INJURY AND DEFORMATION TRENDS WITH OFFSET CRASH TESTS

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ABSTRACT

Deformable barrier, 64km/h offset crash tests are conducted under international New Car Assessment Programs. Injury and deformation data from more than 140 offset crash tests carried out since 1995 by EuroNCAP, the Insurance Institute for Highway Safety and Australian NCAP have been analyzed.

Trends for head protection, leg protection and structural performance are discussed. The test results confirm that increased uptake of front airbags in Australia has brought about an improvement in head protection. Improvements in structural performance appear to have led to improved leg and foot protection globally.

Vehicle designs have evolved to provide better occupant protection in offset crashes. Consumer crash test programs have accelerated this process.

INTRODUCTION

The Australian New Car Assessment Program (ANCAP), US Insurance Institute for Highway Safety (IIHS) and EuroNCAP have conducted 64km/h offset crash tests since the mid 1990s. Details of test results are available from these organisations, allowing us to compile a sizeable database of injury and deformation measurements for most of the crash tests. This paper sets out the results of our preliminary analysis of offset crash test results for 142 models of passenger car ("people movers" and sports utility vehicles were excluded). Results have been analysed by year model to check for trends over the last 6 years.

SAMPLING ISSUES

Due to gaps in the data, the sample does not cover all cars tested over the evaluation period. Table 1 sets out the number of vehicles analysed, by each test organisation and year model.

Note that the sample sizes in some cells were small. To assist in interpretation of the results the graphs in this paper include confidence intervals based on a t-distribution at a 95% confidence level.

Table 1. Sample Sizes

YEAR MODEL	ANCAP	ENCAP	IIHS	ALL
1995	3	-	12	15
1996	12	11	4	27
1997	3	11	14	28
1998	7	14	8	29
1999	5	4	9	18
2000	3	4	18	25
ALL	33 (23%)	44 (31%)	65 (46%)	142

All injury measurements are for the driver. IIHS crash tests do not include a passenger.

Under the EuroNCAP assessment protocol scores are assigned to each injury measurement and modifiers (penalties) apply to some of these scores (see Appendix). No modifiers have been applied in the following analysis.

RESULTS - INJURY MEASURMENTS

Driver HIC

Figure 1 shows the trends for driver Head Injury Criterion (HIC). For USA and Europe the average driver HIC has not changed over the 6 years. In this same period in Australia the average HIC has reduced from 800 to about 500. This is most likely explained by the later introduction of airbags in Australia. For example, two thirds of the Australian 1995 year models did not have a driver airbag whereas 20% of 1999 models did not have an airbag. In contrast driver airbags have been almost universally fitted in the USA and Europe since before 1995.

When the results are split into airbag and non-airbag models the consistently good performance of airbags is evident (Table 2).

The EuroNCAP assessment protocol rates a HIC under 650 as "good" and a HIC of 1000 or more as "poor" (see Appendix).

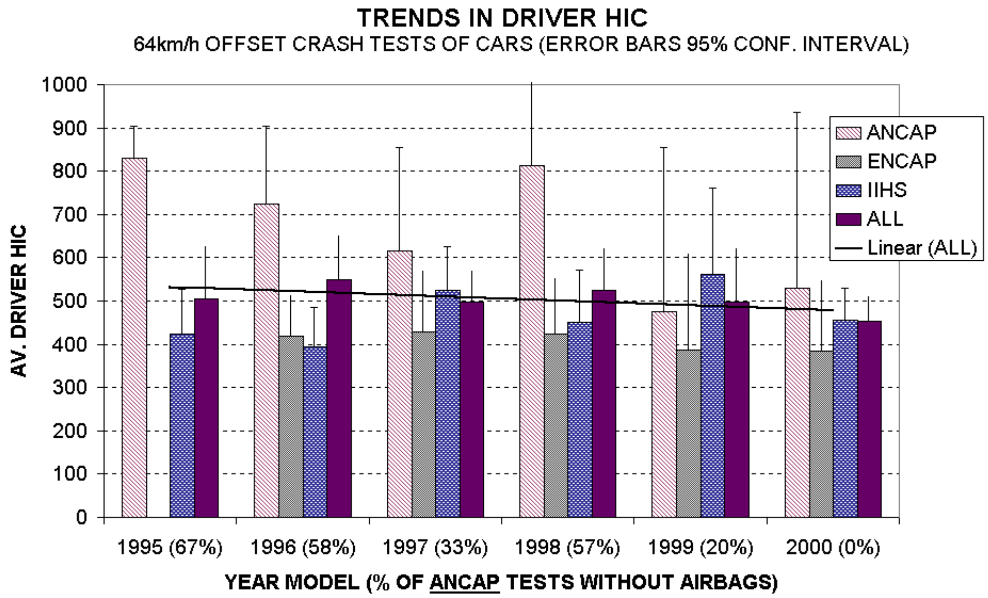

Figure 1. Trends in Driver HIC

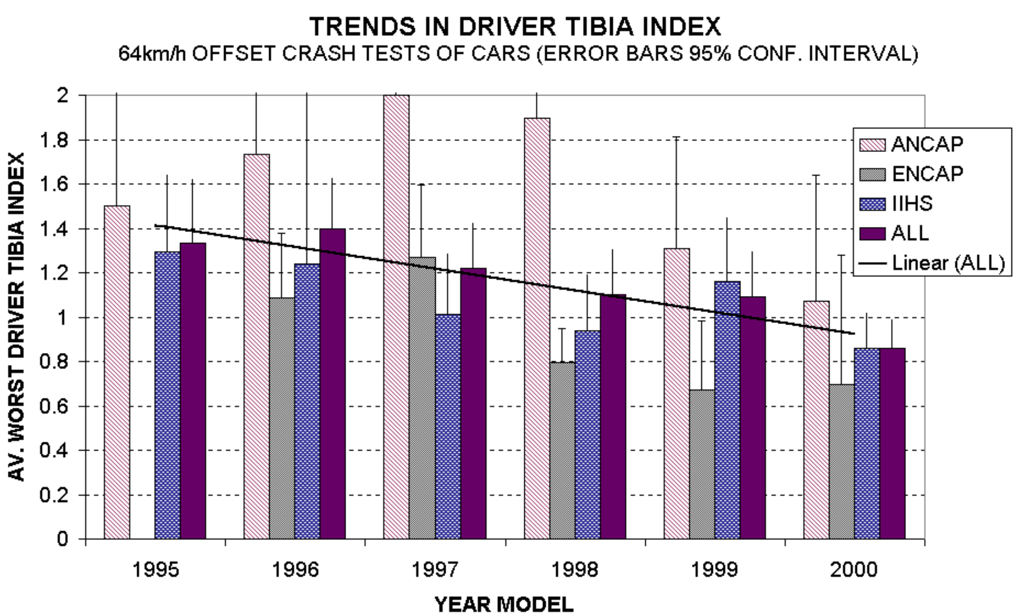

Figure 2. Driver Tibia Index (Worst of 4 values)

Table 2. Average HIC and airbag

YEAR MODEL	NO AIRBAG	AIRBAG
1995	847	454
1996	827	453
1997	855	469
1998	926	461
1999	990	470
2000	-	454

Driver Tibia Index

Separate tibia index values are calculated for left and right legs and, for recent tests, for the upper and lower tibia. The worst of these four readings is used in the analysis (as it is for scoring under the EuroNCAP protocol). Results are plotted in Figure 2.

There appears to be a strong downward trend (that is, reduced risk of serious injury) over the six years but this is only marginally significant due to the large confidence intervals.

The EuroNCAP assessment protocol rates a tibia index under 0.4 as "good" and more than 1.3 as "poor". The overall (global) average by 2000 was 0.85 so there is still room for substantial improvement.

RESULTS - DEFORMATION MEASUREMENTS

A-Pillar Movement

Residual rearward displacement of the A-pillar (adjacent to the upper hinge of the front door) gives an indication of the integrity of the passenger compartment. Large displacements are usually associated with catastrophic collapse of the roof, driver's door and floorpan (Paine and others, 1998).

EuroNCAP applies a "chest score modifier" to A-pillar displacements greater than 100mm, scaling up to a 2 point penalty at 200mm displacement.

IIHS does not report A-pillar displacement but does report the reduction in the width of the driver's doorway. This has been used as a surrogate for a-pillar displacement in the analysis.

Results are plotted in Figure 3. There appears to be a strong downward trend over the six years for EuroNCAP, IIHS and combined (global) data.

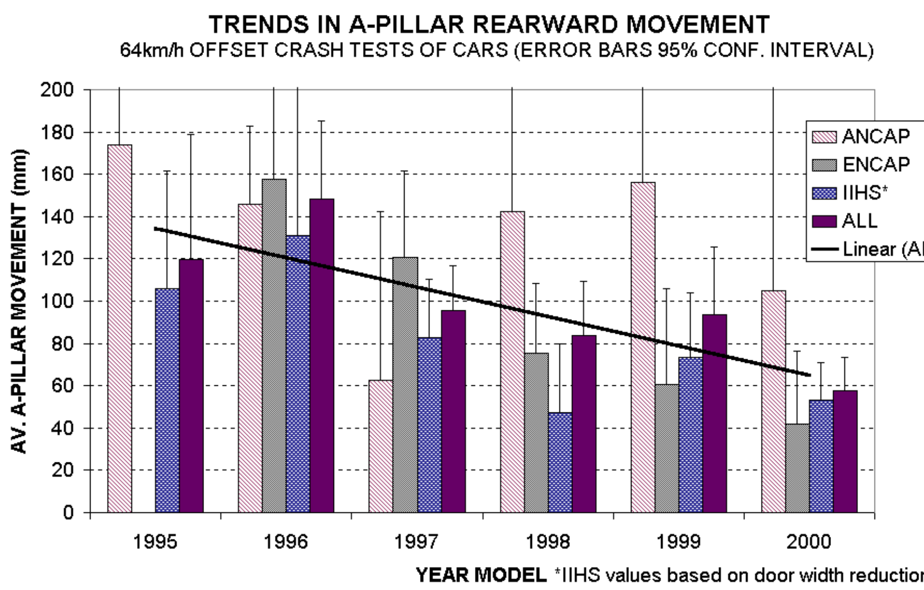

Figure 3. A-Pillar Rearward Displacement

However, ANCAP data is inconclusive due to large confidence intervals.

Brake Pedal Movement

Residual rearward displacement of the brake pedal gives an indication of one source of injury to lower legs. It is also an indicator of firewall deformation.

In the absence of injury measurements for dummy feet the EuroNCAP protocol derives a "foot score" from rearward brake pedal displacement. A maximum (good) score of 4 points is obtained if the displacement is less than 100mm and zero points is obtained if the displacement is 200mm or more. The worst of foot score and the two tibia scores is used for the lower leg score under the protocol.

Results are plotted in Figure 4. There is a slight downward trend for combined (global) values, indicating reduced risk of injury. Data for the early years of ANCAP and IIHS tests were not available. IIHS showed a peak in 1999 but the confidence interval was large, suggesting a large variation in results for that year.

DISCUSSION

Caution is needed when interpreting these preliminary results. The sample sizes and, in some years, the large variation between vehicles produced large confidence intervals.

Also the trends may be affected by the selection methods used by the test organisations. For example, 1996 had a greater proportion of small cars (63% of all tests) compared with 1999 (38%). Furthermore, the mix of "luxury" and "cheap" cars may vary from year to year.

In Australia the publication of NCAP crash test results has increased consumer awareness and has led to faster uptake of airbags.

In Europe and the USA airbags are almost universally fitted and there appears to have been no change in the head protection provided by airbags over the six years of the analysis. Since the average HIC for airbag-equipped vehicles is well into "good" range (for EuroNCAP rating purposes) it could be argued that the offset test program will not lead to further airbag improvements. However, both EuroNCAP and IIHS assessment protocols take into account airbag performance issues such as unstable head contact (head rolling off the side of the airbag) and the airbag bottoming out. These are likely to have an influence on airbag and steering column design.

Footwell and floorpan design appear to be receiving greater attention from vehicle designers. This can be attributed, in part, to the consumer offset crash tests that can be very demanding on the vehicle structure in this region. Structures that channel crash forces around the vulnerable footwell area are becoming more commonplace (Paine and other 1998).

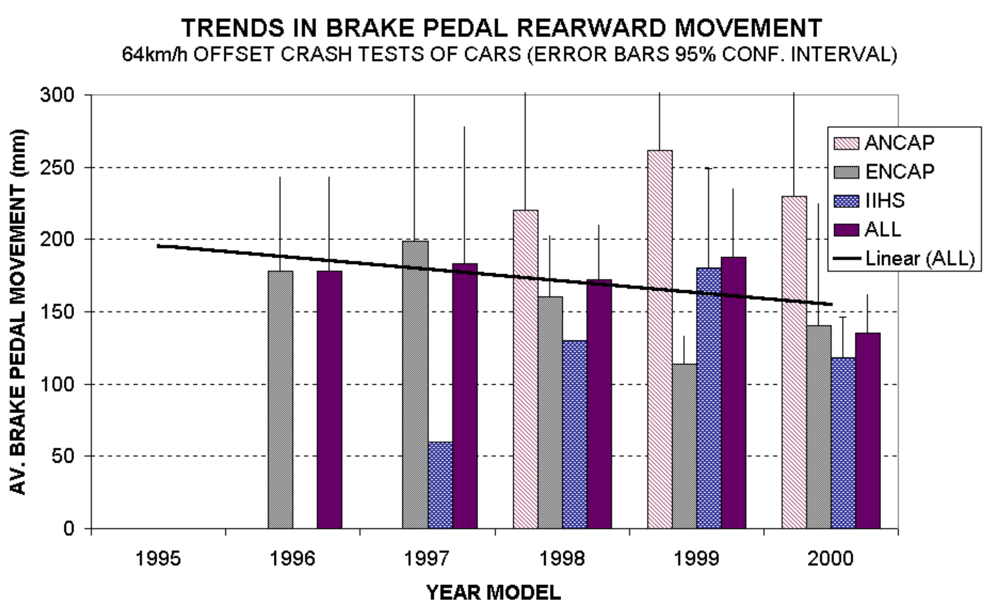

Figure 4. Residual Brake Pedal Displacement

CONCLUSIONS

Subject to caution about sample sizes and confounding factors, this analysis of injury and deformation data from 142 offset crash tests of cars performed under Australian, European and USA consumer crash test programs has revealed that, between 1995 and 2000, there was:

- a clear advantage from airbags for head protection (as indicated by HIC) but no clear improvement for airbag-equipped vehicles over the period.
- indications of an improvement in lower leg protection (as indicated by tibia index) over the period but brake pedal displacement shows no clear reduction and
- a clear improvement in structural performance (as indicated by residual a-pillar displacement)

Consumer crash test programs continue to be influential in the design of new vehicles.

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APPENDIX - SUMMARY OF EURONCAP ASSESSMENT CRITERIA

BODY REGION	DESCRIPTION	UNITS	LOWER	UPPER	POINTS	TYPE
OFFSET CRASH TEST						
HEAD	HEAD RESULTANT (3ms)	g	72	88	4	Sliding
HEAD	HIC	HIC	650	1000	4	Sliding
HEAD MODIFIER	AIRBAG_STABILTY	Y/N			1	Step
HEAD MODIFIER	STEER COL. VERTICAL	mm	72	88	1	Sliding
HEAD MODIFIER	STEER COL. REARWARDS	mm	90	110	1	Sliding
NECK	SHEAR	kN	1.9	3.1	4	Sliding
NECK	TENSION	kN	2.7	3.3	4	Sliding
NECK	EXTENSION	Nm	42	57	4	Sliding
CHEST	CHEST COMPRESSION	mm	22	50	4	Sliding
CHEST	CHEST VISCOUS CRIT.	m/s	0.5	1	4	Sliding
CHEST MODIFIER	A-PILLAR DISPLACEMENT	mm	100	200	2	Sliding
CHEST MODIFIER	CHEST CONTACT	Y/N			1	Step
CHEST MODIFIER	STRUCTURAL INTEGRITY	Y/N			1	Step
UPPER LEG	KNEE DISPLACEMENT	mm	6	15	4	Sliding
UPPER LEG	FEMUR COMPRESSION	kN	3.8	9.07	4	Sliding
UPPER LEG MODIFIER	CONCENTRATED KNEE LOAD	Y/N			1	Step
UPPER LEG MODIFIER	VARIABLE KNEE CONTACT	Y/N			1	Step
TIBIA	TIBIA COMPRESSION	kN	2	8	4	Sliding
TIBIA	TIBIA INDEX	index	0.4	1.3	4	Sliding
TIBIA MODIFIER	BRAKE PED. VERTICAL	mm	72	88	1	Sliding
FOOT	BRAKE PED. REARWARDS	mm	100	200	4	Sliding
FOOT MODIFIER	FOOTWELL RUPTURE	Y/N			1	Step
SIDE IMPACT CRASH TEST						
HEAD	HEAD RESULTANT (3ms)	g	72	88	4	Sliding
HEAD	HIC	HIC	650	1000	4	Sliding
CHEST	CHEST COMPRESSION	mm	22	42	4	Sliding
CHEST	CHEST VISCOUS CRIT.	m/s	0.32	1	4	Sliding
ABDOMEN	ABDOMEN FORCE	kN	1	2.5	4	Sliding
PELVIS	PUBIC SYMPHYSIS FORCE	kN	3	6	4	Sliding
PEDESTRIAN IMPACTS						
HEAD	HIC	HIC	1000	1500	2	Sliding
UPPER LEG	BENDING MOMENT	Nm	220	400	2	Sliding
UPPER LEG	SUM OF FORCES	kN	4	7	2	Sliding
LOWER LEG	KNEE ANGLE	degree	15	30	2	Sliding
LOWER LEG	KNEE DISPLACEMENT	mm	6	7.5	2	Sliding
LOWER LEG	TIBIA ACCELERATION.	g	150	230	2	Sliding

Notes: This is a summary and is subject to change. Check the EuroNCAP website for the latest requirements.

"LOWER" is the lower limit, below which the injury measurement scores 4 points. In the case of modifiers, there is no penalty below this limit.

"UPPER" is the upper limit. Injury measurements at or above this limit score zero points. In the case of modifiers the maximum penalty applies.

"TYPE" refers to the application of points. "Sliding" means that a linear sliding scale applies between the lower and upper limits. "Step" applies only to modifiers. Below the upper limit there is no penalty. At or above the upper limit the maximum penalty applies. With chest modifiers the combined penalty from all modifiers is limited to 2 points.