Variation in Design & Performance of Australian Pedal Cycle Helmets: Towards a Consumer Information Program for Child Pedal Cycle Helmets

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Biography
Julie Brown has worked in the vehicle and equipment safety research and policy area for over 15 years. Much of her research experience has involved the study of child road user protective equipment and performance in the real world and in laboratory tests. Julie is currently working on a number of child impact injury related research projects at the Prince Of Wales Medical Research Institute.

Abstract
This paper reports the findings of a study investigating the potential development of a consumer evaluation program of pedal cycle helmets for child pedal cyclists. The essential step in justifying a consumer program is to identify any existing differences in the level of protection offered by current helmet designs to child cyclists.

The primary objective of this work was to identify and document any variation in protective features of the helmets currently available. If worthwhile variations were found then previous experience had shown that a consumer information program could drive overall improvements in helmet protective features. A two stage process was employed to study variations in design currently in the marketplace. Firstly a visual survey of helmets in the marketplace was conducted and secondly a series of dynamic tests were carried out on a small sample of helmets. Available injury data was also reviewed as best it could be given the surprisingly limited detail available on these databases.

Results from visual examination of helmets currently on the market in Australia, and dynamic evaluation of a small exemplar sample helmet showed that significant variations in performance exist. This paper argues that a consumer information program, such as that employed for new cars (NCAP) and child restraint systems (CREP), is justified by the variations in performance.

1. INTRODUCTION

Consumer information programs aim to assess the comparative protection afforded by specific products and pass this information onto consumers. This then allows consumers to use this knowledge in the purchasing decision making process. Without such information, consumers have only manufacturers marketing material and (in most cases) the knowledge that the product meets any minimum performance requirements.

From a safety perspective, the objectives of consumer programs are two-fold. Firstly they work to raise the profile of safety (or level of protection provided) in a consumers mind. They create the perception to manufacturers that consumers will use this information. Subsequently and most importantly, they encourage manufacturers to supply products that not only meet minimum regulatory performance requirements but provide a level of protection at least equal to the better products available.

Currently, the New Car Assessment Program (NCAP) and the Child Restraint Evaluation Program (CREP) are the main two consumer information programs operating in Australia. NCAP programs are also conducted in many other countries, such as North America, Europe and Japan. North American road safety institutions are soon to implement a child restraint evaluation program.

The Australian New Car Assessment Program and the Child Restraint Evaluation Program were introduced for slightly different reasons, however in both areas (i.e new vehicles and child restraints) the same two basic conditions existed. These were that the regulatory framework was such that legislating best practice in design was difficult and variations in the level of protection being provided by products currently on the market existed.

Pedal cycle helmets are another area where the two basic criteria for a consumer program type approach exist. That is the process for introducing improved designs onto the market is difficult and as has been shown by this current research, there are significant variations in the level of protection provided by pedal cycle helmets currently on the market.

This paper presents the results of a preliminary evaluation program investigating differences in design and performance of pedal cycle helmets currently on the Australian market. The focus of this work has been on helmets designed for use by children in the 5 – 16 years age range. This group has been targeted since review of available injury data suggests children of this age range contribute a significant percentage of the NSW pedal cycle casualty problem. However, the scope of this work could easily be extended to the entire pedal cyclist population.

2. AIM

The primary objective of this work has been to explore variation in features and performance of pedal cycle helmets currently available on the Australian market. A two stage process was been employed to study variations in design. Firstly a visual survey of helmets in the marketplace was conducted and secondly a series of dynamic tests based on current standards were carried out on a small sample of helmets. The assumption for the latter is that since most test methods included in standards are derived from real world crash research, laboratory tests specified in the standards are a reasonable representation of conditions present in real world crashes.

3. METHOD

3.1 Visual Survey

A visual survey of pedal cycle helmets currently available on the Australian market was carried out to identify variations in visually obvious features such as helmet type; outer shell type; shell attachment mechanism; ear-strap and ear-strap adjuster configuration; chin strap buckle type; head-band/nape strap, and ventilation. A simple assessment of static retention ability was also performed for each helmet. This was achieved by fitting each helmet to a standard ISO ‘J head form. Observations related to area of coverage were also made.

A total of seventy-three Standards Approved helmets were inspected. Three non-Standards approved models were also included in the sample for comparative purposes. The survey therefore involved visual examination of 76 different pedal cycle helmets.

3.2 Dynamic Tests

A small sample of helmets (5) was selected from the 76 helmets surveyed to under go a series of dynamic tests. The sample of helmets was selected to provide examples of various features related to the level of protection likely to be provided. Features such as type and design of outer shell, area of coverage and retention system were used to select this sample.

Dynamic testing involved the assessment of dynamic stability, energy absorption and load distribution.

The procedures used to assess the above features were developed from the methods and criteria required by the Australian Standard and other international standards. In most cases the most stringent criteria in current use has been adopted for this evaluation. Tables 1,2 & 3 contain the test conditions for dynamic stability, energy absorption & load distribution respectively.

TEST No	Stab1	Stab2	Stab3	Stab4
HELMET CONDITIONING	Ambient temperature & humidity	Ambient temperature & humidity	Ambient temperature & humidity	Ambient temperature & humidity
LOAD LOCATION	load applied to front edge of helmet	load applied to rear edge of helmet	load applied to front edge of helmet	Load applied to rear edge of helmet
MASS OF TEST APPARATUS EXCLUDING DROP MASS	Between 2.9kg & 3.1 kg	Between 2.9kg & 3.1kg	Between 0.9kg & 1.4kg	Between 0.9kg & 1.4kg
TEST MASS DROP HEIGHT	170-180mm	170-180mm	600 mm	600 mm
TEST FORCE DROP MASS	Between 9.9kg & 10.1 kg	Between 9.9kg & 10.1kg	Between 3.950kg & 4.050kg	Between 3.950kg & 4.050kg

Table 1: Dynamic Stability Test Conditions

TEST No	EA1	EA2	EA3	EA4	EA5	EA6
CONDITIONING	Ambient	Ambient	Ambient	Ambient	Ambient	Ambient
ANVIL SHAP	Flat	Flat	Hemi	Hemi	K/stone	K/stone
HEADFORM MASS (TYPE 7) ASSEMBLY	4.1	4.1	4.1	4.1	4.1	4.1
DROP HEIGHT/ IMPACT VELOCITY	1500 mm (5.48m/s)	2736mm (7.32 m/s)	1271mm (4.99 m/s)	1792mm (5.93 m/s)	1113mm (4.67 m/s)	1792mm (5.93 m/s)
IMPACT ENERGY (J)	60.1	110	49.8	72	72	72

Table 2: Energy Absorptions Test

TEST NO	LD1
CONDITIONING	Ambient
ANVIL SHAPE	Flat
DROP HEIGHT	Between 995 mm and 1015 mm

Table 3: Load Distribution Test Conditions

4. RESULTS

4.1 Visual Survey

In summary, a number of significant variations in features related to the ability to achieve correct positioning were noted. In particular, differences in retention strap adjustment mechanisms and buckles were observed to have the potential to impact on this feature.

All of the conventional helmets and recreational/bicycle helmets examined were found to have similar retention systems in that they consisted of two straps on each side of the helmet, one attached forward of the ear and the other rearward of the ear (or ear straps). The ear straps converge just below the level of the ear into a single strap through an adjuster.

All of the adjustment systems consisted of a locking mechanism, or a non locking mechanism. The locking types fell into two categories; a cam lock arrangement or a rotating locking mechanism.

Observations made during examinations revealed that ear strap adjusters incorporating locking mechanisms were better because these helmets did not tend to inadvertently move out of position as often as the helmets incorporating non- locking mechanisms.

Differences in the adjustment of the buckles straps were also observed, with one group of helmets in particular having an adjustment arrangement much easier to lengthen and tighten than all the others.

It is interesting to note that helmet standards in general, while paying attention to the strength of retention systems in varying degrees, do not pay much attention to the role which adjustment mechanisms play in ease of use, correct positioning and maintenance of correct positioning.

Large variations in the mode and degree of ventilation were noted. The number of ventilation slots/holes on individual helmets ranged between 4 and 30, and were of various sizes. Positioning of ventilation slots/holes also varied, ranging from almost over the entire surface of the helmet to a restricted area on top of the helmet and in the front and rear of the helmet.

Finally significant variations in extent of coverage with respect to the test line and the basic anatomical plane were observed.

4.2 Dynamic Stability

Results from dynamic stability tests are shown in Figures 1,2,3 and 4.

As can be seen from these figures, testing demonstrated that all helmets allowed an undesirable amount of rotation in at least one test, and significant variation was observed in the degree of rotation between each of the helmets tested.

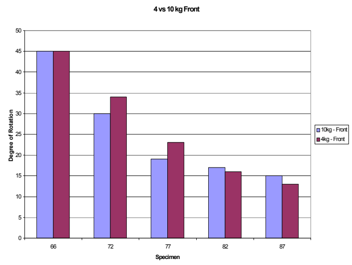

Figure 3:Degree of Motion Up and Over

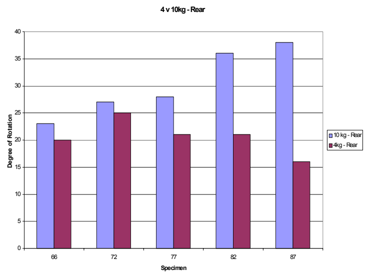

Figure 4: Degree of Motion (4 v 10kg Drop

In the worse performing helmets, rotation up and over the forehead (frontal movement) was found to occur to a greater degree then rearwards rotation. This type of rotation (Frontal movement), up and over the forehead is the more problematic since this motion allows for greater exposure of the more vulnerable frontal regions of the head. Interestingly, a couple of the better performing helmets in the frontal roll off assessment allowed the greatest rotation in the more severe rearward roll off tests.

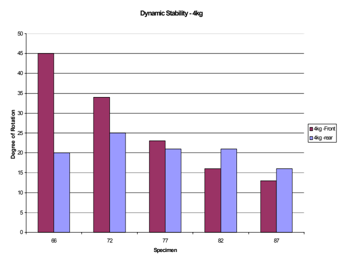

Figure 5: Degree of Rotation - 4kg Drop Mass

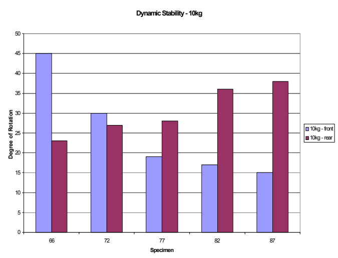

Figure 6: Degree of Rotation - 10kg Drop Mass

This is probably not as great a problem as the frontal roll off since the more vulnerable regions of the head remain covered during this motion.

An interesting observation made during the dynamic stability assessment is that the absolute degree of rotation was not always indicative of the potential for exposing vulnerable areas of the head since the potential was also found to depend to some extent on degree of coverage in original position.

There did not appear to be any design or cost reason why a helmet with good initial coverage could not use a better retention system to offer an even greater level of coverage.

4.3 Energy Absorption

Graphical summaries of results are shown in Figures 5,6,7,8.

In summary the results of this dynamic testing demonstrated large variations in energy absorption capabilities between helmet models & different locations on the same helmet in vicinity of vulnerable areas of head.

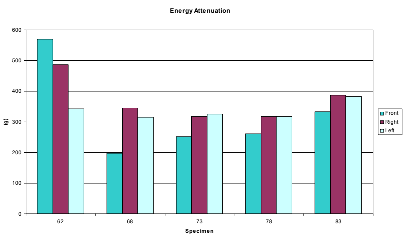

Figure 9: Energy Absorption – All

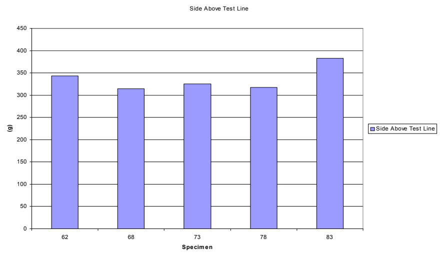

Figure 11: Lateral test sites

Figure 9 compares the energy absorption features on the sides of the sample helmets above and below the test line. Results from Sample 1 illustrate a potential problem. This helmet obviously provides coverage below the test line, which is theoretically a desirable feature. However, energy absorption below the test line is not as good as it is above the test line.

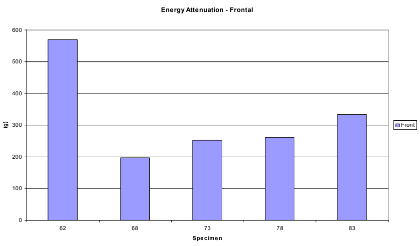

Figure 10: Frontal Test Sites

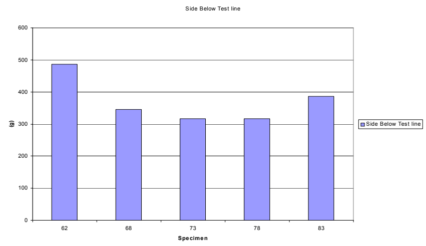

Figure 12: Lateral test sites

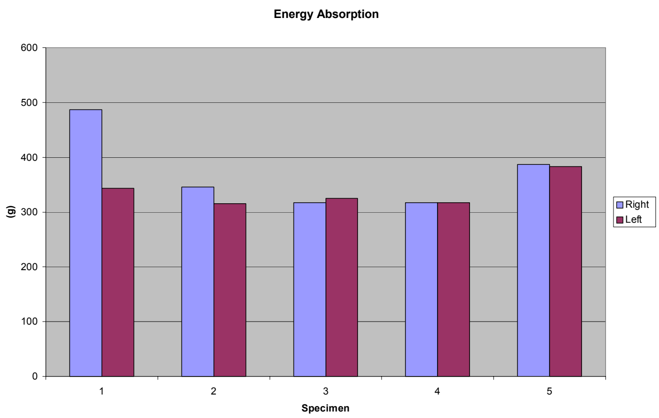

Figure 13: Energy absorption above and below test line (side locations)

The degree of severity used in this series of tests was equivalent to that used in the Snell standard, possibly the most stringent of all international pedal cycle helmet standards. It is interesting to note that most of the helmets tested here failed to meet the energy absorption requirements of the Snell Standard.

4.4 Load Distribution

Results from the load distribution tests illustrate variations between the helmets evaluated ability to distribute load, although all but one test demonstrated that the helmets tested were able to maintain loads to be low 250g. . The one tests where deceleration exceeded 250g was the below test line, side test on sample 2. This result suggests demonstrate a similar concern to that observed in the energy absorption tests. That is while this helmet obviously provides coverage below the test line, which is theoretically desirable feature, poor load distribution characteristics exist in this ‘extra area’. Graphical summaries of these results are shown in Figures 11,12,13 & 14.

5. DISCUSSION

The primary objective of this work was to explore the variation in pedal cycle helmet features related to the level of protection likely to be provided to a wearer involved in an impact. Knowing whether or not variations exist are vital to understanding whether or not a consumer information program (like that in place for new cars, NCAP, and child restraint systems, CREP) would be a viable strategy for improving the widespread level of protection provided.

Review of the Australian Standard compared to international pedal cycle helmet standards has also revealed that in many respects the Australian Standard is inferior in terms of the level of protection required. (This is in stark contrast to the Australian Child restraint standard which is arguably the toughest in the world.) Variations in requirements also exist between many of the international standards. Free trade practices mean that helmets on the market in Australia can be approved to a number of different standards. An inherent difference between standards in it self suggests that variations in performance of helmets sold in Australia is likely.

Results from visual examination of helmets currently on the market in Australia, and dynamic evaluation of a small exemplar sample helmet suggest that significant variations do exist.

A consumer information program is a means by which such variations could be communicated to the public.

Consumer information programs are now accepted as effective strategies for encouraging improved design of safety equipment. Historically efforts could be made through Standards committee etc for such changes, but in situations affected by free trade, changes to any single standard would not ensure the level of protection afforded by all available helmets. Consumer information programs work towards ensuring that all products provide a level of protection at least equal to the better protection provided by products of that type. They achieve this by giving consumers the knowledge to make informed purchases. This in turns encourages manufacturers to voluntarily improve their product.

This work has indicated a number of design areas where the encouragement of improvement is warranted. One of the more contentious areas appears to be that of increased head coverage.

The area of the head covered by helmets is largely dictated by a test line nominated in the Standard to which they are approved. Although numerous researchers in Australia and overseas have recommended significant increases in the area of coverage, little progress has been made in this regard. In particular, crash investigation studies conducted in Australia have shown that most injury producing injuries occur at the front and side of the helmet, near or below the Australian Standards test line.

Williams (1989) reported that 63% of helmet impacts occurred below the helmet test lines of both the Australian Standard and other relevant international standards. Possibly more importantly he noted that 51.1% of impacts below the test line occurred on the forehead or temple region of the rider's head. McIntosh (1995) also noted that most injury (AIS>2) involved impacts to the front and sides of the head and "tended to be close to the helmet rim". He also reported that those case involving head injury AIS <2 had impacts that "were distributed over a variety of locations and were not located near the rim."

For children, Brown et al (2000) reported a difference in extent of vascular injury by impact location, with injury observed to be more extensive in lateral impacts.

The most vulnerable areas of the head therefore appear to be in the frontal and temporal regions, the temporal regions particularly in children, and very close to if not below the test line in these areas.

Visual inspection of most of the pedal cycle helmets currently on the market revealed that there are a wide variety of helmets with some form of 'extended coverage'. However results from the dynamic evaluations suggest that simply recommending purchasing helmets that cover a greater extent of the more vulnerable regions of the head (i.e. the front and sides of the head) would not necessarily lead to improved protection for wearers. This is because results from the energy absorption and load penetration tests demonstrated that these characteristics can be significantly different below the current standards test line. To be able to recommend purchase of helmets with increased coverage it would therefore be necessary to also evaluate the level of protection being provided beyond the 'standard' coverage. This evaluation could be done within a consumer information program.

To provide optimum protection, a helmet must not only be designed to protect the most vulnerable areas of the head, but it must also fit closely to the wearer's head and remain in that position in a crash. Design features related to how well a helmet can be correctly positioned on a child's head, and be retained in this position during an impact are also of a high priority. Visual examination of helmets currently on the market also revealed differences in the adjustment mechanisms of many helmet retention systems that would lead to some helmets being more user friendly in terms of securing a good and tight helmet fit. While this characteristic was not subjectively evaluated here, any further development of a consumer type evaluation of pedal cycle helmets would logically include such an evaluation. This is particularly important because the ease of adjustment is not assessed in any form in the Australian Standard, yet a good tight helmet fit is essential to a helmets ability to provide it's optimum level of protection.

Dynamic retention, as assessed by the frontal roll off test, also appears to be a potential indicator of superior helmet performance, with wide variation in the degree of motion observed in our sample. This up and over the forehead motion is extremely significant, as this part of the head has been widely reported to be frequently involved in injury producing impacts. Most Standards that include a dynamic retention evaluation in their assessment method use a set allowable degree of motion as pass/fail criteria. Our observations suggest that the absolute degree of rotation is not always a true indicator of performance since helmets with a greater extent of coverage can possibly afford to move a greater detail then an extremely minimally designed helmet before exposure of the more regions of the head become likely.

Energy absorption and load distribution assessments relate to how well any particular helmet will mitigate injury producing loads in the real world. Significant differences in the requirements related to these features exist in different standards. The degree of severity used in the energy absorption tests was equivalent to that used in the Snell standard. Snell standard is recognized as probably the most stringent of all international pedal cycle helmet standards. Many helmets internationally are approved to the Snell Standard. Most of the helmets tested here failed to meet the energy absorption requirements ofSnell. This in itself is a definite indicator of the potential room for improvement in the performance of many helmets currently on the market in Australia.

The impact of degree and method of providing ventilation was not assessed in any great detail here. It was however that wide variation in the degree of ventilation, in particular the number of ventilation slots and the position of these slots, exists in the marketplace. While characteristics such as those evaluated in this work, i.e. extent of coverage, energy absorption and dynamic stability are probably the highest priority in terms of encouraging helmet designs with high levels of protection in the real world, ventilation features can have an impact on the useability of a helmet and features such as load distribution in particular type of impacts. Therefore any consumer information based evaluation procedure should include some form of assessment of ventilation features. This should be based on both ventilation (air flow/heat loss) capability, and any compromise in performance because of ventilation slots.

A secondary objective of this work has also been to examine more thoroughly the available data for evidence that improving these design features would improve the injury outcome of child cyclists. It was found that none of the currently available sources of data could provide enough detail of both helmet use and nature of head injury. It is also evident that New South Wales (and for that matter, the rest of Australia) is in dire need of data related to helmet wearing rates.

The lack of such data suggests a potential area for further necessary research.

However, regardless of the level of performance identified by real world studies, the results obtained here demonstrate there is a significant variation in high priority performance features in Australian pedal cyclists. Some helmets are likely to be providing greater levels of protection than others. In addition, while all helmets on the Australian market must meet provide the minimum level of protection prescribed in the Australian Standard; other Standards exist that require a much high level of protection. Almost none of the helmets tested in our small sample here would be able to meet the energy absorption requirements prescribed by the Snell standard. Many could not meet the retention requirements of European standards. Even without evidence from injury/real world helmet performance, this information alone would warrant the introduction of a strategy to encourage helmet manufacturers to provide helmets that match the level of protection provided by the best helmets. Likewise, from a consumer perspective, the variations in the level of protection would be valuable information to assist helmet purchasers (particularly parent purchasing helmets for children).

6. CONCLUSION

This work has demonstrated: -

- Variations in high priority protective features of pedal cycle helmets exist in currently available Australian helmets.
- The level of protection provided by many Australian Standards approved helmets is likely to be below world's best practice (in terms of meeting the most stringent of international standards)
- Since some helmets on the Australian market could meet the most stringent of international standards, scope for improving the design of other helmets exists by encouraging all manufactures to provide the same level of protection as the better helmets. A consumer information program for pedal cyclist helmets would be the most efficient way of achieving this.
- There is no casualty/fatality and nature of injury data for pedal cyclists with enough detail to allow investigation of real world performance of current Australian pedal cycle helmets.
- There is no current useful objective Australia (and NSW) information regarding pedal cycle helmet wearing rates.

Acknowledgements
This research project is supported by a grant from the Motor Accident Authority of New South Wales. The authors would also like to thank the NSW RTA Crashlab for assistance with dynamic testing.

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