Potential Use of Crash Test Data for Crashworthiness Research

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Abstract

Crash tests of popular motor vehicles such as the USA New Car Assessment Program (NCAP) have been conducted for more than two decades, initially using the 56km/h full frontal crash test. During the 1990s crash testing began in Australia, Europe, Japan and Korea. The offset frontal crash test and 90^o moving barrier side impact were introduced during this time. In the USA the Insurance Institute for Highway Safety also commenced offset frontal crash tests and NHTSA added the oblique moving barrier side impact test to its program.

To date more than 300 offset frontal crash tests and more than 70 side impact tests (90^o) have been conducted throughout the world by NCAP-related organisations. Over one dozen pole impacts have now been conducted in Europe. The results of these tests are primarily used to derive crashworthiness ratings for the information of consumers. There is, however, tremendous potential for crash test data and video to contribute to crashworthiness research. We review the data being collected during these crash tests and suggest ways that they can contribute to improved vehicle design and occupant protection.

INTRODUCTION

Consumer crash tests under various New Car Assessment Programs (NCAP) are conducted primarily to give consumers an indication of the crashworthiness of vehicles they may be considering for purchase. The types of crash tests conducted include:

a) Full frontal - the vehicle is travelling at 56km/h and collides with a rigid barrier that engages the entire front of the vehicle

b) Offset frontal - the vehicle is travelling at 64km/h and collides with a deformable barrier that engages 40% of the front of the vehicle on the driver's side

c) European Side impact - the vehicle is stationary and is struck by a deformable 950kg barrier travelling at 50km/h that engages driver's side of the vehicle at 90^o.

d) US Side impact - the vehicle is stationary and is struck by a deformable 1367kg barrier travelling at 53.9km/h that engages driver's side of the vehicle at 63^o

e) Pole test - the vehicle is travelling sideways at 29km/h and strikes a rigid pole with a diameter of 254mm.

f) Pedestrian protection - special test devices are impacted against vehicle components to simulate a pedestrian being struck by the front of the vehicle. The tests include a child headform, an adult headform, an upper leg test device and a knee/lower leg test device. In general the tests simulate an impact at around 40km/h.

The usual outcome of a series of crash tests is the assignment of a star rating to each vehicle. The reduction of injury measurements from several dummies in one or more crash tests to a star rating is considered necessary by some organisations for the purpose of presentation of the results to consumers. There is, however, a wealth of crashworthiness information that is collected by NCAP organisations. This information could be useful for safety researchers, crash investigators, vehicle designers, safety equipment designers and regulators. The purpose of this paper is to examine this information and to suggest ways that it can be utilised for improving vehicle design and occupant protection.

DATA COLLECTED

Full frontal crash tests

Full frontal crash tests are conducted by the US National Highway Transport Safety Administration (NHTSA) and by Japan NCAP. Full frontal crash tests were conducted by Australian NCAP from 1992 until 1999, when Australia aligned with the Euro NCAP test protocol (that does not currently include a full frontal crash test).

Head, chest and upper extremity injury measurements are recorded for a driver and front passenger dummy. High speed film/video is recorded from various angles. Vehicle deformation measurements and photographs are available.

Offset crash tests

Offset frontal crash tests are conducted by Euro NCAP, Japan NCAP, Australian NCAP and the US Insurance Institute for Highway Safety (IIHS). Australian NCAP commenced offset crash tests (at 60km/h) in 1993. In 1995 Australian NCAP, IIHS and EuroNCAP began crash testing at 64km/h. Japan NCAP published its first offset crash test results in 1999.

Head, chest and upper extremity injury measurements are recorded for a driver and front passenger dummy. High speed film/video is recorded from various angles. Vehicle deformation measurements and photographs are available. Euro NCAP assessment criteria are set out in the appendix.

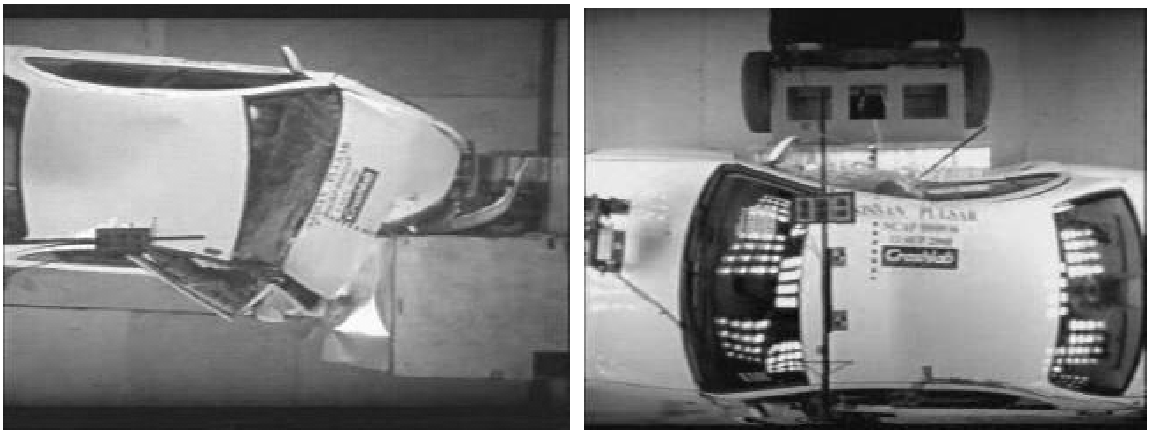
In Europe and Australia child dummies (TNO P1.5 and P3) are placed in child restraints in the rear seat. Head and chest acceleration measurements and high speed film/video are available for these dummies but the injury measurements are not biofidelic [1].

European side impact tests

European side impact tests are conducted by Euro NCAP, Japan NCAP and Australian NCAP. Japan NCAP conducts the test at 55km/h, compared with 50km/h in Europe and Australia.

Head, chest and abdomen and pelvis injury measurements are recorded for a driver dummy. High speed film/video is recorded from various angles. Photographs and limited vehicle deformation measurements are available. Euro NCAP assessment criteria are set out in the appendix.

In Europe and Australia child dummies (TNO P1.5 and P3) are placed in child restraints in the rear seat. Head and chest injury measurements and high speed film/video are available for these dummies but the injury measurements are not biofidelic [1].



Figures 1a and 1b. Frontal offset and European side impact crash tests (ANCAP)

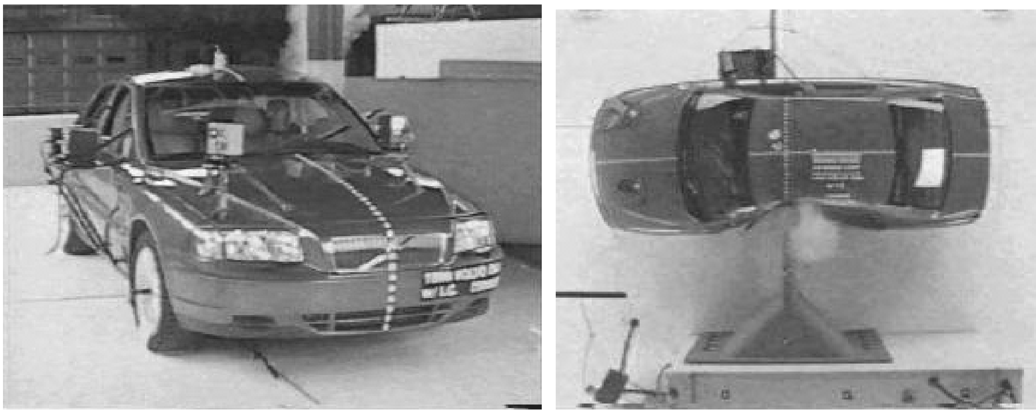
US side impact tests

US-style side impact tests are conducted by NHTSA. Injury measurements are recorded for a driver and rear seat adult passenger dummy. High speed film/video, photographs and limited vehicle deformation measurements are available.

Pole test

Pole tests are conducted according to the Euro NCAP protocol in Europe. The test is only carried out where the vehicle has head-protecting upper airbags (such as curtain airbags) and a good head injury result is obtained in the European side impact test. The pole test is optional and is funded by the vehicle manufacturer. No vehicle tested by Australian NCAP has been eligible for a pole test. IIHS in the USA has carried out research on the pole test but has not conducted consumer tests.

Head, chest and abdomen and pelvis injury measurements are recorded for a driver dummy. High speed film/video is recorded from various angles. Photographs and limited vehicle deformation measurements are available.



Figures 2a and 2b. Pole test with curtain airbag (IIHS)

Pedestrian protection

Pedestrian protection tests are conducted in accordance with the Euro NCAP protocol in Europe and Australia [2].

Head deceleration is recorded for the child and adult headform tests. Femur bending moment and axial force is recorded for the upper legform test. Tibia acceleration, knee shear displacement and knee bending angle are recorded for the lower legform test. Euro NCAP assessment criteria are set out in the appendix.

Photographs and some high speed film/video are available for these tests.

Figure 3a and 3b. Snapshots at peak of Euro NCAP lower and upper legform impact tests (TRL)

POTENTIAL USES OF CRASH TEST DATA

Improving vehicle design

The results of NCAP tests can be useful for determining ways to improve vehicle design.

Designers of the vehicles that have undergone NCAP testing can check the accuracy of computer modelling and prototype crash tests with the results of NCAP tests. Dummy injury measurements and vehicle deformation can be compared with predicted values. Mechanisms of structural collapse can be determined from post-crash inspection of the vehicle and by viewing the high-speed video of the crash test. Dummy kinematics can be assessed from high-speed video and checking for interior contacts. Seat belts, seat and airbags can be inspected to check that they operated as intended. For example, the dynamics of the crash sometimes compromise airbag performance in ways that might not be evident from a post crash inspection. In one recent case a sudden upward movement of the steering column just prior to the peak of the crash probably affected airbag performance but the column dropped back down by the time the crash was over. Only careful analysis of the video revealed the potential problem.

Comparisons between vehicles that perform well and those that perform poorly can reveal ways design features that improve crashworthiness [3].

In Australia, vehicle manufacturers are invited to observe the crash tests and conduct a brief post-crash inspection. They have the option of purchasing the crash-tested vehicle if they wish to conduct a more thorough analysis. In theory, if the manufacturer does not wish to purchase the wreck then a competitor could purchase it to learn more about its performance but in practice, this does not occur in the Australian car industry.

Understanding injury mechanisms

Dummy kinematics and points of contacts can reveal potential sources of injury to human occupants. Ways of improving occupant restraint systems can be determined.

Results of NCAP tests can be compared with injuries suffered in similar real-world crashes. Assumed links between dummy injury measurements and actual risk of serious injury can be verified by comparing NCAP tests with the outcome of real world crashes.

There is also an opportunity to add extra instrumentation and camera angles to learn more about specific injury mechanisms. For example, there is increasing awareness of serious lower leg injuries in side impact crashes [4]. In a recent Australian NCAP side impact test the dummy legs were painted and the post-impact inspection suggested a fairly concentrated mid-span loading of the tibia/fibula by the interior door trim where it covered the radio speaker. Further work is needed to establish whether the loading was sufficient to cause a fracture in a human.

Although the measurement of leg injury potential is not part of the Euro NCAP protocol it might be a relatively simple exercise to add instrumented (Hybrid III) legs to the EuroSID dummy. Also small onboard cameras could be used to better understand the dynamic interaction between the dummy legs and the vehicle interior.

Performance of child restraints

Child restraints are included in the frontal offset and side impact crash tests conducted according to the Euro NCAP test protocols. Injury measurements, head contact marks and video can provide new information about the performance of child restraints [5]. For example, previously there was little information available about the performance of child restraints in side impacts. Now onboard cameras in the Australian NCAP tests provide good views of dummy and restraint movement in the side impact test.

There are concerns about the biofidelity of the TNO P-series child dummies and the links between child dummy injury measurements and the risk of serious injury in children [6]. Experience with real-world crashes in Australia indicates that young children in forward facing child seats are surviving extremely severe crashes without injury, including neck injuries [7]. Several of the crashes studied in Australia as part of the 1993 'CAPFA Study' were at much higher severity than the Euro NCAP frontal offset test and yet the children were uninjured. Since the 1970s the Roads and Traffic Authority of NSW has been informally monitoring serious car crashes involving child seats and infant capsules. In the absence of severe intrusion, no cases of serious injury to correctly restrained children have arisen in frontal crashes. Decades of Australian experience therefore confirm the concept that the most important priority with child restraints is to limit excursion of the occupant and minimise the risk of head impacts [7,8].

Figure 4a and 4b. Snapshots at peak of side impact and frontal offset crash tests showing child restraint dynamic performance (ANCAP)

In recent Australian NCAP tests the child dummy head decelerations exceeded the limits proposed by Euro NCAP [5]. This suggests that the Euro NCAP limits are inappropriate and that more research is needed on the subjects of child restraints and child injury tolerances. A particular concern is that if the Euro NCAP criteria were applied in Australia then child restraints might be designed for greater occupant excursion (to reduce body decelerations, as measured for the Euro NCAP protocol) and therefore greater risk of injury through head contacts.

CONCLUSIONS

NCAP crash tests are an important but under-utilised source of data for road safety research. It is considered that there is scope for greater co-operation between NCAP organisations and researchers on the use of such data, and the collection of extra data to meet specific research needs.

At an international level it is understood that objective, repeatable tests are being developed to assess the performance of vehicles in other crash circumstances. These include vehicle to vehicle compatibility, rear impacts and rollover crashes. It is important that, in designing the data collection aspects of these tests, consideration is given to the potential uses of the test data and video beyond that needed for the assessment criteria. Experience with current NCAP programs suggests that this is not an easy task because the future needs of road safety researchers are difficult to anticipate.

DISCLAIMER

The views expressed in this paper are those of the authors and do not necessarily represent the views of any organisation.

REFERENCES

1. Trosseille X, Cassan F. and Schrooten M. 'Child restraint system for children in cars - CREST results', *Proceedings of 17th Enhanced Safety of Vehicles Conference*, Netherlands 2001.

2. Paine M. and Coxon C. 'Assessment of Pedestrian Protection Afforded by Vehicles in Australia', *Proceedings of Biomechanics Conference*, Institution of Engineers Australia, Sydney, March 2000.

3. Paine M., McGrane D and Haley J (1998) Offset crash tests - observations about vehicle design and structural performance. *Proceedings of 16th ESV, Windsor.*

4. Arndt N, Grzebieta R, Fildes B and Sparke L (2002) 'Lower extremity injuries in side impact crashes', *Proceedings of ICrash 2002,* Society of Automotive Engineers, Australasia (also PhD Interim Report, December 2001 by Naomi Arndt).

5. Paine M., Brown J and Griffiths M (2001) 'Crash and sled tests using child dummies', *Proceedings of Impact Biomechanics Australia Conference, 2001,* Institution of Engineers Australia.

6. Brown J, Paine M, Griffiths M and Kelly P (2001) 'Assessing child restraint performance using child dummy response' , *Proceedings of Impact Biomechanics Australia Conference, 2001,* Institution of Engineers Australia.

7. Henderson M, Brown J and Paine M (1994) 'Injuries to restrained children' *Proceedings of the 38th Annual AAAM Conference*.

8. Webber K. (2000) 'Crash Protection for Child Passengers: A Review of Best Practice', *UMTRI Research Review* July-September 2000, Vol.31,No.3

9. Griffiths M. (1996) Consumer crash test programs - international harmonisation and scope for injury reduction. *Proceedings of 15th ESV*, Melbourne.

10. Hobbs C.A., Gloyns P.F. and Rattenbury S.J. (1999) *Assessment Protocol and Biomechanical Limits*, European New Car Assessment Program, TRL May 1999.

11. IIHS (1996) *Crashworthiness Evaluation: Offset Barrier Crash Test Protocol, Version III.* Insurance Institute for Highway Safety.

APPENDIX - SUMMARY OF EURONCAP ASSESSMENT CRITERIA - VERSION 3.1

BODY REGION	**DESCRIPTION**	**UNIT**	**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/BOTTOMS OUT	Y/N			1	Step
HEAD MODIFIER	STEER COL. VERTICAL OR LATERAL	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	ANY PEDAL VERTICAL	mm	72	88	1	Sliding
FOOT	ANY PEDAL 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 type of injury score or modifier (penalty 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. For each body region the combined penalty from all modifiers is limited to 2 points. In addition to the modifiers shown in the table, one point is deducted from the test score for each door (including a rear door) that opens during the crash. This applies to both offset and side impact test scores.