The Australian Child Restraint Evaluation Program

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1 Abstract

Consumer information programs aim to bring about change by influencing purchasing decisions and providing market pressure based motivation for manufacturers to improve their products. A consumer information based child restraint evaluation program has been operating in Australia since 1992. The assessment and evaluation procedures used in this program were recently reviewed and have been significantly enhanced. This paper presents the revised assessment methods and representative results from the most recent series of the Australian Child Restraint Evaluation Program (CREP). Although all restraints tested have passed the minimum requirements of the standard, results indicate a number of areas where specific attention to improvements in the packaging and design of child restraints would be warranted. These include features related to reducing the likelihood of misuse and the level of protection provided in crashes. In particular the results suggest there is substantial scope for improving the performance of convertible child restraints and booster seats. These results demonstrate significant variations in child restraints currently on the market both in terms of crash performance and ease of use. For the program to be successful in achieving its aims there needs to be widespread dissemination of the results. It is critical to the program that Child Restraint Evaluation Program (CREP) results are readily available to consumers and they are encouraged to use this information in making their purchasing decisions.

2 Background

A consumer based child restraint evaluation program (CREP) had been operating in Australia since 1992. The Roads and Traffic Authority of NSW (RTA), the National Roads and Motorists Association (NRMA) and the Australian Consumers' Association (ACA) combined their resources to design and implement the initial child restraint evaluation program. This was the first time a consumer based strategy had ever been applied to child restraints.

Up until the late 1980's, the Australian market for child restraint systems, particularly forward facing child seats, was dominated by locally developed Australian made products. Because they were locally based, these products were designed to do well and were tested against the requirements of the Australian Standard, which, because it has had top tether availability in new vehicles since 1976, was able to demand higher performance requirements than overseas products.

In the late 1980's, a variety of developments in the child restraint industry indicated that there was a possible trend toward the use of imported products which were adapted to satisfy the requirements of the Australian Standard. Road safety authorities and child safety stakeholders foresaw that a possible outcome of this was that there could be a shift in protection offered by product. The likely shift was from locally developed product which exceeded the Australian Standard by considerable margins, to adapted imported product which could meet the local Standards with lower margins. Such a development had the potential to reduce the overall level of protection offered to children in crashes.

This was a matter of considerable concern to the New South Wales Roads & Traffic Authority, and based on their recent experience with the adoption of a consumer program for car safety (known as the Australian New Car Assessment Program, NCAP), it appeared that their best chance to prevent such a development was to establish a consumer program for child restraint systems which could provide science based information to consumers on which child restraints offered the highest level of protection in dynamic tests simulating crashes, and which were the easiest to use.

The underlying philosophy of CREPs to influence consumers and to provide motivation for manufacturers to market products that are at least equal to the best currently available, and that offer protection above the minimum requirements (in this case Australian Standard for child restraints: AS 1754). Assessment of dynamic performance in simulated impacts more severe than that required by the Australian Standard, and more stringent assessment criteria than the requirement of this Standard have been a vital ingredient of the program since its inception. By assessing performance at levels beyond that required by the standard, variations in the performance of the restraints on the market become clear. Evidence from the field clearly shows that a restraint must be used correctly for the highest levels of protection to be achieved. Further more, misuse of child restraints is a common problem [5-12]. Reducing the propensity for misuse through improved restraint design is therefore a priority. In acknowledgement of this, since its inception CREP has also included an assessment of the ease of use of restraints on the market.

The first iteration of this program comprised of three assessment units; an assessment of dynamic crash performance, for which the RTA took responsibility; an evaluation of ease of installation and use, the trials for which were designed and conducted by the ACA; and an assessment of vehicle compatibility, which came under the control of the NRMA. Since the initial program, the assessment methods have evolved significantly.

Over the last few years, the value of using this type of program to drive improvements in the level of protection provided to children in cars has been recognised by lead road safety agencies in North America and Europe. The Insurance Corporation British Columbia (Canada), the USA's National Highways Traffic Safety Administration, (NHTSA) and the Consumer Union (CU) (a North American organisation), developed more advanced ease-of-use assessment models for CRS assessment [2,3]. This development, together with concerns that the CREP dynamic performance assessment may not be keeping pace with the Australian New Car Assessment Program (ANCAP) led to a review of the CREP assessment procedures in 2005. The outcome of this review were more comprehensive and less time consuming ease-of-use assessment protocols, and a revised dynamic test protocol with innovative scoring protocols [4].

Australia is currently the only country in the world using such sophisticated assessment protocols for both ease of use and dynamic assessment of child restraints. This paper briefly describes these assessment protocols and scoring methods. Exemplary results obtained using these protocols are also presented demonstrating the variation in performance that currently exists in child restraints on the Australian Market. These types of variations highlight the scope for improvement in the design of Australian Child Restraints.

3 Methodology

3.1 Dynamic Test

The performance of each child restraint was assessed in a series of frontal and side impacts. Performance was measured against criteria set out in the dynamic assessment protocols. These include a selection from the dynamic test requirements of AS/NZS 1754-2004 and the unique requirements developed specifically for CREP. Full details of these criteria can be found at http://tinyurl.com/29me5k. A horizontal crash sled was used to produce the deceleration pulses.

3.1.1 Frontal Test

In past CREP assessments, two frontal impacts were conducted, one at the same severity as the Australian Standard (49km/h, 20g), and one at a higher severity of 56km/h and 34g. In the first series of CREP, all restraints were subjected to both tests. However in all previous series since then, booster seats have been excluded from the higher severity test due to concerns regarding the robustness of the test dummy. Booster cushions (i.e. booster seats with no back) have not been included in the program since the first series of CREP.

Review of results obtained from these earlier evaluations found no worthwhile information was being gained from the lower severity frontal impact test. As a consequence the 49km/hr test has been dropped, and all restraints, including booster seats, are now subjected to the 56km/h test with a 34g pulse.

Dummy choice in the frontal test is based on the mass of the dummy being equal to or above the upper end of the mass limit for each type of restraint. The TNO P3/4 (9kg), a surrogate for a 9 month old infant, is used for rearward facing restraints with upper mass limit of 9kg; the TNO P11/2 (11kg), a surrogate for an 18 month old child, for rearward facing restraints with upper mass limit of 12kg; the TNO P6 (22kg), a surrogate for a 6 year old child for forward facing restraints (upper mass limit of 18kg); and the TNO P10 (32kg), a surrogate for a 10 year old child, for booster seats (upper mass 26kg).

The sled was calibrated in accordance with AS 3629.1 to produce a deceleration pulse as near as practicable to the maximum (34g) allowed by AS 3629.1 and a velocity change of 56 km/h.

3.1.2 Side Impact Test

To date, side impact performance in CREP has involved subjecting child restraints to two simulated side impacts: one test at 90^{o} and another at 45^{o}. The pulse used is the same as that required by the Australian Standard. To increase the severity of the test, a simulated side door structure was positioned adjacent to the test seat. The door structure replicates a simplified rear door of a sedan, in shape and size, and is static.

Since the last CREP series and prior to the review of assessment procedures, the Australian Standard test methods and performance requirements in side impact were modified to also include the side door structure. This differs from the CREP door in that a poly carbonate inner door skin replaces the metal one used in CREP. Except for this detail, the 90^{o} CREP side impact test now replicates the Standard test.

The Standard also now requires all restraints (other than booster cushions) to prevent head contact with the door. However for forward facing restraints and booster seats, the dummies specified by the Standard represent children at the lower end of the CRS size range, in terms of seated height. For this reason, the 90^{o} test continues to be included in the CREP assessment, but the dummies used are chosen to better represent the seated height of children at the upper end. For forward facing restraints, tests are conducted with a TNO P3 the seated height of which was modified to 605mm, representing a 4 year old. Similarly, the booster seats were tested with the seated hight of a TNO P6 increased by 40 mm, representing a 50th percentile 8 year old. Assessments were made on the absence or presence of head contact as well as the degree of head containment.

During the review of the original procedures, the 45^{o} test was also found to be providing limited information useful in discriminating between the performances of the restraints. As a consequence, the 45^{o} test has been replaced with one that more closely resembles a US NCAP side impact - that is at 66^{o}. The same dummies and performance aspects assessed in the 90^{o} test are used in the 66^{o}.

All restraints are subjected to both these tests. Booster cushions (i.e. boosters without backs) remain excluded from CREP assessment. At this stage, the side impact test pulse remains at 32 km/h and 17g as per the requirements of AS 3629.1. Review of recent Australian NCAP side impact data suggests that this is an adequate severity.

Precautions were taken to minimise the effects of the sled’s motion on the dummy and the device being tested, as the sled accelerated away from rest, without modifying the way in which the device operated, nor the response of the dummy to the test pulse.

3.1.3 Scoring Protocol

In earlier versions of CREP, ranking and scoring of results consisted of, “preferred buy” ratings being given to a number of devices in each restraint type category. These were awarded to restraints that performed well in a number of areas; however the method was relatively subjective. The recent review of the program determined that there was significant scope for development of a more objective rating system that included formal documentation of objective protocols. A ratings system similar in methodology to the system being used in the ease of use assessment (and based on the method used by NHTSA) was therefore developed.

The features being assessed in the dynamic component are divided into a set of performance categories. Within each category, there are a set of items or individual Performance Aspects (PA). Each PA has been given a weighted factor between 1 and 4 based on their importance in terms of offering crash protection in the real world. A numerical scale of 4 (good) to 0 (unacceptable) is used to rate the outcome for each PA. Scores for each PA are obtained by multiplying the outcome score by the weight for that PA. Category scores are arrived at by adding the scores obtained for that category and calculating what percentage this is of the maximum possible score for that category. Each category is then awarded an A, B, C or D ranking based on the breakpoints set out in Table 1.

Table 1. Ranking Score Calculations – CREP Dynamic Testing

Ranking	‘Performance Aspect’ Set Score	Overall Score
A	The ‘PA‘ set score ≥ 83% of maximum ‘PA’ scores that could be obtained for the set	The sum of the ‘PA’ set scores as percentages divided by the number of sets ≥ 83%
B	The ‘PA‘ set score < 83% but ≥ 67% maximum ‘PA’ scores that could be obtained for the set	The sum of the ‘PA’ set scores as percentages divided by the number of sets ≥ 67% but < 83%
C	The ‘PA‘ set score < 67% but ≥ 50% of maximum ‘PA’ scores that could be obtained for the set	The sum of the ‘PA’ set scores as percentages divided by the number of sets ≥ 50% but < 67%
D	The ‘PA‘ set score < 50% of maximum ‘PA’ scores that could be obtained for the set	The sum of the ‘PA’ set scores as percentages divided by the number of sets < 50%

These breakpoints have been set on the basis that any device scoring less than or equal to 50% of the maximum score is judged as ‘unacceptable’ and given a ‘D’ ranking. The range between 50% and 100% has then been divided into 3 equal ranges.

There is also one limiting rule applied to category and overall rankings. This rule is that if any device receives two or more ‘0’ scores (i.e. an ‘unacceptable’) score that device can not be awarded an A or B ranking for that category or for an overall ranking.

Stage 4 of CREP introduced two new Performance Aspects in evaluating CRS i.e. 'Crash Energy Management – Torso', henceforth referred to as 'Torso Energy Management' (TEM) and 'Crash Energy Management – Head' is henceforth referred to as Head Energy Management (HEM), for infant restraints in frontal testing. TEM complements the previous performance aspect of 'Load Distribution'. Both TEM and load distribution are assessed using the outputs from a tri-axial accelerometer in the dummy's chest. How well a restraint manages energy in the torso region of a crash dummy is usually only explored using the peak resultant chest acceleration. However, this type of measure does not take into account the duration of the load. A measure that looks at the torso acceleration and the time over which these accelerations are felt would be a much better indication of how well a restraint system was managing the energy in the torso region. For this reason, the algorithm used to calculate HIC36 using resultant head accelerations over a 36ms time interval was used to evaluate the 'Torso energy Management' or TEM.

3.2 Ease of Use Test

Review of results from earlier releases of the Australian CREP demonstrated that while substantial comparative information was collected about the ease of use of restraints on the Australian market (showing there were considerable differences between products), little information regarding the outcome of these assessments was actually communicated to the public. Furthermore, the methods used relied wholly upon expert opinion and were not documented in an objective way.

Following this review, significant changes were made to the ease of use evaluations and a methodology developed that allows for more objective rating of features weighted on their likely impact on reducing misuse, and the types of misuse that are influenced. This method is heavily based on the current North American ease of use rating schemes [3].

The full details ease of use criteria can be found at http://tinyurl.com/29me5k. The protocol is similar to that used by NHTSA [3] with additional assessments of some features and a modified feature assessment ranking.

This method requires each feature listed within five 'categories' to be assessed individually. The 'categories' are: Packaging, Instructions, Labels, Securing/Releasing the Child, and, Securing/releasing the restraint within the vehicle (the latter was not used for booster ratings). Good, Acceptable, Marginal and Poor ratings were recorded for each feature according to the criteria set out for that feature, and where necessary additional comments were made. Results were stored within an electronic database. Digital photographs of each restraint and relevant components were taken.

Initially, it was intended to use the same scoring protocol as NHTSA [3]. In this method each feature within each category is assigned a weighting factor of 3, 2 or 1 according to risk of injury and severity of misuse. The features associated with the highest risk of severe injury if misuse occurs are given a 3 weighting. A numerical scale is also used to score the assessment outcome for each feature, with 3 points equating to good, 2 points to acceptable and 1 point to marginal and zero for poor. Under the NHTSA method, the two numbers are then multiplied together to provide a feature score (from 9 to zero). The scores within each category are then summed and divided by the sum of the applicable fixed weighting factors to provide a weighted average score. Similarly, an overall weighted average score is obtained by dividing the sum of all feature scores by the sum of all fixed weighting factors. The NHTSA weighted average will always be between 1 and 3 and within this range either 'C' 'B' or 'A' ratings are awarded for scores of < 1.7, 1.7 but < 2.4 and 2.4 – 3, respectively.

This approach to scoring had never been attempted in Australia. For this reason, results obtained using this ranking procedure, were carefully examined prior to finalization of the scoring protocol. Early analysis revealed that the "A, B, C" ratings did not usefully discriminate between products. This was contrary to the outcomes from direct observation of restraints during assessment, which identified significant differences. In particular most categories and overall ratings came out a "B" under the tripartite method. To overcome these problems, the weighted average method has been modified to allow A, B, C, and D ratings to be assigned for each category and for the overall performance to be based on a quartile ranking system.

In addition, a weighting factor of 4 was introduced to provide for design features that were innovative and effective in reducing the propensity for misuse - in effect a "wish list". An example is "Audible and visual indication that harness is adjusted correctly" (no such devices are available for Australian CRS at this time).

Under the NHTSA ranking method the range between the maximum and minimum value (with minimum value being 1/3 of the maximum value) is divided into 3 equal segments. Breakpoints are therefore 80% of the maximum score and above for A, 57% of the maximum score and above for B and below 57% for C. Our modification involves dividing this same range (i.e. range between maximum and 1/3 of the maximum) into four, so that breakpoints become 83% of maximum and above for A, 67% and above for B, 50% and above for C. Anything less than 50% results in a D.

In the case of the overall rating, it was decided to assign equal weights to each category, since safety related issues are inherent in the weights assigned to each feature within a category. Therefore an overall percentage was calculated from the average of the category percentages. The overall rating for a mode (forward or rear facing) was based on the same quartile breakpoints (83%, 67% and 50%). For convertibles, an overall rating was based on the worst mode rating.

The process for determining scores and ratings is graphically illustrated in Figure 1.

Figure 1. Ease-of-use rating process

3.3 Test Specimens

Assessments for recent series of CREP (Stage 4) were divided into two phases, Stage 4A and 4B. In stage 4A, 17 makes and models from two manufacturers were evaluated. The restraint systems tested include two rearward facing CRSs (Type A), five convertible rearward facing and forward facing CRSs (Type A/B), three forward facing child restraints (Type B), two convertible forward facing and booster CRSs (Type B/E), and five booster seats (Type E).

In stage 4B, the remaining commercially available child restraint systems in Australia were tested. These restraints consist of 14 makes and models from six manufacturers which include five convertible rearward facing and forward facing restraints (Type A/B), one convertible forward facing and booster system (Type B/E), and eight booster seats (Type E).

The restraints were selected at random from stock in the manufacturers' warehouses and retail outlets

4 Results

In this paper, the makes and models of the restraints are withheld but they will be published in the official Buyer's Guide to Child Restraints in stakeholder websites when ready.

4.1 Dynamic Test

5.1.1 Frontal Tests

Frontal tests were performed on each individual restrain system. The tests were performed at sled speed of 56 km/h and 34g.

Rearward Facing Restraints
For rearward facing child restraints, eight Performance Aspects (PA's) were assessed, these include:

1. Head Retention;
2. Dummy Retention;
3. Upward and Rotational Displacement Of the CRS In Rebound;
4. CRS Security and Integrity;
5. Load Distribution;
6. Torso Energy Management (TEM);
7. Head Energy Management (HEM), and
8. Adjuster Slip

The first four PA's are weighted three as they are the most significant measures in protecting the occupant. Load distribution, head energy management and Torso Energy management are assigned weighting factors of two. Adjuster Slip is weighted to one.

In head retention, the dummy's head appeared to be well supported by the restraint throughout the impact phase of the test in all but one of the tests. Video footage analysis showed that pre-impact, the test dummy's head was completely exposed (See Figure 2). Accordingly, the device was assigned a 'PA' score of zero. Each of the remaining devices was assigned the maximum possible score of four.

Figure 2. Head exposure allowed by one of the restraints in frontal test.

Eleven out of the twelve devices were able to meet the head displacement requirements of AS/NZS 1754-2004 in this more severe test. The restraint that could not achieve this was assigned a PA score of zero. The extent of upward motion can be seen in Figure 4. Although the remaining eleven devices were able to meet requirement of the AS 1754, the performance of one of the restraints was superior to those of the other devices. This restraint exhibited excellent control over rotation, with the dummy's head remaining below plane BE in Figure 3 and at least part of the device remaining in contact with the test rig seat cushion, during rebound (see Figure 5). For its performance it was assigned a PA score of four.

Figure 3. Figure 4.1 from AS/NZS 1754-2004 showing head excursion limits.

Figure 4. Child restraint showing head upward excursion above the plane CD in Figure 3.

Figure 5. Child restraint showing the best head upward excursion.

The remaining restraints allowed the dummy's head to move within area between planes BE and CD shown in Figure 3. The extent to which head excursion occurred can be seen in Figures 6.

Figure 6. Child restraint showing head upward excursion within area between planes BE and CD in Figure 3.

Forward Facing Restraints

A total of 16 forward facing child seats were evaluated in both Stage 4A and 4B. For frontal test, seven performance aspects were assessed in forward facing restraints, which include:

1. Forward head excursion
2. dummy retention
3. Upward Displacement of CRS in Rebound
4. CRS retention and integrity
5. Head Energy Management

6. Operation of Quick Release Device
7. Adjuster Slip

In forward facing restraints in frontal crashes, forward head excursion is the most significant performance aspect. This performance describes how well the restraint system manages dummy deceleration and is highly correlated with real world crash protection. For this reason, it is weighted maximum value of four. The remaining PA's are weighted with the values of three, two and one.

No pre-defined limits of head excursion performance were set. Instead, the revised protocols allow for an objective comparison of restraint performance. Head excursion is recorded and scores assigned based on the range of excursions obtained. The best score four (4) is given to that restraint with the minimum excursion, the next best three (3) to those within 50mm of that excursion, and so on. The lowest forward head excursion was recorded 1016 mm as shown in Figure 7 for which it was assigned a score of 3. In Figure 7 the back of the restraint can be seen to be almost parallel to the seat back of the test rig. There were significant differences between this restraint and the poorer performing devices. Figure 8 illustrates one of the poorer performing restraints where there was 100mm more head excursion. In this Figure the upwards rotation of the base of the restraint that underlies the extreme head excursion can be seen.

Figure 7. The lowest measurement of forward head excursion in Stage 4 series.

Figure 8. The highest measurement of forward head excursion in Stage 4 series.

Similarly, head energy management is scored using the range of HIC36 scores obtained. The range is divided into 3 and the best score given to those devices in the lowest third and the worse score given to those in the highest third. The results are shown in Figure 9.

Figure 9. HIC values for forward facing CRS in frontal tests.

Booster Seats

Booster seats aim to improve the fit of adult lap sash belt and their performance, particularly in frontal impact should be assessed in these terms. A total of 16 booster seats were evaluated in frontal impact test. Four Performance Aspects for booster seats were assessed, these include:

1. Dummy Retention;
2. Submarining;
3. Seat Belt Sash Strap Location, and

4. Booster Seat Security and Integrity

In frontal impact tests, a high priority was placed on the pre impact and during impact positioning of the sash and lap parts of the belt. High scores of four (4) were given when the pre impact position of the sash was across and in contact with the dummy's shoulder and chest prior; and the lap portion of the belt remains in place over the dummy's pelvic region, during the impact phase of the test. Unacceptable (0) scores were given to those restraints that failed to meet these criteria and there was no criterion in between.

Submarining is the most common problem in booster seats, therefore, it was assigned a weighting factor of 4. A score of 4 was given to devices where the seat belt lap strap remains in place over the dummy's pelvic region during the impact phase. Unacceptable (0) scores were given to devices where the dummy moves forward and down during the impact phase so that the seat belt is repositioned above the dummy's abdominal region.

Devices with anti submarining clips were clearly superior in controlling the position of the seat belt lap strap. In these devices, the lap belt remained in contact with the upper part of the legs throughout the event (see Figure 10). Those devices were assigned a score of 4. In the tests involving devices without anti submarining clips, the lap belt appeared to move up onto the dummy's lower torso (see Figure 11) or into the gap between the legs and the torso.

Figure 10. Booster seat showing lap strap kept in place over dummy's upper thighs by anti-submarining clip.

Figure 11. Booster seat showing lap strap riding-up over dummy's lower torso.

Dummy retention in booster seats included three possible scores. A high score for complete retention and an unacceptable (0) score for complete ejection if the dummy's torso came free of the sash during the impact phase. A third low score (1) was available if the dummy's torso rotated so that it was only partially restrained by the sash.

Figure 12. Booster seat showing dummy's shoulder disengaged the sash strap.

Six out of sixteen restraints were unable to maintain contact between the occupant's shoulder and the seat belt sash strap as shown in Figure 12. Although most of those restraints were fitted with a sash guide mounted behind the dummy's shoulder, however, it disengaged the sash strap and failed to perform its function. For this performance those restraints were scored 0. The remaining restraints appeared instrumental in maintaining contact between dummy's shoulder and seat belts, therefore they were assigned PA score of 4.

5.1.2 Side Impact Tests

To provide high levels of protection in side impact, child restraint systems need to minimise contact between occupants and the vehicle interior and, if contact occurs, minimise the severity of that contact. The greatest priority is head protection.

Rearward Facing Restraints

Results from 90^{o} side impact tests have shown that a head strike outside the device was not recorded for any of rearward child restraints. However, some of restraints performed better in protecting the dummy's head. In these better performing restraints the dummy's head remained below the top edge of the side wing during the whole of the impact phase of the event (as shown in Figure 13). Thus, it was assigned 'PA' score of four. The worse performing device in head retention was one in which a significant proportion of the dummy's head was exposed above the top edge of the side wing throughout the crash phase (See Figure 14). This device scored a one for this PA. In the remaining devices, part of the dummy's head was above the top edge of the side of the device or the side wing, although the degree of head exposure in these devices was much less than observed in the worse performing restraint. All of these devices were assigned PA scores of one.

Figure 13. Rearward facing child restraint system showing good protection in 90^{o} side impact test.

Figure 14. Rearward facing child restraint system showing head exposure above the top edge of side wing in 90^{o} side impact test.

In 66^{o} side impact test no head strike was observed in any of the rearward facing restraints. In comparison to the 90^{o} side impact tests, there were fewer devices that exposed the dummy's head to the risk of a head strike. This indicates that the 90^{o} test is more onerous in this regard and that for this reason it should be retained in future iterations of the program.

Forward Facing Restraints

In the 90^{o} side impact tests, head strikes on the door structure or window were observed in almost all devices. Only one device was able to prevent a head strike, however, even in this device the dummy's head moved beyond the edge of side wing. Accordingly, the device's PA score was reduced to one. Figure 15 illustrates a typical case of head strike.

Figure 15. Typical head strike in some of forward facing child restraints in 90^{o} side impact test.

In the 66^{o} side impact tests on some of the restraints both shoulder straps remained in position during the impact phase of the test. However, the left-hand shoulder strap slipped completely off the shoulder during rebound. Consequently, these devices were assigned PA scores of 1.

Booster Seats

From the sixteen booster seats tested in 90^o side impact, only one device was able to prevent a head strike on the door structure, for which it was assigned a 'PA' score of four. The remaining devices all allowed the dummy's head to strike the door structure; therefore, each device scored unacceptable (0). Figure 16 shows a typical head strike on booster seats.

Figure 16. Typical head strike in some of booster seats in 90^o side impact test.

Following the 66^o side impact tests, the inboard side wing of some restraints was found to have broken away from the main body of the enclosure, but to have remained inside the cover. This failure, which appears to have occurred when the side wing was struck by the dummy's torso during rebound, may have been a factor in the dummy's head or head and upper torso moving beyond the inboard side structure of the device. This in turn may have been a factor in the seat belt sash strap disengaging the upper torso. Therefore these devices were assigned PA scores of 1 and the remaining device scores of 4.

5.1 Ease-of-Use Assessment

Due to results of CREP stage 4B ease-of-use assessment have not been finalised, the following findings are examples drawn from stage 4A only.

Exemplar overall ease of use results are shown below in Figures 17-19. As shown in these results all restraints assessed in this series scored an overall B or C rating. While the protocols allowed for discrimination across the spread of results, the spread was still relatively small. Rather than a reflection of the protocols, this is likely due to the fact that less than half of the currently available restraints have been tested and most of these were from a single manufacturer. Therefore instruction booklets and labels etc have the same format.

Figure 17. Ease-of-Use overall results for Boosters.

Figure 18. Ease-of-Use overall results for forward facing child seats.

Figure 19. Ease-of-Use overall results for rearward facing infant restraints.

The fact that no restraint achieved an 'A' rating reflects the scope for improving features that would influence the propensity for misuse.

At this stage only the overall rating score is published in public documents, and available on stakeholder websites. However, scores from the individual categories (shown in Figures 20-22) provide more detailed information, both regarding the comparative performance and the scope for improvement.

Rearward Facing Restraints

Figure 20 illustrates exemplar results for rearward facing infant restraints. Most of the rearward facing restraints on the market in Australia is convertibles. The need for installation in two different ways results in potential for confusion around the correct seat belt path and is reflected in these results. Similarly there were significant differences in the ease of achieving and maintaining proper use of the restraint between the rearward facing restraints assessed. There was also a broad range of scores in the label category.

The poorer performers demonstrated a need for attention to the following issues

- colour coding seat belt paths, labels and instructions for the different modes
- easy removal of covers and rethreading of the harness system
- improved positioning and clarity of labels.

Figure 20. Ease-of-Use category results for rearward facing infant restraints.

All devices could be improved through the provision of feedback mechanisms to indicate correct use.

Forward Facing Restraints

Exemplar results for forward facing seats are shown in Figure 21. There was one restraint that clearly stood above in terms of ease of installation, with the correct belt path being much easier to achieve than it was in all of the other restraints. Similar problems with labelling and instructions to that observed among the rearward facing seats were also apparent in the forward facing restraints. There were also substantial differences in features related to achieving proper use of the internal harness system,

Figure 21. Ease-of-Use category results for forward facing child seat.

The poorer performers demonstrated a need for attention to the following issues

- complexity of achieving correct seat belt path
- colour coding seat belt paths, labels and instructions for the different modes
- easy removal of covers and rethreading of the harness system
- improved positioning and clarity of labels.

As with rearward facing restraints, all devices could be improved through the provision of feedback mechanisms to indicate correct use.

Booster Seats

Since there is little involved in installing a booster seat into a vehicle, and so there was no assessment of features related to installation in these types of restraints. Exemplar results from the other categories assessed are shown in Figure 20 and illustrate distinct differences between restraints.

While securing a child within a booster seat is relatively uncomplicated, evidence form the field suggest that misuse of the sash is high among booster seat users. There is therefore a need for booster seat manufacturers to provide restraints that will assist in minimising this form of misuse. The scope for manufacturers to do this is reflected in the low scores for this category shown in Figure 22. Booster seats are also required to serve children over a wide range of seated heights. Many seats assessed in Stage 4A failed to do this. There was also some variation in the labelling and instruction categories for the same types of reasons discussed for rearward and forward facing restraints. More so than the other types of restraints, the boosters also demonstrated distinct differences in the quality of packaging. This was primarily in regard to the level and clarity of information supplied concerning which children should be using boosters. Premature graduation from booster seats to seat belts, and from forward facing child seats to booster seats are widespread problems in the field [11-12]. Providing this sort of information on packaging would greatly assist parents in making good choices at the point of purchase.

The poorer performers demonstrated a need for attention to the following issues

- features to assist in reducing misuse of the sash belt
- assistance in the correct use of features designed to achieve correct belt fit
- accommodation of children within the full spectrum of anthropometry for which booster seats use is required
- colour coding seat belt paths, labels and instructions for the different modes
- improved positioning and clarity of labels.
- Improved clarity and information on packaging

Figure 22. Ease-of-Use category results for boosters

Finally, it is important to note that not all restraints currently on the Australian market were assessed to the new protocols and that the exemplar results presented in the above Figures are a sample of the restraints that have been assessed thus far.

6 Discussion and Conclusion

The overriding objective of a program such as CREP is to provide children with improved levels of crash protection - beyond the minimum required by the Standard. Firstly the program aims to influence consumers to buy restraints which rate well, and avoid the restraints which do not. This secondly provides an economic incentive for manufacturers to develop and market better performing products. Thirdly, to assist manufacturers, the program provides detail of where their products rate well and where they do not. Therefore it also provides useful step-by-step guidance on where and how the product needs to be improved.

For the program to achieve its objective there must be wide dissemination of the results, and the results must be in a format that is useful to the consumer. Experience from other vehicle safety advocacy programs, such as the Australasian New Car Assessment Program, and the Used Car Safety Ratings shows that consumers want complex scoring information distilled into a simple form they can understand. In this case, it was felt that the dynamic and ease of use scores were quite different and should be presented separately. This would enable consumers to make their own judgement if they thought one factor was more important than the other.

Following the release of the results from Stage 4A, newspaper coverage was been widespread, demonstrating that the information from this program is appreciated in a range of areas, including maternity hospitals, child injury prevention groups and parent/consumer groups.

There is an ongoing significant level of enquiry to telephone information lines that confirms that the CREP stakeholders are strongly associated in the public's mind with the distribution of child restraint rating information.

This type of attention underlies the effectiveness of the program.

In the past, based on consumer feedback, it appears that CREP programs have had a major effect on shaping consumer purchases.

The RTA and NRMA reported that the CREP brochures for earlier stage of CREP were the most popular brochures they had. Many retailers reported that consumers only wanted to purchase the restraints shown as performing well in the program’s brochures, and many retailers reported that consumers sought exchanges and refunds on products which were not reported as performing well in CREP 1 and 2.

Child safety stakeholders are dependent upon influencing the purchasing power of consumers to persuade manufacturers to keep better performing products on the market. Retail outlets are where this power is exercised. A potential enhancement of the overall program would be to develop training and information programs targeted at these types of potential information sources.

An important part of the consumer evaluation process is to provide guidance to manufacturers regarding where the highest priority areas for significant gains in performance lie. This recent series of ease of use assessments has indicated a number of features where specific attention is warranted. These include;

- provision of information regarding correct and appropriate use in languages other than English on packaging and within instruction booklets,

- one page pictorial set up and usage guides,

- better clarity in diagrams such that the information contained with diagrams on packaging, labels and in instructions books conveys all necessary information with no need to read any additional text,

- placement of labels on restraints in the vicinity of the task to which they refer, and

- colour coding of instructions, labels and seat belt routing (particularly for individual modes of use in convertible restraints).

The incorrect use of in-built harness systems (in forward facing and rearward facing restraints) and the sash of seat belts (in booster seats) are areas raising concern in the field. There is a need to encourage manufacturers to optimise their designs to reduce the propensity for this form of misuse. Bonus points were available in this series for restraints that provided some means of warning when the harness/belt was being used incorrectly (or conversely some feedback system denoting correct use). No restraints currently have any features like this and this would be one area where manufacturers could gain some edge for future programs.

Of note, there was a substantial difference in the head excursion allowed between the best and the worst performing forward facing restraints. Overall, the results suggest there is specific scope for improving the performance of;

- convertible child restraints generally,
- booster seats, particularly those that do not incorporate adequate sash guides and crotch straps, and
- forward facing and booster seats in side impact, particularly in the head protection provided in side impact at the upper end of their mass limits.

While consumer information-based assessment programs focusing on child restraint design are likely to enhance the ease of use and dynamic performance of child restraints, the child restraint is only one piece of the protective system in the real world. There is also a need to encourage vehicle manufacturers to improve the ease of installing and using child restraint systems in specific models of vehicle and the development of effective strategies to achieve this is required. One possible measure raised in the past is the addition of some form of child restraint compatibility assessment to programs such as NCAP. An example of a possible scoring system is outlined by Brown et al [13].

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