPV	Manual Belts	1133	75	26.1	41.3	56.6	
	1990	MPV	Manual Belts	1103	63	24.1	23.4	41.9	
	1995	MPV	Air bag + Belts	484	52	3.5	12.5	15.5	
	1997	MPV	Air bag + Belts	692	61	7.0	21.0	26.5	
	1999	MPV	Air bag + Belts	824	61	10.6	21.0	29.4	51.6

MAKE/ MODEL/ STYLE GROUP	MODEL YEAR	TRUCK TYPE	DRIVER PROTECTION	HYBRID III DRIVER HIC	HYBRID III DRIVER CHEST G	% DRIVER SEVERE HEAD INJURY RISK	% DRIVER SEVERE CHEST INJURY RISK	% DRIVER SEVERE INJURY RISK	AIR BAG SEVERE INJURY EFFECTIVE-NESS
5 Toyota 4-Runner 4WD 4-Door	1985	MPV	Manual Belts	1729	70	74.1	33.2	82.7	
	1990	MPV	Manual Belts	1528	52	58.5	12.5	63.7	
	1993	MPV	Manual Belts	1482	65	54.5	26.0	66.4	
	1996	MPV	Air bag + Belts	920	56	14.3	15.9	27.9	
	1998	MPV	Air bag + Belts	760	57	8.7	16.8	24.0	
	1999	MPV	Air bag + Belts	693	45	7.0	8.1	14.5	68.8
6 Chevrolet C-10/ Chevrolet C-1500/ GMC C-15/GMC C-1500/ GMC Sierra C-K 1500 2WD Pickup	1984	PU	Manual Belts	625	40	5.6	5.9	11.1	
	1988	PU	Manual Belts	1044	51	20.5	11.8	29.8	
	1993	PU	Manual Belts	925	45	14.5	8.1	21.4	
	1995	PU	Air bag + Belts	487	39	3.5	5.5	8.8	
	1996	PU	Air bag + Belts	498	39	3.7	5.5	8.9	
	1997	PU	Air bag + Belts	314	37	1.9	4.8	6.7	
	1998	PU	Air bag + Belts	726	46	7.8	8.6	15.7	51.7

MAKE/ MODEL/ STYLE GROUP	MODEL YEAR	TRUCK TYPE	DRIVER PROTECTION	HYBRID III DRIVER HIC	HYBRID III DRIVER CHEST G	% DRIVER SEVERE HEAD INJURY RISK	% DRIVER SEVERE CHEST INJURY RISK	% DRIVER SEVERE INJURY RISK	AIR BAG SEVERE INJURY EFFECTIVE-NESS
7 Chevrolet Astro/ GMC Safari 2WD Van	1985	Van	Manual Belts	2576	76	98.2	43.0	99.0	
	1988	Van	Manual Belts	1876	78	82.7	46.4	90.7	
	1989	Van	Manual Belts	2163	70	92.9	33.2	95.3	
	1992	Van	Manual Belts	2416	66	97.0	27.4	97.8	
	1994	Van	Air bag + Belts	832	62	10.9	22.2	30.7	
	1996	Van	Air bag + Belts	613	61	5.4	21.0	25.3	
	1999	Van	Air bag + Belts	529	65	4.1	26.0	29.0	70.4
8 Chevrolet S-10 Blazer/ GMC S-15 Jimmy/ GMC Jimmy Sonoma/ Oldsmobile Bravada 4WD 4-Door	1991	MPV	Manual Belts	1200	77	30.8	44.7	61.7	
	1993	MPV	Manual Belts	749	68	8.4	30.2	36.1	
	1995	MPV	Air bag + Belts	932	48	14.8	9.8	23.1	
	1997	MPV	Air bag + Belts	595	57	5.1	16.8	21.0	
	1998	MPV	Air bag + Belts	668	51	6.4	11.8	17.4	
	1999	MPV	Air bag + Belts	800	45	9.9	8.1	17.2	59.7

MAKE/ MODEL/ STYLE GROUP	MODEL YEAR	TRUCK TYPE	DRIVER PROTECTION	HYBRID III DRIVER HIC	HYBRID III DRIVER CHEST G	% DRIVER SEVERE HEAD INJURY RISK	% DRIVER SEVERE CHEST INJURY RISK	% DRIVER SEVERE INJURY RISK	AIR BAG SEVERE INJURY EFFECTIVE-NESS
9 Ford Explorer/ Mazda Navajo/ Mercury Mountain-eer 4WD 4-Door	1991	MPV	Manual Belts	1057	57	21.2	16.8	34.5	
	1993	MPV	Manual Belts	1032	55	19.8	15.0	31.8	
	1995	MPV	Air bag + Belts	525	49	4.0	10.4	14.0	
	1998	MPV	Air bag + Belts	567	56	4.6	15.9	19.7	49.1
10 Chevrolet S-10 GMC S-15 Sonoma 2WD	1987	PU	Manual Belts	1152	63	27.4	23.4	44.4	
	1992	PU	Manual Belts	1158	64	27.8	24.7	45.6	
	1994	PU	Air Bag + Belts	1116	57	24.9	16.8	37.5	
	1995	PU	Air Bag + Belts	1065	56	21.7	15.9	34.1	
	2000	PU	Air Bag + Belts	852	61	11.6	21.0	30.2	24.3

Average	**55.5**