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NCAP STAR RATING AND SAFETY OF REAR SEAT OCCUPANT

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INTRODUCTION

New Car Assessment Program (NCAP) gives star ratings to the vehicles based on their crashworthiness. The program uses results of crash tests performed with 50% male HYBRID III dummies in the driver and right front passenger seats and gives separate star ratings for the driver and right front passenger positions. These star ratings are available from the safer car website [1], and are perceived as an indicator of general safety of the vehicles for people trying to purchase a vehicle. A one-star rating would show the lowest, and five-star would be the highest safety ranking. As the NCAP star ratings of the vehicles have improved over years, front occupant protection has improved as well; however, recent studies have shown that rear occupants are less protected in newer model years of vehicles [2]. Safety of rear occupants is not evaluated with the NCAP program. In this paper an attempt is made to verify whether the NCAP scores can show the level of protection provided to the rear occupants or not.

METHOD

Forty nine tests were available from the National Highway Transportation Safety Administration (NHTSA) vehicle database, having at least one adult 5% female or 50% male dummy restrained (with 3 point belt) in one of the rear seats. All the selected crash tests were frontal vehicle to barrier tests with "00" impact angle (12 o'clock direction). The crash speeds for these tests were 40-56 km/h. The NCAP star ratings of driver in frontal crashes were extracted from the safer car program website [1]. Two analyses were performed on the data, a case by case review, and an average value evaluation.

For the first analysis, the cases performed at NCAP speed are included in two tables based on the crash dummy types. It includes 15 tests which were performed at speed of 56 km/h. The vehicles were from

model years 2004 to 2006. Body types of these vehicles included passenger car, utility vehicle, minivan, and pickup. Fifty percentile male dummies were present in the rear seat of 11 tests. Fifth percentile female dummies were present in the rear seat of 10 tests. Injury measures studied included HIC15, HIC 36, 3 ms clip chest acceleration, and chest deflection.

For the second part of the analysis the average value of safety criteria were calculated for all the 49 tests available regardless of the crash speed (40-56 km/h) and dummy size (adult 5% female or 50% male). The Laituri risk of AIS3+ chest injury was also presented as an alternative chest injury criterion. Equation 1 shows the Laituri risk function used for 50% male dummy, for other dummy sizes the equivalent deflection was calculated using the method recommended by Laituri [3]. Chest accelerations were normalized for dummy sizes using limits defined in final airbag rule [4]. Table 1 shows the head and chest injury limits based on the final rule.

$$P_{AIS3+}^{Thorax} = \frac{1}{1 + e^{-\left(-7.777 + \frac{21.99}{0.855} \left(\frac{\delta_{HMM50}(mm) + 11}{229} \right) \right)}} \quad (1)$$

Table 1 : Recommended Injury Criteria, the Final Rule [4]

Recommended Criteria	50% Male	5% Female
HIC (15 msec)	700	700
Chest Acceleration (g)	60	60
Chest Deflection (mm)	63	52

RESULTS

Table 2 shows the eleven tests having a 50% male dummy in the rear seat performed at speed of 56 km/h. These tests include one 3-star vehicle, two 4-star vehicles, and seven 5-star vehicles. All dummies have chest acceleration and chest deflection lower than the recommended criteria mentioned in Table 1. However, considering HIC15 (Head Injury Criteria) it can be observed that 3 of the rear seat dummies have HIC15 over 700, the recommended criteria in Table 1. Furthermore, average HIC15 shows an increase from 460.6 to 497.3, and 735.4 with the increase in star rating of the vehicle.

Table 2. Tests with 50% male dummy at 56 km/h

(H3: HYBRID III, HT: HYBRID III dummy with THOR LX legs)

TSTNO	Star	Year	Body Type	Seat position	Occ. Type	3ms Clip (g)	Chest Defl. (mm)	15 ms HIC	Avg. HIC15	36 ms HIC
5140	3	2004	UV	6	H3	38.7		460.6	460.6	890.1
5138	4	2004	4-D Sedan	6	H3	48.8		631.0	497.3	1116.3
5713	4	2005	MINIVAN	3	HT	54.3	42.4	363.6		594.6
5136	5	2004	MINIVAN	3	H3	44.5	33.8	554.2	735.4	832.0
5136	5	2004	MINIVAN	8	H3	45.0		988.6		1802.1
5137	5	2004	UV	6	H3	45.3	33.5	1095.6		1955.1
5139	5	2004	4-D Sedan	6	H3	45.5		630.4		966.8
5388	5	2005	4-D Sedan	4	H3	49.7	35.6	750.8		1304.8
5404	5	2005	4-D Sedan	4	H3	52.2	45.6			
5714	5	2005	MINIVAN	3	HT		33.7	660.2		971.3
5715	5	2006	4-D Pickup	3	HT	33.6	50.0	467.7		737.8

Table 3 summarizes the results of the ten tests having 5% female dummy in the rear seat performed with a closing speed of 56 km/h. Five dummies had a HIC15 value over 700, the recommended limit in Table 1, four of them in 5 star NCAP rated vehicles. Chest deflection, and 3 ms clip chest acceleration values were all below the recommended values of 52 mm and 60 g. However, 4 dummies had a chest deflection of over 45 mm (3 of them in 5 star vehicles), and 4 dummies had a 3 ms clip chest acceleration of more than 50g (all of them in 5 star vehicles). The average HIC15 value increased with the increase in the star rating of the vehicle (from 540.5 to 737.4 and 806.5 for 3, 4 and 5 star rated vehicles).

Table 3. Tests with 5% female dummy at 56 kph

TSTNO	Star	Year	Body Type	Seat Position	Occ. Type	3ms Clip (g)	Chest Defl. (mm)	15 ms HIC	Avg. HIC15	36 ms HIC
5210	3	2004	UV	3	H3	41.5	42.2	540.5	540.5	900.7
5143	4	2004	4-D Sedan	3	H3	42.0	32.8	533.8	737.4	1101.3
5713	4	2005	MINIVAN	4	H3	46.4	45.4	940.9		1567.4
5144	5	2004	MINIVAN	9	H3	52.8	37.2	1052.6	806.5	1615.5
5145	5	2004	4-D Sedan	3	H3	48.6	47.2	780.8		1139.7
5211	5	2004	UV	3	H3	51.2	49.2	659.0		1102.8
5388	5	2005	4-D Sedan	3	H3	52.9	37.7	923.8		1394.3
5404	5	2005	4-D Sedan	3	H3	53.4	43.4	1160.4		1753.0
5714	5	2005	MINIVAN	4	H3	43.4	38.6	686.0		1170.5
5715	5	2006	4-D Pickup	4	H3	36.0	47.6	382.7		800.0

For the second analysis all the tests were included regardless of vehicle speeds and dummy sizes. Eighteen dummies were in the rear

seat of 3 or 4 star vehicles, and 42 dummies in the rear seat of 5 star vehicles. Figure 1 shows that average risk of head injury (HIC15 and HIC36) is higher in the 5 star vehicles compared to 3 and 4 star vehicles; however, risk of chest injury is lower for 5 star vehicles.

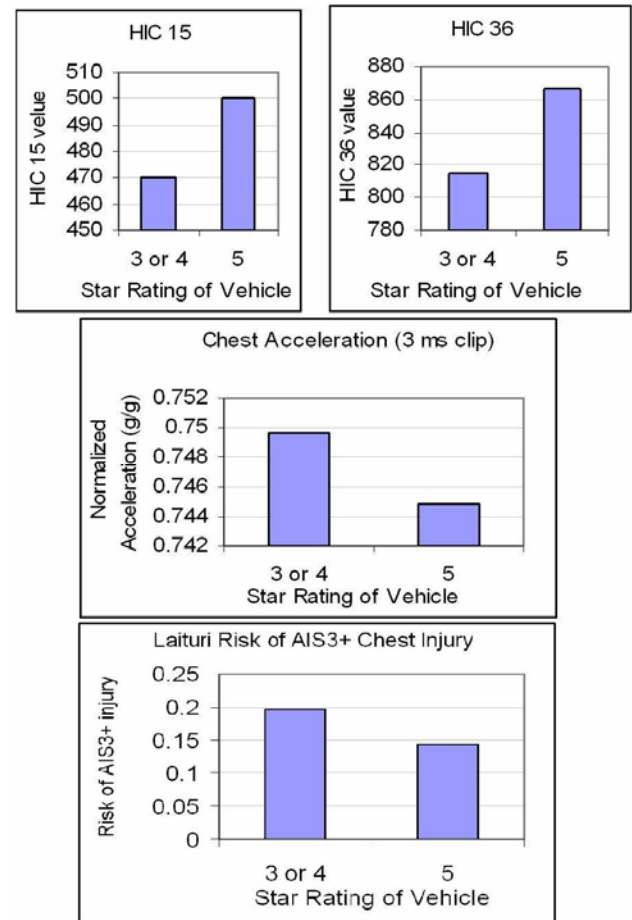


Figure 1. Injury measures for the rear seat occupant versus driver NCAP star rating of the vehicle

CONCLUSION

Results show that NCAP star rating of vehicles should not be perceived as an indicator of the level of protection available to the rear occupant as well. In fact for the frontal crash vehicle tests available from NHTSA, the rear occupant benefited from more head injury protection in the 3 and 4 star rated vehicles compared to the 5 star rated ones.

REFERENCES

1. <http://www.safercar.gov/>.
2. Sahraei Esfahani E, Digges K., 2009, "Trend of Rear Occupant Protection in Frontal Crashes over Model Years of Vehicles", SAE Technical Paper, 2009-01-0377.
3. Laituri T. R., Prasad P., Kachnowski B. P., Sullivan K., and Przybylo P. A., 2003, "Predictions of AIS3+ Thoracic Risks for Belted Occupants in Full-Engagement, Real-World Frontal Impacts: Sensitivity to Various Theoretical Risk Curves", SAE Technical Paper, 2003-01-1355.
4. Eppinger R., Sun E., Kuppa Sh., Saul R., 2000, "Supplement: Development of Improved Injury Criteria for the Assessment of Advanced Automotive Restraint Systems – II", http://www-nrd.nhtsa.dot.gov/pdf/nrd-11/airbags/finalrule_all.pdf.