EVALUATION OF CHILD RESTRAINTS FOR HOLDEN COMMODORES

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Paper Number 474

ABSTRACT

A two-stage study was conducted to identify a suitable child restraint (CRS) to fit a Holden Commodore vehicle. Seven CRS were evaluated: 1 infant capsule (rear-facing), 3 dedicated forward-facing restraints and 3 convertibles (rear-facing mode for infants and forward-facing mode for children). Stage 1 testing involved an evaluation of goodness-of-fit and quality of installation. Stage 2 testing involved dynamic sled tests (frontal and side-impact) using the 5 best performers from Stage 1. Amongst the rear-facing restraints, the capsule performed better than all convertibles, showing least reduction of front seat space and greatest lateral stability under a 200N force. Of the restraints tested in forward-facing mode, one dedicated forward-facing restraint was found to be superior. The sled tests showed differences in dummies' forward head excursion, forward and lateral stability of CRS, and side-impact head protection. Overall, although the findings suggested a good level of protection, several areas for design improvement were highlighted including methods of fixing the restraint to the vehicle and the size of the side wings.

INTRODUCTION

Recent estimates of effectiveness have suggested that overall, child restraints may reduce injury by approximately 70% and severe injury by 90% compared with unrestrained children (Carlsson, Norin, & Ysander,1991; Durbin, 2001; Isaksson-Hellman, Jakobsson, Gustafsson, Norin, 1997; Mackay, 2001; Partyka, 1990; Tingvall, 1987; Weber, 2000). Generally, while these figures suggest that restraint effectiveness is high, a number of authors have indicated that there is a need for design improvement. In addition, restraint effectiveness is influenced by the compatibility of the restraint, its anchorage system and the characteristics of the vehicle seat. The purpose of this study was to identify a suitable restraint, from amongst those currently available in Australia, to fit a Holden Commodore vehicle.

This paper is restricted to consideration of restraints for infants (< 9kg and <70cm) and young children (8-18kg and 70-100cm).

Injuries Sustained by Restrained Children

Most injuries sustained by restrained children are minor in nature (Henderson, 1994; Isaksson-Hellman, Jakobsson, Gustafsson, Norin, 1997; Tingvall,1987; Webber, 2000). Children in child restraints are less likely to be injured than children wearing adult seat belts (Durbin, 2001) and many injuries result from inappropriate restraint usage (NHTSA, 1999). For example, Durbin (2001) reported that when considering all serious injuries, children wearing adult seatbelts were 53% less likely to be injured than children who were unrestrained and that children in child restraint were 60% less likely to be injured than children wearing adult seat belts.

The head and face are the more commonly injured regions and the head is the region most frequently involved in serious and fatal injuries in restrained children. In side impact crashes, head injuries most commonly occur from either contact with the vehicle interior and / or contact with a restraint (see Henderson & Charlton, in press, for a review). Limiting head excursion in frontal impacts, preventing head contact and minimising head loads in side impacts are critical criteria for good child restraint performance.

Restraint Design

In Australia, approved child restraints must comply with Australian Standard AS 1754. This standard prescribes specific requirements including material requirements, design and construction, and performance. As a result of this Standard and associated vehicle design rules (ADR 34/01 and ADR 3/00), a number of significant benefits can be observed in CRS design and usage in Australia compared with the current state in North America and Europe (Paine, Brown & Griffith, 2002). These include,

- Mandatory top tether strap;
- Single point of adjustment of the harness;
- Six point harness with double crotch straps;
- Rear seat mounting normal practice.

Although the Standard sets a minimum level of performance for all Australian child restraints, differences exist in the level at which Standards approved restraints perform under standardised conditions. These differences are particularly evident in measures of dummy head excursion in frontal impacts and degree of head containment in side impact (Crashlab, 2000).

In addition, the performance of a CRS is likely to be influenced by the interaction between the characteristics of the vehicle seat and the CRS. Such factors include:

- compatibility between the contours of the vehicle seat and CRS;
- compressibility of the vehicle seat;
- the configuration of the seatbelt attachment of the CRS to the vehicle.

This study evaluated selected CRS in a two-stage test program for (i) goodness-of-fit and quality of installation (ii) crash performance using dynamic sled tests. Of interest was the relative performance of the restraints in a Holden Commodore vehicle.

STAGE 1: FITMENT TRIALS

Method

Seven CRS were selected for the fitment trials based on previous research (CrashLab, 2000; Henderson, 1994). All had top-tethers. Three types of restraints were included:

- 1 dedicated infant capsule (rear-facing, for infants < 9kg and <70cm);
- 3 dedicated forward facing restraints (for children 8-18kg and 70-100cm); and
- 3 convertibles (rear-facing mode for infants and forward-facing mode for children).

Goodness-of-fit

All rear-facing restraints (capsule and three convertibles in rear-facing mode) were evaluated for goodness-of-fit in the vehicle. Forward-facing restraints were not assessed because they posed no restriction on front seat space. Each of the rear-facing CRS was installed according to the manufacturer's instructions in the centre, near-side (left) and off-side (right; behind driver) rear seating positions. For all trials, the front driver and passenger seat backs were set at 22 degrees to the vertical. During the installation process, front seats were moved to their foremost positions. Once installed, the CRS was moved to the most rearward position. Where applicable, contact between CRS and front seatback was noted and the amount of reduction in front seat travel was recorded (in absolute distance (mm) and as a percentage of total fore-aft travel).

Stability

A 200N force was applied to the top and base of the CRS. This provided a measure of the quality of installation by assessing the potential for the top tether and adult seatbelt to restrain the CRS against forward and lateral forces. The following subset of displacement measurements is reported:

- Lateral displacement (mm) CRS with 200 N force applied to top (top/front for convertible in rear-facing mode and capsule) on inboard side;
- Forward displacement (mm) of top of CRS with 200 N force applied to top slots of shoulder harness straps (CRS in forward-facing mode, only);
- Forward displacement (mm) of base of CRS with 200 N force applied to base on outboard side.

Results and Discussion of Stage 1

Goodness-of-Fit

All rear-facing restraints were installed in centre rear seat position without compromising front seat travel. That is, with the front seats in their rear-most position, no contact was observed between the seat backs and CRS. However, when installed in the off-side (right) and near-side (left) positions, the convertible-type restraints all made contact with the rear of the front seats. Figure 1 shows the percentage reduction in front seat travel for convertible and capsule type restraints, averaged across near- and far-side seat positions. Installation of the infant capsule resulted in considerably less reduction in front seat travel compared with the convertibles (means were 40% and 66%, respectively).

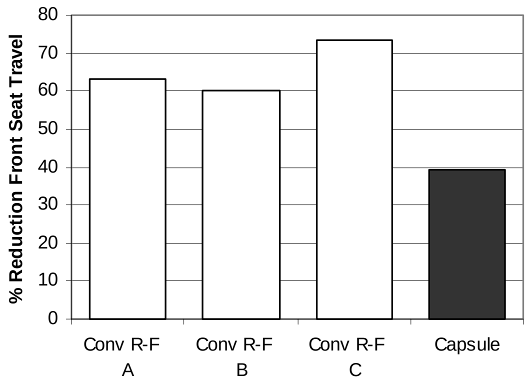

Figure 1. Percentage reduction in front seat travel for rear-facing convertibles and capsule CRS

Installation of Convertible C required the front seat to be moved forward 74% of the total available travel distance, resulting in the greatest compromise in front seat space. With front seat space compromised to such an extent, it is likely that for some proportion of the adult population, driver and passenger safety and comfort may be affected. Hence, Convertible C was excluded from further testing.

Stability

Table 1 summarises the results of the installation trials evaluating stability of CRS with a 200 N force applied. For CRS with a recline mode, the performance range for upright and reclined modes of installation is presented.

Table 1. Displacement measurements (mm) with 200 N force applied to CRS (range upright - reclined mode where applicable)

CRS TYPE		Lateral Disp (top)*	Forw'd Disp (top)*	Forw'd Disp (base)**
Dedic F-F	A	105	5	50
	B	87 - 153	20 - 28	25 - 77
	C	95 - 160	7 - 20	130 - 120
Conv F-F	A	70 - 140	20 - 45	120 - 110
	B	125 - 60	7 - 25	130 - 125
	C	100 - 155	3 - 20	65 - 55
Conv R-F	A	500	N/A	45
	B	470	N/A	130
	C	500	N/A	50
Capsule		400	N/A	88

* CRS installed in centre rear
** CRS installed in side rear

Results for lateral displacement of the forward-facing CRS indicated a relatively high level of stability. Lateral movement ranged between 60 mm and 160 mm. Compared with forward-facing restraints, rear-facing restraints were considerably less stable. The infant capsule moved slightly less than the convertibles (400 mm compared with 470-500 mm, respectively).

Application of an external force to the top of the CRS resulted in relatively little displacement of the top of the CRS for both restraint types tested, (range was 3mm to 45 mm). Forward displacement of the base of the CRS was also relatively small although there was some degree of variability within restraint types.

The quality of installation with an external force applied was used as a measure of the effectiveness of the CRS attachment system in minimising movement of the restraint during an impact. As expected, instability was relatively high in the lateral direction. Lateral displacement was considerably more marked in rear-facing CRS compared with restraints in forward-facing mode. This can be attributed primarily to longer top tether strap configurations in rear-facing CRS. Convertible types showed more sideways movement than the infant capsule. Relatively good levels of stability were observed when the force was applied to the top of the CRS in the fore-aft direction. Slight variations in fore-aft displacement were observed, particularly between restraints in upright and recline modes. These differences are likely to be attributed to small differences in the length of top tether strap. Given the potential for this fore-aft displacement to translate into forward excursion of the child occupant's head in the event of a crash, it was of particular interest to explore the performance of these restraints under dynamic sled testing in Stage 2. Restraints in recline mode allowed slightly more forward displacement than was evident in upright mode. Fore-aft movement of the base of the CRS was generally higher for the convertible restraint type in forward-facing mode. One particular dedicated forward-facing restraint (CRS C), showed the greatest amount of lateral movement as well as forward movement of the base (in recline mode) and therefore was excluded from further testing.

SLED TESTS

The five best performing CRS from the fitment trials in the earlier stage of the project were evaluated in the sled tests. These were

- Dedicated forward-facing restraints A and B;
- Convertibles A and B; and the
- Infant capsule.

Twenty-two HyGe sleds test were conducted using a Holden Commodore VX Sedan buck. The sled tests were based on the dynamic test requirements of (AS/NZS 1754:1995), with some of the tests designed to exceed the requirements of the Standard.

The CRS were fitted in the right and left side rear seating positions in a simulated 64 km/h offset deformable barrier frontal impacts, crash severity of around 71 km/h. In addition, 50 km/h side impact simulations (near and far-side) were conducted with a crash severity of around 16 km/h. Only near-side data are reported in this paper.

New seat belts were used in each sled test and front seats and rear seat belt anchor points were reinforced where necessary to withstand numerous sled tests.

The test dummies used in the sled tests were:

- Hybrid III 3 years old;
- TNO P3 (15 kg);
- TNO P1.5 (9 kg); and
- CRABI 6 months old.

A number of measures of dummy kinematics were recorded, however, only Head Injury Criteria, derived from head accelerations data, are reported here.

In addition, all tests were recorded using high speed on-board cameras. These recordings were analysed using digitising software to measure the maximum forward excursion of the dummy head and contact with the vehicle interior (and other dummy body parts) was noted by two independent observers.

Results and Discussion of Stage 2

Table 2 summarises the data for frontal impacts for the various restraint types. As expected, the acceleration forces on the head, represented by HIC36, were higher for forward-facing restraints compared with rear-facing restraints.

Differences were observed in the HIC36 values for the four forward-facing restraints. Differences were also evident for the two dummy types. Best performances were noted for Dedicated forward-facing restraint A and Convertible B with the Hybrid III dummy. HIC values were fairly similar across the three rear-facing restraints and were suggestive of good head protection in a frontal impact.

Analysis of the maximum forward motion of the dummy head also revealed differences among the restraint types. In particular, one child seat, Convertible A, allowed the dummy head to contact the back of the driver seat during the impact. In addition, Convertible B and Dedicated forward-facing restraint B allowed the dummy head to contact its knees.

Table 2. Summary of dummy measures for frontal tests

CRS TYPE	Dummy	HIC 36	Max Head Excur (mm)	Head Contact
Dedic F-F A	TNO 1.5 HIII	1510 802	485 516	No No
B	TNO 1.5 HIII	1746 1170	584 572	Yes-kn Yes-kn
Conv F-F A	TNO 1.5 HIII	1092 1113	550 580	Yes-kn Yes-rfs
B	TNO 1.5 HIII	- 843	563 563	Yes-kn No
Conv R-F A	CRABI TNO 1.5	415 423	150 150	No No
B	CRABI TNO 1.5	493 557	150 150	No No
Capsule	CRABI	547	120	No

Summary data for side impact tests are presented in Table 3. Low HIC values were recorded for all CRS. This was not unexpected given the relatively low crash speed used in these side impact tests. Another important indicator of protection in side impact is the extent to which the head is contained within the CRS and evidence of head contact with the vehicle interior (door or window). In forward-facing mode, both convertibles permitted the dummy head to strike the vehicle and in rear-facing mode, Convertible B also allowed dummy head contact with the vehicle door.

Table 3. Summary of dummy measures for side impact tests (nearside)

CRS TYPE	Dummy	HIC36	Head Contact
Dedic F-F A	TNO 1.5 TNO 3	129 60	No No
B	TNO 1.5 TNO 3	41 31	No No
Conv F-F A	TNO 1.5 TNO 3	30 88	No Yes
B	TNO 1.5 TNO 3	46 26	No Yes
Conv R-F A	CRABI TNO 1.5	53 141	No No
B	CRABI TNO 1.5	82 118	No Yes
Capsule	CRABI	79	No

Given the relatively low HIC values, it could be argued that head contact was not problematic. However, the fact that three of the restraints were unable to retain the dummy head in a relatively low crash speed suggests that at high crash speeds, serious head injury may result.

Differences in the capacity to prevent head contact may be explained by the size of the side wings and the stability of the CRS. Dedicated forward-facing restraint A had large side wings and clearly offered better containment of the head than the other restraints tested with the 1.5 and 3 year old dummies. An important factor in maintaining CRS stability is the method of attachment of the restraint to the vehicle. The dedicated forward-facing CRS differed in their method of attachment in terms of seatbelt configurations. In restraint A, the lap portion of the seat belt wraps right around the front of the base of the child seat, while in restraint B, the seat belt fits through the back of the child seat.

SUMMARY AND CONCLUSION

In summary, the two-step evaluation was designed to evaluate a range of child restraints that are currently on the market for their suitability for use in the Holden Commodore vehicle. The research process compared CRS performance on various measures, including goodness-of-fit, the stability of the restraint and various crash protection measures such as the ability of the restraint to prevent the dummy head from contacting the vehicle interior and its capacity to contain the head in a side impact crash.

Overall, the research confirmed that child restraints on the market in Australia offer a high standard of protection for young occupants in the event of a severe crash. The findings showed that there were differences between child restraints on a number of measures. In the range of restraints suitable for infants, the infant capsule-style performed better that the rear-facing convertibles. For older children, the dedicated forward facing restraints generally performed better than the convertibles in forward-facing mode. One dedicated forward facing restraint in particular, clearly showed better stability and head protection, primarily due to the seat belt configuration around its base and the large wings surrounding the child's head.

Although the findings suggested a good level of protection, several areas for design improvement were highlighted. These include:

- better systems of attachment of the CRS into the vehicle to optimise stability and minimise fitment error (e.g. incorporating ISOfix systems);
- improved side impact protection by increasing the size and padding of side wings of the CRS.

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