

# **PEDESTRIAN INJURY PROJECTION IN AUSTRALIA IF VEHICLES ACHIEVED A HIGHER PEDESTRIAN STAR RATING**

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## **ABSTRACT**

Pedestrian tests are now included in vehicle crash testing carried out by Australian NCAP to the same procedure as EuroNCAP. Australia has a five year average of 338 pedestrians killed each year amounting to 18% of the total road toll, with many more admitted to hospital. Test data from EuroNCAP Pedestrian tests have been used to indicate the present likelihood of serious head injury to struck pedestrians. Predictions on serious head injury rates are made if the Australian vehicle fleet achieved a minimum of 3 star pedestrian rating or better by the EuroNCAP test and assessment protocols. Estimates of the number of years for the fleet to achieve a higher level of performance are made. Some locations of vehicle bonnet sites that cause high HIC readings are made for designers to take note of.

## **INTRODUCTION**

Pedestrian testing commenced in Australia in 1999 with the adoption by Australian NCAP of the EuroNCAP test and Assessment protocols. Since that time there has been a steady test program of new vehicles tested to the pedestrian frontal injury program of EuroNCAP. The University of Adelaide Road Accident Research Unit Pedestrian test facility is fully operational. Tests carried out are the child and adult head form impact on the bonnet or windscreen, upper leg impact tests across the upper surface of the front of the car, and lower leg impact tests on the bumper area. In this paper, only the head form test will be considered as life threatening. Leg form tests while indicating serious injury are generally not likely to be life threatening. However they can be very debilitating to the injured person.

## **GOVERNMENT REGULATIONS**

There are no present government regulations concerning pedestrian testing required in Australia. Some concern has been expressed at the level of unprotected road user fatal injuries and serious injury.

Australia is waiting for the European Community to act rather than regulate without similar requirements from Europe. Progress of the ECE is being watched to see how regulations requiring pedestrian tests are introduced across Europe. A watching brief is also maintained on Japan to see if the Japanese Government moves with a unique test dummy.

## **INTERNATIONAL PEDESTRIAN SAFETY PERFORMANCE**

Pedestrian fatality rates in Australia compared with other OECD nations suggest considerable scope to improve the safety of Australian pedestrians. In 1997 Australia was ranked 14<sup>th</sup> in terms of fatalities per 100,000 population and 11<sup>th</sup> in terms of fatalities per 10,000 vehicles registered.

Australia has a mean of 1.78 pedestrian fatalities per 100,000 population. In pedestrian fatalities per 10,000 vehicles the mean is 0.28 pedestrian fatalities per 10,000 vehicles.

The OECD median in 1997 was 1.68 pedestrian fatalities per 100,000 population and 0.33 pedestrian fatalities per 10,000 vehicles.

The total pedestrian number killed when struck by vehicles has a five-year average of 338 per year for around 18 % of all fatal road crashes.

Analysis of the high-risk groups show young adults and the elderly to be over represented in serious injury accidents. Alcohol is also a factor in struck pedestrian fatal crashes.

## **PEDESTRIAN INJURY VALUES**

Serious head injury to adults and children is considered a life threatening injury, while injury to upper and lower legs is debilitating, but not life threatening. Hence head injury was the focus of this analysis to look at vehicle safety improvements to reduce serious and fatal pedestrian head injuries.

Test data from many EuroNCAP and ANCAP pedestrian tests shows that the majority of vehicles

tested in the period from 1996 to 2001 have achieved a 2 star rating out of a possible 4 star maximum. Three vehicles in the pedestrian tests achieved 3 star ratings, the Daihatsu Sirion as tested by EuroNCAP and Australian pedestrian tests on the 2000 model year of both Mazda 323, and Nissan Pulsar. It is considered that these figures are representative of the vehicle fleet in unmodified vehicles. Pedestrian injuries are expected to be more serious if attachments like bull bars and additional headlights are fitted to the fronts of vehicles in pedestrian possible contact areas.

Large cars made and sold in Australia in the past 3 years have pedestrian scores in the 2 star range, and these cars represent about 30% of market share. The tests show that leg injury protection was very low, while there were some encouraging data from the child and adult head form tests results.

### Head Impacts

Typically the legs are struck first which rotates the body with the head striking the bonnet top. In the EuroNCAP protocols for head impact, two head-forms are used to simulate vehicle head impact at 40 KPH. A child head-form with a mass of 2.5 kg and an adult head form with a mass of 4.8 kg. The child head-form strikes are to the front of the bonnet (wrap-around distance 1 to 1.5m) while the adult head-form strikes are to the rear of the bonnet and sometimes the glass (wrap around distance 1.5 to 2.1 m).

Six tests are conducted with each headform, based on three equal transverse zones and two impacts within each zone. One impact location is chosen for highest injury potential, such as above engine parts, suspension mounting points or bonnet hinges. The other is chosen to be the least injurious. Where the left and right zones have similar structures judged to be the most injurious the next worst location is chosen for one of the zones.

### Assessment of Injury results

The scores for each impact are summed to give an overall score. Table 1 shows the maximum possible score for each test, with a maximum overall score of 36 points. Table 2 shows the relationship between points scored and stars used in consumer reports.

Note that 24 points is possible from child and adult head form tests, which could give a 3 star rating with zero points from leg tests.

**Table 1.  
Test Scores**

| Type of Test   | Impact Locations                | Max Score |
|----------------|---------------------------------|-----------|
| Child Headform | 6 on bonnet and Fender          | 12        |
| Adult Headform | 6 on bonnet, Fender top & Glass | 12        |
| Upper Leg      | 3 on Front top of Bonnet        | 6         |
| Lower leg      | 3 on Lower Bumper               | 6         |

**Table 2.  
Star Rating Relationship to the Overall Score**

| Pedestrian Score | Stars |
|------------------|-------|
| 27.5 or more     | 4     |
| 18.5 – 27.49     | 3     |
| 9.5 – 18.49      | 2     |
| 0.5 – 9.49       | 1     |
| Less than 0.5    | Zero  |

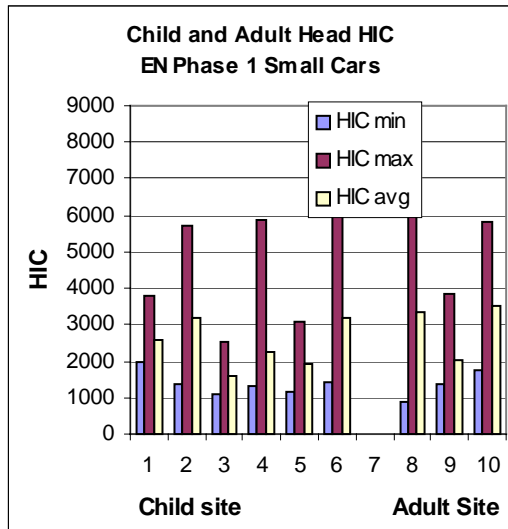
### TYPICAL EURONCAP INJURY RESULTS

Euro NCAP has been publishing Pedestrian test results since 1996 and continues to build the database for popular vehicles operating on roads across Europe. Similar vehicles also operate in Australia and much of the data on pedestrian injury performance would also be applicable on Australian roads.

In the following figures, data is presented on the best, worst and average HIC number for child and adult head contacts on the fronts of the cars tested in both Europe and by Australian NCAP. The data presented is considered typical of the fleet of vehicles operating where pedestrian contact is possible.

EuroNCAP Phase 1 tested the Fiat Punto, Ford Fiesta, Nissan Micra, Renault Clio, Rover 100, Vauxhall Corsa and VW Polo.

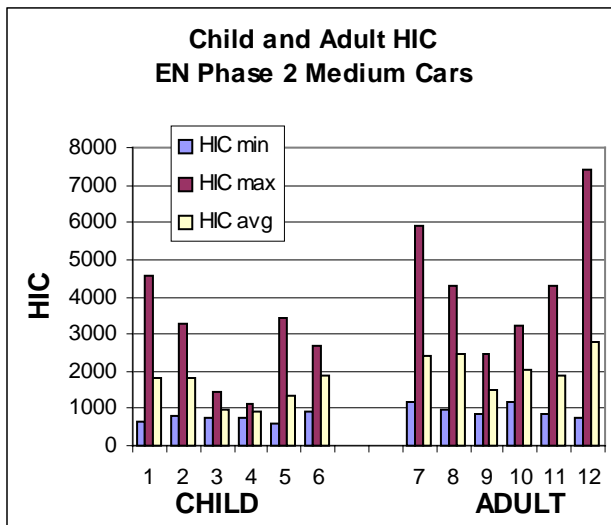
Figure 1 shows the maximum HIC reading obtained for each site point, which would cause very serious head injury. The average for each site is mostly a HIC of above 2000, which is likely to cause very serious head injury.



**Figure 1. Phase 1 EuroNCAP Head Data.**

In Phase 2 of the EuroNCAP pedestrian test program the vehicles were, Audi A4, BMW 316, Zantia, Mondeo, Primera, Peugeot 406, Laguna, Rover 620, Saab 900, Vectra, Volvo S40, and VW Passat. The max HIC, average HIC and minimum site HIC is shown on Figure 2.

Note in Figure 2 that the maximum HIC are very high, but the average for 9 child sites is under 2000, with adult averages mostly above 2000 HIC, which is likely to cause very serious head injury.

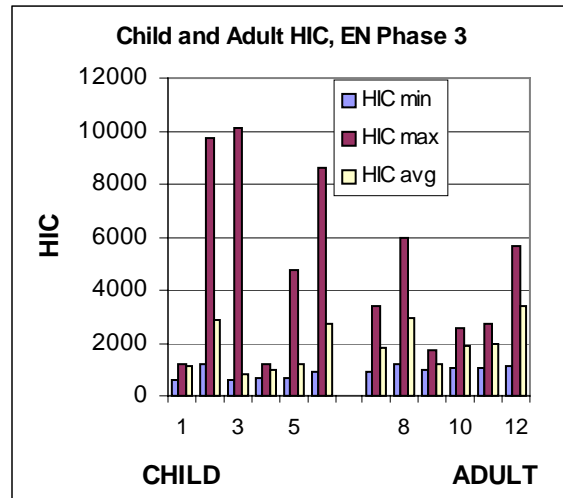


**Figure2. EuroNCAP Phase 2 Head Data.**

In EuroNCAP Phase 3 a large number of small cars were tested, consisting of, Audi A3, Xsara, Lanos, Brava, Civic, Accent/Excel, Lancer, 306, Megane, Baleno, Corolla, Golf, and Toyota Avensis

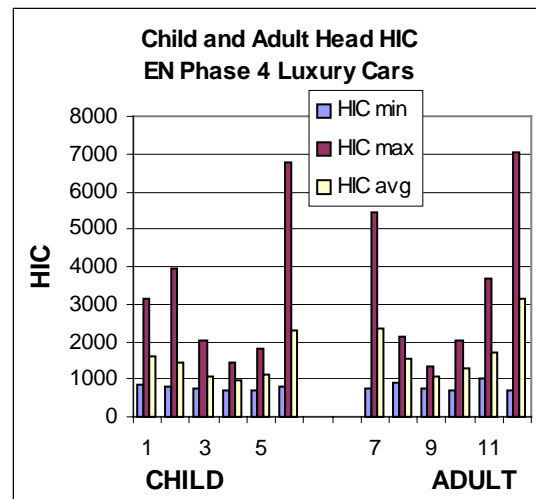
Figure 3 shows the head HIC data in for the sites as minimum, average and maximum.

In this series the average site HIC is much lower than in Phase 1 and 2 which is encouraging.



**Figure 3. EuroNCAP Phase 3 Head Data**

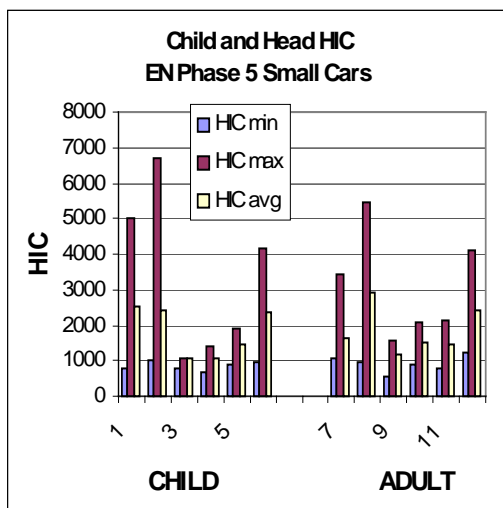
In EuroNCAP Phase 4 the European Luxury cars were tested consisting of Audi A6, BMW 5, Mercedes E Class, Opel Omega, Saab 9-5, Toyota Camry, and Volvo S70. Figure 4 shows the site minimum, average and maximum for this group.



**Figure 4 EuroNCAP Phase 4 Head Data**

The child head result average in 5 sites for Phase 4 cars is well under 2000 with the adult head average for 4 sites of 1500 HIC which is the lowest result achieved.

In Phase 5 of the EuroNCAP pedestrian test program the following cars were tested. Ford Escort, Focus, Mercedes A Class, Nissan Almera, Renault Megane and Vauxhall Astra. Data from these tests is shown of Figure 5.



**Figure 5. EuroNCAP Phase 5 Head Data.**

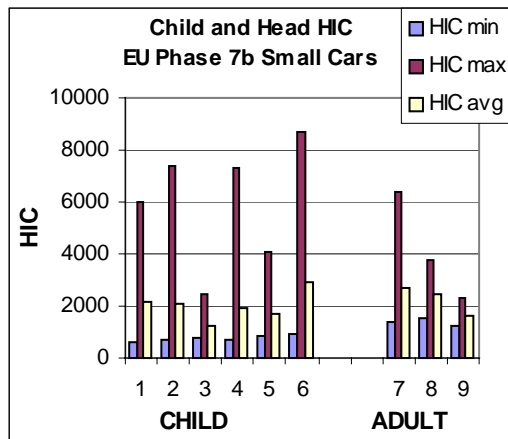
On some sites in Figure 5, the head maximum and average is well above 2000, which are of concern for both child and adult head form tests. This would indicate that there was a severe life threatening risk if the vehicle struck a pedestrian.

Data for Euro NCAP Phase 7b cars included Toyota Yaris/Echo, Clio, Fabia, Polo, Peugeot 206, Sirion, Matiz, Fiesta, Ibiza, Ka, Micra, Saxo, Seicento, and Megane.

Cars in EuroNCAP Phase 7b had some very high maximum HIC sites likely to cause very serious head injury to both child and adults.

The average HIC are also well over HIC 2000 but there was some good average results under 1500 HIC for the low injury sites selected by the manufacturers in the site selection protocol.

These cars were available new in the year 2000 and means they are going to be in the market for many more years.

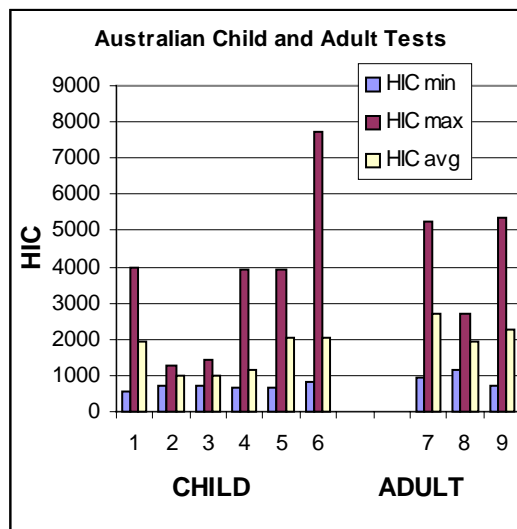


**Figure 6. EuroNCAP Phase 7b Car Head Data.**

## TYPICAL AUSTRALIAN CAR INJURY RESULTS

### Australian Pedestrian Test Head Data

ANCAP commenced pedestrian testing in 1999 with results in small and large cars that are representative of a large segment of the market.



**Figure 7. Australian Car Head Data.**

Child Head HIC for the cars tested by Australian NCAP were for two groups of cars. Large Australian 2000-2001 model year passenger cars of: Ford Falcon, GM Commodore, Mitsubishi Magna and Toyota Camry. Small cars were the Subaru Impreza, Hyundai Accent, Nissan Pulsar,

Mazda 323, Daihatsu Sirion, Kia Mentor, Daewoo Nubira and Lanos.

Data used is from actual tests on sites with no default data as allowed by the assessment protocol used. The test sites results show average readings in the 2000 HIC area for 6 of the 9 sites, which would cause life threatening head injury.

However there were encouraging data from 3 test sites with averages around the 1000 HIC acceptable head injury risk area.

## **ESTIMATES OF HEAD INJURY IMPROVEMENT**

The average age of the passenger vehicles in Australia is 10.5 years, with vehicle ownership at 1.6 people per vehicle, for a total fleet of 10.8 million vehicles (1997 data).

The data from EuroNCAP and Australian pedestrian tests is considered applicable to the Australia fleet of vehicles with a pedestrian star rating mostly in the 2 star class. This would indicate that the average child and adult head impact site would have a HIC value of 2000, which is likely to cause serious head injury to 80 % of the population.

If the head injury could be lowered to 1000 for new vehicles, then the risk of serious head injury may fall to 17% of the present serious injury level.

Australia has a pedestrian fatal number of 338 pedestrian killed each year. A reduction from 80% to 17% in head injury risk by lowering the HIC average to 1000 could result in a reduction in fatalities due to head injury to 72 average per year a saving of 264 lives each year.

To achieve this lowering of pedestrian fatal injuries would require all of the vehicle fleet to meet the 1000 HIC average level. It would also require impact speeds to be lower than 40 kph. Once legislation is in force, then it would take time for the fleet to change over. As seen by the lengthy negotiation within ECE to set pedestrian test standards, the likelihood of rapid legislative change is low.

Australia will follow international legislative programs on pedestrian injury reduction. Once legislation is in place, designers and manufacturers need time to develop changes to meet new

requirements. The result is the vehicle fleet will remain similar in head injury risk until vehicle design changes are introduced to lower the risk of serious head injury to struck pedestrians.

It is estimated that following introduction of any new pedestrian head injury regulations, another 2 years would be required for new vehicles to be entering the vehicle fleet. Another 5 years would be required for sufficient of the fleet to be upgraded with lower head injury risk to have a significant effect on pedestrian fatal head injuries.

Safety planning should continue to develop and encourage manufacturers to consider pedestrian safety measures in new vehicle designs, but the reality is that it will take many years for the changes to be reflected in the unacceptable pedestrian head injury road toll.

## **ANCAP Consumer Information on Pedestrian Injury.**

There has been little response from consumers or fleet owners to the publication of pedestrian injury results and other strategies are needed to ensure pedestrian head injury is given more attention by new vehicle buyers when new vehicles are selected.

## **VEHICLE DESIGN IMPROVEMENT**

High HIC readings of above 2000, which are likely to cause severe pedestrian head injury in a vehicle strike, have been measured in the following frontal head impact areas.

### **‘A’ Pillar**

This is treated as a 0-point adult head location unless a manufacturer can show that test data would indicate that the point would be worth testing in the NCAP program. There is no known vehicle from EuroNCAP or Australian NCAP published results that has been tested that makes the A pillar test point worth testing and injury from a head strike is usually fatal.

### **Lower glass at base of windscreen**

Points in this area have given mixed results, if the top of the instrument panel has a hard surface underneath, then the adult head injury HIC is generally high indicating serious injury if the pedestrian head contacts this part of the vehicle.

## **Bonnet Hinges**

The attachment of the bonnet hinge to the bonnet has been made with bolts with the threaded surface pointing upwards. A head contact in this area results in a very high HIC, which would usually be fatal. Options appear to be to shift the position of the fastener so the top of the bolt is not immediately under the bonnet surface. The present almost universal design of hinge to bonnet attachment results in a very stiff structure with no capability to absorb energy when struck.

## **Fender flange**

Some manufacturers have now moved the fender flange to the curved edge of the top frontal surface where it becomes ineligible for an adult or child head strike. If the head were to hit this flange, it is thought that the head would glance from the surface lowering the energy of the contact. Traditional fender flanges are very stiff and result in high HIC readings that would be fatal to most pedestrian strikes.

## **Wiper Pivots**

When placed just under the bonnet surface, they can cause very high HIC readings that would be fatal in a pedestrian head strike. A lowering of the pivot structure so there is some energy absorbing structure to protect the head would lower the potential injury from a head strike on this part of the car.

## **Strut Tower, Front Suspension.**

McPherson Strut top tower locations are often just under the surface of the bonnet, with the result there is little energy absorbing capacity when struck by a child head form. The high HIC would be fatal in a child pedestrian strike.

High strut towers are good for long suspension movement so there is a conflict in design, styling and the choice of suspension system employed.

## **Engine components located on top of the engine.**

Many small brackets are located on top of the engine limiting the effectiveness of absorbing energy space. The stiff brackets and parts attached to the bracket are likely to result in a high HIC, which would be fatal to a child or adult headform strike.

## **Components in engine compartment**

Some pedestrian tests have shown that small components can have a significant effect when an adult or child head form strikes the bonnet. Examples are battery hold down bolts, power steering pump and fluid tanks, or air filter cover corners resting on stiff under structure.

## **Bonnet**

On some adult and child head form tests the bonnet with its associated inner panel has recorded high HIC readings when the space under the bonnet inner was clear of stiff structure for more than 80 mm below the headform impact point. It is thought that the panel when struck behaves as a complex vibrating structure and can behave as a very stiff structure at the time the head form is moving into the panel. The use of sound deadener material on the underside of the bonnet is not shown to be effective in reducing HIC readings.

## **Bonnet leading edge**

There is scope for reducing the stiffness of components at the leading edge of the bonnet. Improvements include moving the location of the bonnet latch inner structure rearward, or to the sides and moving transverse stiffeners back from the leading edge of the bonnet.

Crush depths, under test, of over 65mm would assist.

## **Front bumper**

A deeper profile to support the leg-form is a possible solution, or to provide a secondary support bar below the bumper would reduce pitching of the leg-form and bending of the knee joint.

The bumper needs localised compliance and then efficient energy absorption. Foam plastics are available to achieve this aim, together with recovery characteristics that minimise damage during low speed car-to-car collisions. The deformed profile of the vehicle during the impact needs to be considered. Spoilers and similar low-mounted, compliant structures can help to reduce the loads on the lower legs.

## **Headlamps**

As the headlamps change from glass to plastic the hardness of the headlamp will change significantly, reducing the possibility of causing severe pedestrian

injury. But to maintain good lamp alignment, the mounting must be stiff and resistant to vibration, which will require some development to meet the overall requirements.

## CONCLUSIONS

Head injury risk to pedestrians from impacts with vehicles accounts for over 18 percent of road crash fatal crashes in Australia.

Head Injury protection to pedestrians in vehicle strikes could be improved by requiring vehicles to meet acceptable head impact HIC levels.

There are legislation proposals before the European Commission, but no introduction timetable has been set.

International regulations for pedestrian testing are recommended as the Australian vehicle fleet use vehicles sourced from Europe, Japan, Korea and the United States.

Test programs have highlighted frontal locations of vehicles where design changes are required to meet potential acceptable head impact levels.

Consumer interest in pedestrian test results is perceived to be low as the total rating of vehicle safety has not included pedestrian safety performance in a single vehicle safety rating. Other alternatives to just ranking pedestrian injury potential should be investigated.

While pedestrian safety is an issue, more rapid results in pedestrian head injury may be achieved by lowering the average speed of vehicles in pedestrian access areas than changing the design of new vehicles. This would require the new speed limits to be adequately enforced to have an immediate effect on those roads where a lower speed limit was an acceptable alternative. For arterial roads where pedestrian access was required, and it was not practical to lower the speed limit, then changes in frontal protection to the vehicle are essential to lower the risk of head injury in pedestrian strikes with moving vehicles.

Other traffic management innovative treatments are required on arterial roads where pedestrian access is likely to lower the risk of pedestrian injury.

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