# IMPROVING CHILD SAFETY RESTRAINT SYSTEMS

Prepared by: Michael Henderson, Consultant
Judith Charlton, Monash University Accident Research Centre
Nicola Pronk, Monash University Accident Research Centre
James Scully, Monash University Accident Research Centre

30 June 2003

## 1. A BRIEF STATEMENT OF THE ISSUE

This paper describes the features that comprise an effective restraint system for young passengers, including an overview of some relevant social and political issues.

## 2. AN ASSESSMENT OF THE ROAD SAFETY ISSUE

### 2.1. Deaths and serious injuries among child passengers

Motor vehicle crashes are one of the leading causes of death and acquired disability for children in Australia and New Zealand.[1]

Figure 1 shows the death and serious injury rates for child passengers in motor vehicles in Australia 1980-1996.

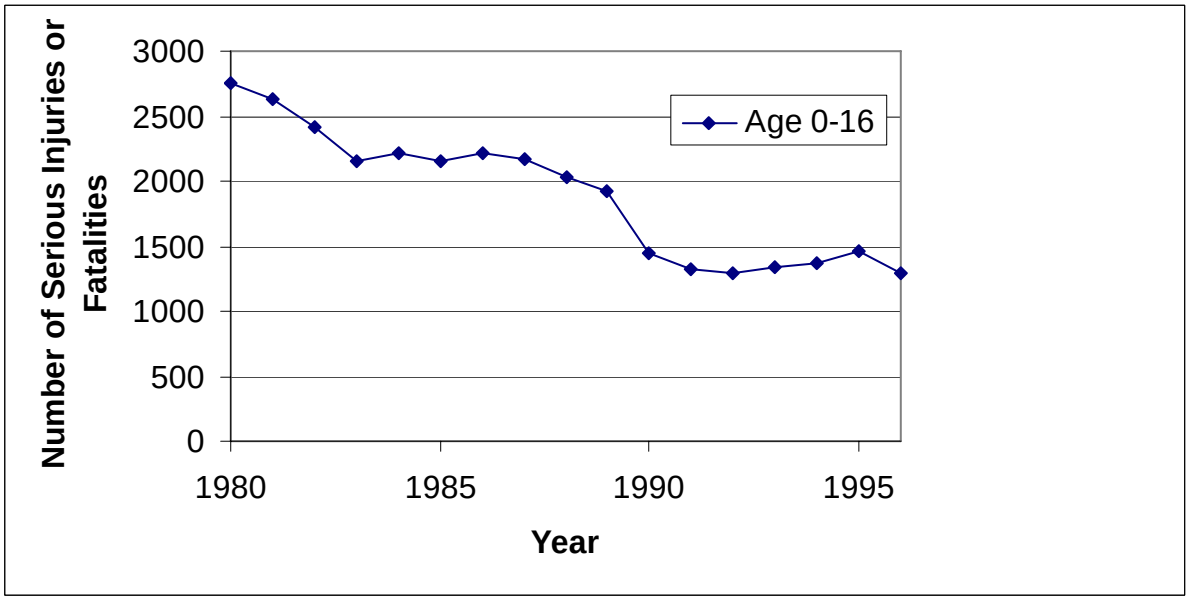


Figure 1 Number of child passenger deaths and serious injuries in motor vehicle crashes in Australia, 1980-1996.[2]

Figure 1 shows that the number of deaths and serious injuries for child passengers more than halved between 1980 and 1996.

Figure 2 shows the numbers of deaths and serious injuries sustained by children in motor vehicle crashes in New Zealand, 1970-2001.

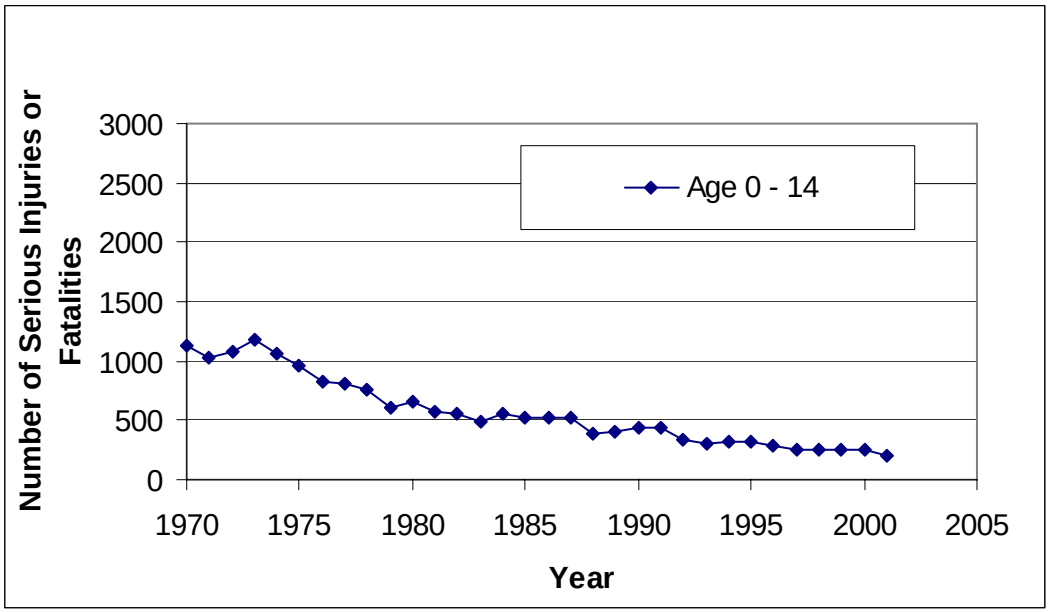


Figure 2 Number of child passenger deaths and serious injuries in motor vehicle crashes in New Zealand, 1970-2001.[3]

As was the case in Australia, the number of deaths and serious injuries sustained by children in motor vehicles in New Zealand has reduced since the 1970s.

## 2.2. Restraint effectiveness

There are no Australian or New Zealand studies estimating the effectiveness of child restraints. However, international studies suggest that child restraints may reduce all injuries by approximately
70 per cent and severe injuries by 90 per cent compared with injuries sustained by unrestrained children.[4,5,6,7,8,9,10,11]

It is probable that Australian and New Zealand child restraint systems are at least as effective as their overseas counterparts and have been a major factor in the overall decline in deaths and serious injuries indicated in Figures 1 and 2.

Children in child restraints are also less likely to be injured than children wearing adult seat belts[6,12], and some injuries may in fact be caused by inappropriate restraint usage.[13] While children wearing adult seatbelts are 53 per cent less likely to be seriously injured than children who are unrestrained, children in child restraints or booster seats are 60 per cent less likely to be seriously injured than children wearing adult seat belts.[6]

## 2.3. Injuries sustained by restrained children

Most injuries sustained by restrained child passengers are minor in nature[7,10,14,15,16,17,18,19,20,21]. One study reported that approximately seven per cent of all reported injuries to unrestrained children were at MAIS 2 (using the Abbreviated Injury Severity scale, where zero = uninjured and six = unsurvivable or fatal injury), compared with just over three per cent for those wearing a seat belt (only), less than two per cent for those restrained using a booster seat and less than one per cent for those restrained in a rear-facing child restraint.[21] It is worth noting that a limitation of a number of child injury studies is that unrestrained children are not included in the study sample. Thus, comparisons between injuries of restrained and unrestrained children are not possible.

Most serious and fatal injuries in restrained children occur to the head[18], mainly due to contact with the vehicle interior.[15] In side-impact crashes, head injuries most commonly occur from either contact with the vehicle interior and/or contact with some part of the restraint.[22] Limiting head excursion in frontal impacts and preventing head contact and minimising head loads in side impacts remains a challenge for good child restraint performance.

There is also some risk of injury to other regions of the body, depending on the type of restraint being used:

- it has been found that non-head injuries have the lowest risk in rearward facing restraints, with minor injuries to the extremities being relatively common in forward-facing restraints.[12]
- injuries to the chest and abdomen are also associated with the use of booster seats in conjunction with adult seat belts.[12,13]

Abdominal and chest injuries are also common in children using adult seat belts.[23]

# 3. CURRENT POLICIES AND PRACTICES IN AUSTRALASIAN JURISDICTIONS

## 3.1. Legislation

In Australia, children less than one year old must be restrained in an approved child restraint which is properly fitted and adjusted. Children over one year old must either be in an appropriate child restraint (that is properly fitted and adjusted) or must occupy a seating position fitted with a suitable seat belt, and use that seat belt.[24]

In New Zealand, children younger than five years old must wear an approved (and properly fitted and adjusted) child restraint, which includes suitable booster seats. Children aged five to seven years must use a suitable child restraint or booster seat if there is one available, otherwise they must use a seat belt if available. If neither a child restraint, a booster seat, nor a seat belt is available, they must travel in the back seat. Children aged eight to fourteen years must use a seat belt if there is one available[25].

## 3.2. Standards

In Australia, approved child restraints must comply with Australian Standard AS1754. In addition, two Australian Design Rules relate specifically to child restraints:

- ADR 34 specifies the requirements for child restraint anchorage and child restraint anchor fittings;

- ADR 3/00 relates to seat anchorages and their attachments. Since 1975 this Rule has included requirements aimed at ensuring seat back and seat anchorage strengths are adequate when loaded with a child restraint in place.

Child restraints sold or used in New Zealand must meet either the Australian/New Zealand Standard 1754, the European Standard ECE 44 or the United States Standard FMVSS 213. New Zealand is currently considering the recognition of the Japanese standard for built-in child restraints.

AS/NZS 1754, ADR 34/01 and ADR 3/00 have collectively resulted in some significant benefits in Australasia compared with the current situation in North America and Europe.[26] These include:

- mandatory top tether strap (in New Zealand, however, restraints that comply with ECE 44 or FMVSS 213 do not require this)
- single point of adjustment of the harness
- six-point harness with double crotch straps
- careful specification of the location of mounting points for top tether straps in vehicles, to assist accessibility and optimise performance (again, in New Zealand, not all restraints may require this)
- a specially developed infant dummy for testing child restraints, with greater body flexibility (which gives it characteristics closer to those of a real infant).

It is important to note that, although the Standard sets a minimum level of performance for all Australian child restraints, there are large differences in how well approved restraints perform under standardised conditions.[27,28] Further, improvements to the design of child restraints are ongoing[29], with specifications for the Standard needing to match the newest developments.

## 3.3. Child restraint usage

Legislation, supported by education campaigns, has resulted in relatively high usage of restraints by children in Australasia. For example, an observational study conducted in Australia in 1994 estimated usage rates exceeding 95 per cent.[30] An observational study undertaken in 2001 in New Zealand identified that overall child restraint usage was 82 per cent, with compliance in some regions as low as 69 per cent.[25]

However, observational studies do not necessarily identify whether child restraints are being used correctly[31] and evidence presented later in this paper shows widespread incorrect usage, or even non-usage. Some authors[34] have identified a number of factors to explain this, including lack of authoritative information, ergonomic barriers (for example, highly-contoured vehicle seats leading to difficulties with installation), or socio-economic barriers (primarily, costs associated with purchasing child restraints).

# 4. A REVIEW OF THE RESEARCH

A number of important variables influence the absolute effectiveness of child restraint systems, including design features, installation and appropriate usage.

## 4.1. Design features

Different types of child restraint systems have been developed to cater for the changing anthropometric and biomechanical characteristics of children:

- Infant capsules cater for infants aged up to approximately six months (less than 9 kg or 70 cm). Important design features of infant restraints are:
  - ability to provide support for the head
  - ability to distribute crash forces uniformly over the whole of the infant's torso and head
  - ability to prevent unwanted motion between the head and the torso, and prevention of contact between the internal harness system and the 'soft' parts of the infant
  - ability to protect the head, in terms of both excessive motion in frontal impact towards the vehicle's seat back, and contact with the vehicle interior in side impact.
- Forward-facing child seats cater for children aged approximately six months to four years (8-18 kg, 70-100 cm)*. Important restraint design features include:
  - ability to provide support for the head
  - ability to limit forward excursion of the head in frontal impact
  - ability to protect the head in side impact
  - ability to prevent unwanted motion between the head and the torso, and prevention of contact between the internal harness system and the 'soft' parts of the infant.
- Booster seats provide the transition between dedicated child restraint systems and adult seat belts and are designed for use by pre-adolescent children (100-145 cm in height). A child's height is a more important indicator of the need for a booster seat than age or weight. Important restraint design features include:
  - raising the child up to a sitting height that allows correct positioning of the lap/shoulder seat belt
  - allowing close fit of the seat belt
  - constructed of material not too easily compressed
  - providing lateral support for a sleeping child
  - ability to provide some head protection in side impact.

In Australia and New Zealand, the need for a top tether for restraint systems that comply with AS/NZS 1754 has meant that children are usually carried in the rear seat, whereas in other countries children are commonly carried in the front passenger seats. The result is that Australia and New Zealand have not experienced the problem of children in front seats being injured by deploying front passenger airbags.

## 4.2. Installation

The level of protection provided by child restraints depends heavily on how well the restraint is fixed to the vehicle to which it is fitted. A study conducted in Australia by the Royal Automobile Club of Victoria (RACV) found that approximately 70 per cent of child restraints were incorrectly fitted.[32,33] Of these errors, 25 per cent were described as potentially serious[33] and included loose seat belts, loose anchor bolts and incorrectly fitted seatbelts. Other studies suggest these figures may over-estimate misuse rates. For example, a study conducted in New South Wales found that approximately 20 per cent of infant capsules and 19 per cent of child seats had safety-related installation problems.[34]

* Children in this age group can also use harness-only restraint systems. However, the inherent design of these restraints is of concern there is the potential for the lap portion of the restraint to be 'pulled up' and come into contact with the soft abdomen, if the shoulder straps are tightened excessively.[23]

## 4.3. Appropriate usage

Incorrect use of child restraints may reduce or nullify safety benefits.[20,15] A New Zealand pilot study of child restraint usage found that, while approximately 64 per cent of drivers believed that it was easy to use a child restraint correctly, 75 per cent were failing to do so.[35] Around 60 per cent had made at least one error installing the restraint, while 65 per cent made at least one error fitting the child into the restraint. Further, the most common errors were serious breaches of correct usage guidelines, including tether straps not fitted or secured to an anchor point, seatbelt incorrectly routed, or seatbelts fitted too loosely.[35] The RACV study mentioned above found similar results.[33] A mix of child restraints with and without top tethers complicates the situation in New Zealand.

Further, it is important that, as children grow, they use a restraint system that is appropriate for their size (particularly height and weight). [30,36] There are a relatively high proportion of children who grow out of a child restraint suitable for young children, and then use either an adult seat belt or no restraint at all, rather than using a child booster seat.[36,37,38] For example, one US study found that more than one-third of pre-school aged children (two to five years old) were inappropriately restrained by vehicle seat belts.[36]

# 5. POLITICAL, SOCIAL AND OTHER FACTORS ASSOCIATED WITH CHILD SAFETY IN CARS

The high rates of incorrect child restraint installation and use in Australia and New Zealand suggest the need for further public education and awareness programs focussing on the importance of correct installation and usage of child restraints – notwithstanding the current efforts of many organizations, including community health centres and automobile associations.

Some recent initiatives by the automotive industry, in specifying suitable child restraints for their models of vehicle and providing advice at dealerships, may assist in improving community awareness about correct fitment and usage. In addition, various state government authorities and automobile associations have established a wide network of restraint fitting stations to assist people to install child restraints correctly. However, not all people choose to use these facilities. Moreover, some families and carers have a need to move restraints regularly between multiple vehicles.

Further, a number of children move directly from a child restraint suitable for younger children to an adult seat belt (or no restraint at all), thus increasing the chance of injury. The extent of the problem, and the underlying explanations for the inappropriate use of adult restraints, particularly by the “booster seat age group”, are not well researched in Australasia. Nevertheless, strategies such as media campaigns, improved laws and extending the use of booster seats to older children may help to increase the use of booster seats.

As discussed above, currently in New Zealand child restraints must comply with the Australian/New Zealand Standard 1754, the European Standard ECE 44 or the United States Standard FMVSS 213. The acceptance of these multiple standards allows restraints on the New Zealand market that do not use a tether strap.

# 6. CONCLUSIONS

Recent estimates suggest that, overall, child restraints reduce the risk of injury by up to 70 per cent. Most injuries sustained by restrained children are minor in nature, and children wearing appropriate child restraints are less likely to be injured than those wearing adult seat belts.

Legal requirements in relation to child restraints have changed over the years, but currently in Australia children travelling in motor vehicles must be suitably restrained. In New Zealand, children under 5 years old travelling in motor vehicles must be suitably restrained. In both countries there are relatively high rates of child restraint usage, although this may vary dramatically between regional areas. In both countries, however, there is evidence that, while restraints are being used, in many instances they are being used incorrectly.

There are three main types of child restraints: infant capsules, forward-facing child seats, and booster seats used in conjunction with seat belts. It is important that children are seated in a child restraint appropriate for their size and weight. While many parents and carers report that they believe that child restraints are easy to install and use, a number of studies have found high rates of errors in installation that could potentially nullify the safety benefits.

More educational/awareness campaigns may help to combat many of the installation and usage problems.

# REFERENCES


1 National Highway Traffic Safety Administration. (2002). Children's health topics: fact sheet. http://www.nhtsa.dot.gov/people/injury/ems/Child_Health/chmfacts.htm [last accessed 12/12/02].

2 Data from the Australian Bureau of Statistics, Catalogues 9403.0 and 9405.0, and the Federal Office of Road Safety Injuries Report, 1996.

3 Data from the Land Transport Safety Authority of New Zealand.

4 Carlsson G, Norin H and Ysander L (1991). Rearward facing child seat: The safest car restraint for children? Accident Analysis and Prevention, 23(2/3), 175-182.

5 Cuny S, Got C, Foret-Bruno J, LeCoz J, Brun-Cassan F and Brutel G (1997). The effectiveness of child restraint systems in France, Child Occupant Protection 2nd Symposium. Society of Automotive Engineers, Warrendale, PA.

6 Durbin D (2001). Booster seat use and effectiveness in crashes. Booster Seats for Children. Closing the Gap Between Science and Public Policy. Association for the Advancement of Automotive Medicine, April 23-24, Washington DC.

7 Isaksson-Hellman I, Jakobsson L, Gustafsson C and Norin H (1997). Trends and effects of child restraint systems based on Volvo's Swedish accident database. SAE 973 229. Child Occupant Protection 2nd Symposium. Society of Automotive Engineers, Warrendale, PA.

8 Mackay M (2001). A global view of real world effectiveness of booster seats. Booster Seats for Children. Closing the Gap Between Science and Public Policy. Association for the Advancement of Automotive Medicine, April 23-24, Washington DC.

9 Partyka S (1990). Lives saved by child safety seats from 1982 through 1987. 12th International Technical Conference on Experimental Safety Vehicles, National Highway Traffic Safety Administration, Washington DC.

10 Tingvall C (1987). Children in cars, some aspects of the safety of children as car passengers in road traffic accidents. ACTA Paediatr. Scand. Suppl., 339, 1-35.

11 Weber K (2000). Crash protection for child passengers: A review of best practice. UMTRI Research Review, 31 (3), 1-28.

12 Winston F, Durbin D, Kallan M and Moll E (2000). The danger of premature graduation to seat belts for young children. Pediatrics, 105 (6), 1179-1183.

13 National Highway Traffic Safety Administration. (1999). Final Economic Assessment. Child Restraint Systems, Child Restraint Anchorage Systems. http://www.nhtsa.dot.gov/cars/rules/rulings/UCRA-OMB-J08/Econ/RegEval.213.225.html [last accessed 20/11/02].

14 Agran P, Anderson C and Winn D (1997). Restraint use among children in fatal crashes, SAE 973300, Child Occupant Protection 2nd Symposium. Society of Automotive Engineers, Warrendale, PA.

15 Henderson M (1994). Children in car crashes: An in-depth study of car crashes in which child occupants were injured. Child Accident Prevention Foundation of Australia, New South Wales Division.

16 Henderson M, Brown J and Paine M (1994). Injuries to restrained children. 38th Annual Proceedings of the Association for the Advancement of Automotive Medicine, September 21-23, Lyon, France.

17 Khaewpong N, Nguyen T, Bents F, Eichelberger M, Gotschall C and Morissey R. (1995). Injury severity in restrained children in motor vehicle crashes. SAE 952711. 39th STAPP Car Crash Conference. Society of Automotive Engineers, Warrendale, PA.

[18] Newgard C and Jolly B (1998). A descriptive study of pediatric injury patterns from the National Automotive Sampling System. 42nd Annual Proceedings, Association for the Advancement of Automotive Medicine, 1-14.

[19] Rattenbury S and Gloyns P (1993). A population study of UK car accidents in which restrained children were killed. Child Occupant Protection Symposium, San Antonio.

[20] Ray L, Anderson M and Murrin P The epidemiology of motor vehicle related injuries in children in San Diego County (1997). Child Occupant Protection 2nd Symposium. Society of Automotive Engineers, Warrendale, PA.

[21] Korner J (2001). Effectiveness of belt-positioning booster seats. Closing the Gap Between Science and Public Policy. Association for the Advancement of Automotive Medicine, April 23-24, Washington DC.

[22] Agran P and Winn D (1989). Injuries among 4 to 9 year old restrained motor vehicle occupants by seat location and crash impact site, 32nd Annual Proceedings of the Association for the Advancement of Automotive Medicine, Seattle, Washington.

[23] Troisseille X., Chamourd F. and Tarriere C. (1997). Abdominal injury risk to children and its prevention. Proceedings International Research Conference on Biomechanics of Injury, Hanover.

[24] National Transport Commission. (2000). Australian Road Rules. http://210.50.193.45/links/aust_road.asp [last accessed 7/4/03].

[25] Land Transport Safety Authority. (2002). Child Restraint Statistics. http://www.ltsa.govt.nz/research/belts3.html [last accessed 20/11/02].

[26] Brown J, Griffiths M and Paine M (2002). Effectiveness of child restraints. The Australian experience. Research report RR 06/02. Australian New Car Assessment Program. http://www4.tpgi.com.au/users/mpaine/roadsafe.html#aaa-cs [last accessed 7/4/03].

[27] Crashlab (2002). Child Restraint Evaluation Program. Dynamic testing. SR2000/003.

[28] Charlton J L, Olsson T, Truedsson N, Kelly P, Fildes B, Smith S and Kobus J (in preparation). Evaluation of Child Restraints for Holden Vehicles. Monash University Accident Research Centre Report.

[29] Langwieder K, Hummel T and Roselt T (2002). ISOFIX – Possibilities and problems of a new concept for child restraint systems. Paper presented at the Monash University Accident Research Centre, Holden Child Restraint System Workshop, March, Melbourne.

[30] Road Safety Bureau, 1994, as cited in Henderson M, Brown J and Paine M (1994). Injuries to restrained children. 38th Annual Proceedings of the Association for the Advancement of Automotive Medicine, September 21-23, Lyon, France.

[31] Wren J., Simpson J., Chalmers D. and Stephenson S. (2001) “Obviously a man designed it”. Barriers to using child car seats. Presented at the Barriers Childhood Injury Prevention Symposium, Children and Young People: Their Environments Conference, 28-30 June, Child Issues Centre, University of Otago.

[32] Harris A (2001). RACV child restraint research. A paper presented at Monash University Accident Research Centre Workshop on Child Restraints, February 2001, Melbourne.

[33] Seymour R (2000). Child restraint research and awareness campaign. Presented at the Road Safety Research, Policing and Education Conference, 26-28 November, Brisbane, Australia.

[34] Paine M and Vertsonis H (2001). Surveys of child restraint use in New South Wales. Proceedings of 17th International Technical Conference on the Enhanced Safety of Vehicles, Paper 214.

[35] Wren J, Simpson J, Chalmers D and Stephenson S (2001). Child vehicle restraint use in Dunedin: A pilot study using short interview and inspection method. Press Release. Childhood Injury Prevention

Symposium, Children and Young People: Their Environments Conference, 28-30 June, Child Issues Centre, University of Otago.

[36] Boyle J and Sharp K (1997). *1996 Motor Vehicle Occupant Safety Survey, Volume 5: Car Safety Seat Report*. National Highway Traffic Safety Administration, Washington DC

[37] Winston F (2001). Behavioral barriers to booster seat use. Booster Seats for Children. Closing the Gap Between Science and Public Policy. Association for the Advancement of Automotive Medicine, April 23-24, Washington DC.

[38] Winston F, Durbin D, Kallan M and Moll E (2000). The danger of premature graduation to seat belts for young children. *Pediatrics*, 105 (6), 1179-1183.

## Acknowledgements:

Thanks to John Wren and Michael Paine for helpful comments on earlier drafts of this chapter and to Mike Keall, Land Transport Safety Authority, for assistance with NZ injury data.