Prevention, 27(4), 571-581.

Rea, M., Murray, W., Darby, P., & Dubens, E. (2004). Comparing IT-based driver assessment results against self-reported and actual crash outcomes in a large motor vehicle fleet. Proceedings of the Road Safety Research, Policing and Education Conference, Perth, [CD-ROM].

Reason, J., Manstead, A., Stradling, S., Baxter, J., & Campbell, K. (1990). Errors and violations: a real distinction? Ergonomics, 33, 1315-1332.

Saricks, C.L., Schofer, J.L., Soot, S., & Belella, P.A. (1997). Evaluating Effectiveness of Real-time Advanced Traveler Information Systems Using a Small Test Vehicle Fleet, Transportation Research Record No. 1588, Intelligent Transportation Systems and Artificial Intelligence., Washington: TRB.

Stradling, S.G., Meadows, M.L., & Beatty, S. (2000). Driving as part of your work may damage your health. In G.B. Crayson (Ed.), Behavioural research in road safety IX, Crowthorne: Transport Research Laboratory.

Sullman, M.J., Meadows, M., & Pajo, K.B. (2002). Aberrant driving behavioursamongst New Zealand truck drivers. Transportation Research Part F, 5, 217-232.

Taylor, A., & Dorn, L. (2005). Stress, fatigue, health, and risk of road traffic accidents among professional drivers: the contribution of physical inactivity. Annual of Reviews of Public Health, 27, 2.1-2.21.

Underwood, G., Chapman, R., Wright, S., & Crundall, D. (1999). Anger while driving. Transportation Research Part F, 2, 55-68.

Xie, C., & Parker, D. (2002). A social psychological approach to driving violations in two Chinese cities. Transportation Research Part F, 5, 293-308.

Issues of Child Occupant Protection: A Literature Review

by Alexia Lennon, Centre for Accident Research and Road Safety, QUT, Beams Road, Carseldine, 4034

Abstract

Though there have been considerable reductions in child mortality and morbidity due to motor vehicle crashes in the past twenty years, road trauma is still a leading cause of death for children in motorised countries and thus an important health and safety issue in Australia. This review identifies key issues of child occupant protection such as the use of age-appropriate child restraints, effects of misuse of restraints, and rear seating of children. Current research findings, with particular emphasis on Australian data, are discussed in relation to avenues that offer potential for enhancing levels of protection.

Introduction

Australia has long been concerned with protecting car occupants generally and has led the world more recently in child-specific car safety through legislation in relation to the design standards and mandatory use of approved child restraints[1]. However, road trauma is still a leading cause of death and serious injury among children under 15 years of age in Australia[2], responsible for killing 66 children in 2004[3] and seriously injuring over 900 more[4]. Clearly, while much progress has been made over the past decades, there are still outstanding issues to address. This paper sets out to identify the key issues and review the current state of knowledge in relation to them, with particular emphasis on the Australian perspective and experience.

Child Restraints

One of the most effective ways of protecting light vehicle occupants is the wearing of seat belts. Australia was the first country to legislate the compulsory wearing of seat belts for occupants aged 8 years or over in 1970 in Victoria, with other states quickly adopting similar requirements[5]. For younger passengers, legislation was set in place during the 1970s and early 1980s[5] and has recently become more uniform with the national adoption of the Australian Road Rules during 1999 and early 2000. Currently, all States and Territories require that infants under 12 months old be restrained in an approved child restraint[6]. These incorporate a six point harness and are secured to the vehicle by both an adult seat belt passed through the frame of the restraint as well as a top tether attached to an anchor point in the rear of the vehicle[1]. For newborn babies, restraints are rear-facing until the infant reaches the weight limits specified for the restraint (9-12 kg depending on type)[7]. After this, forward-facing child restraints must be used until the child is at least 12 months old. All other passengers travelling in motor vehicles in Australia are required to be appropriately restrained in either approved child-specific restraints or seat belts[6].

Risks associated with adult seat belts use for children

Although children aged between 12 months and 16 years are required to use an approved restraint, the type of restraint is not specified. Once a child is 12 months old, this means that adult seat belts may be worn and still comply with current Australian legislation. While the use of adult seat belts is associated with reduced risk as well as severity of injury for children, compared to being *unrestrained*[8-10], evidence is accumulating that the protection offered by adult belts is far from optimal for most children.

Analysis of US child-specific crash data bases which monitor the injuries sustained by children in real crashes reveal that children aged under 8 years are at elevated risk of injury when using adult seat belts rather than dedicated child restraints[11, 12]. Recent Australian research found that suboptimal restraint, including misuse of the restraint (for instance, harness too loose) or use of the wrong size (inappropriate) restraint, particularly adult seat belts for smaller children, results in significantly higher risk of serious injury to these children[13].

These findings underline that children's physical dimensions and less mature anatomy are generally not compatible with the configuration of restraints designed for use by adults[13]. Optimum performance of seat belts depends on good fit, meaning that the lap portion sits low across the abdomen or across the upper thighs, and is secured by mature anterior superior iliac crests (the top front parts of the pelvis). The shoulder portion should cross the shoulder, collarbone and chest without resting against or touching the neck. The American Academy of Pediatrics[14] suggests that these fit requirements are generally not possible for a person who is less than 145cm tall, which only 5% of children have achieved at 8 years old and most don't reach until 10 or 11 years old[15].

Australian in-depth studies of child injuries in real crashes show that most children involved receive only minor injuries, however, the head is the most commonly injured area and the area most severely injured[16]. For this reason, good protection of children must limit head excursion. However, children's smaller size when using adult belts results in greater risks of serious injury from head contact with the vehicle interior due to excessive head excursion[12, 13]. Abdominal injuries may also result from poor fit of lap belts, and contact of the child's neck with a poorly fitting sash portion may result in neck or spinal injuries[12].

For all the above reasons, children should use restraints designed specifically to suit their sizes.

Protective effect of child-specific restraints

Several different types of child-specific restraint are available on the Australian market. Each type is specific to a particular size range. They are designed to absorb or to spread the forces during a crash onto the sturdier parts of the body as well as reduce the extent to which the occupant's body, particularly the head, comes into contact with vehicle structures[1]. Also important is the principle of securing the restraint tightly to the vehicle and the child to the restraint in order to allow the child to "ride down" the crash with the vehicle[16] (see Brown and colleagues[16], for a detailed discussion). The restraints most commonly used are: rear-facing infant restraints (for infants 0-9kg or 12kg); forward-facing child restraints (CRS) designed for children 8-18kg and incorporating a chair and six-point harness; and convertible restraints which can be used as rear facing until the child is 9kg then 'convert' to forward-facing for children up to 18kg. Children over 14kg can use belt-positioning booster seats (BPBs), with or without high backs, or a convertible CRS/booster seat until they reach 26 kg. Child harnesses, suitable for children 14-32 kg, convert lap-only belts into four-point belts (with the upper two straps joining as a top tether), and may be used in conjunction with booster seats for children too small to wear the adult belt alone.

Performance of dedicated child restraints, particularly those designed for younger children, has received considerable research attention in Australia and internationally. For infants under 12 months and smaller children, US Fatality Analysis Reporting System (FARS) crash-database analyses suggest that rear-facing and forward-facing CRS reduce the risk of fatality by 71% and 54% respectively[17, 18]. More recent research using crash data from US insurance claims records suggests that forward-facing CRS may be much more effective than this, reducing injury and death by as much as 78%[19]. Australian research on forward-facing CRS has shown that the requirement for a high-mounted top tether produces considerable reduction in frontal-impact head excursion in dynamic testing using different restraints and under a variety of configurations (eg. tight, firm and loose tether adjustments)[20], thus providing very good protection to children wearing them properly[16]. Moreover, CRS may be more protective in higher speed crashes. Unpublished RTA crash barrier test findings (cited in [16]) showed that child dummies in top-tethered CRS, when tested at crash speeds varying from 40kph to 100kph, experienced a levelling off of head injury criteria (HIC) values at about 60kph. In comparison, for adult dummies restrained in seat belts, HIC values rose exponentially with increasing impact speed. .

Further to Australia's experience with sled tests and laboratory performance, two comprehensive Australian studies of child restraint performance under real-world conditions have been conducted. The first, by Henderson in 1993 included 131 crashes involving 247 children aged 14 years or under[21]. Around 92% of these children were using a restraint of some kind and most received no injuries or only minor injuries. Of the children using forward-facing CRS (n = 38), only 1 was killed and this was deemed to be due to gross misuse of the restraint: the adult belt was used over both child and seat. Similarly, the other four cases of serious injury in this group were also due either to gross misuse or to severe intrusion into the occupant space.

Very recently another in-depth study of children aged 2-8 years presenting to two hospital emergency departments after crashes also found very high (93%) levels of restraint use[13]. Case review of 152 children and in-depth crash analyses of a smaller sub-sample of 47 were conducted. As in the previous study, there were few fatalities (5%) in this sample, and around 20% of children sustained serious injury. All the fatalities and a high proportion of the severe injuries occurred in the highest impact crashes. Notably, when restraint type was classified as optimal or sub-optimal (discussed below), no optimally restrained child was either killed or seriously injured, even in the more severe crashes.

Taken as a whole, the evidence cited above has led to the assertion that forward-facing CRS, particularly as used in the Australian context, are very effective in protecting those children for whom they are designed (ie up to 18kg/approximately 4 years old) in frontal crashes[22]. For side impact crashes the protection offered by CRS is highly dependent on how well the restraint is fitted to the vehicle. This is because in side impacts, bottom anchorages are thought to be more critical influences on sideways movement, which in turn affects passenger movement and contact with the vehicle interior. Although CRS already perform well, recent research has suggested that fully-rigid fixing of the bottom anchors gives superior coupling of the restraint to the vehicle[23] and thus may offer room to improve performance. In dynamic testing this fully-rigid system was the only one which prevented dummy head contact with the test door for both 6 month old (CRABI) and 3 year old (Hybrid III) dummies.

Another aspect of CRS that has shown capacity for enhanced performance is the degree of protection offered by the side 'wings' which sit at jaw/head height to support and retain the head. Currently, very few restraints on the Australian market offer any energy absorption in these side structures. Moreover, dynamic testing suggests that current side-wing designs may not be sufficiently long to fully retain the heads of children at the upper limits of the height range for which they are intended[23] exposing children to head impact. Addition of energy-absorbing padding between the outer and inner surfaces of the side-wing has been shown to reduce the test-dummy HIC significantly, but this was only the case when the head was retained within the restraint[23]. This suggests that side impact protection offered by CRS could be improved by focus on these two design areas.

Protecting primary school-aged children

Belt-positioning booster seats

Though the evidence cited above demonstrates that CRS suiting children approximately 0-4 years old are very effective in protecting younger children, protection of older children appears to be less effective. Analyses of mass crash-data bases in the US have shown that seat belts are less effective at protecting older children than the CRS are at protecting 1-4 year olds, with reductions of injury calculated to be 38% and 60% respectively[24]. For older, taller and heavier children, the belt-positioning booster seat (BPB) was developed in order to lift, or boost, the child to a position where the adult seat belt system fits adequately and can thus offer similar crash protection to that afforded an adult[25].

BPBs on the Australian market are designed for children 14-26kg and come in three types: high-backed models, high-back child car seat/booster combinations and 'cushions' which have no back[26]. Combination seats are made from hard plastic, while the other types may be made of hard plastic or moulded polystyrene. All variations allow the adult belt to stay low on the child's hip/thigh. High-back BPBs (and some cushions) have adjustable clips, slots or tabs that hold the sash portion of the belt so that it can be correctly positioned across the shoulder, collarbone and sternum. Many high-back BPBs have deeper side-wings to retain the head. These wings are also helpful in maintaining a sleeping child's position within the seat and seatbelt.

BPBs are capable of improving the safety of older children. Child-specific crash surveillance data from the US focussing specifically the 4-7 years age group revealed that using BPBs lowered the odds for injury by 59% compared to children secured in adult seat belts[11]. Moreover, children in BPB seats were significantly less likely to suffer injuries to the abdomen due to the lap belt riding up over the child's abdomen. Case analysis and in-depth Australian research of children presenting to an emergency department after a crash, though involving small numbers, confirms the protective effect of BPBs for 5-8 year old children: children in BPBs were significantly less likely to suffer serious injuries than were their counterparts in adult seat belts[13].

While these real-world data tell us that there are important advantages for early school-aged children in using BPBs, dynamic testing reveals considerable room for improvement in design to increase the protection offered in side-impact crashes[27]. In sled tests of right-angle side impacts, high-back BPBs did not prevent head contact of the Hybrid III 6 year-old dummy with the side door window any better than did adult seat belts. Further, at this angle of impact, dummy head contact occurred in every test[27]. As Australian data suggest that around 30% of impacts may be side-on[13], and US research has shown that children involved in side impacts are more than three times as likely to sustain a serious head injury[28], further development of BPBs to include side wings of appropriate size with energy absorbing characteristics could offer important protection to children in this age bracket during side impact crashes.

Sub-Optimal Restraint

Though it appears that children can be well protected by using approved dedicated restraints, evidence is accumulating that restraint misuse or use of the wrong sized restraint for the child (inappropriate use) is common, resulting in many children being sub-optimally restrained. In addition, children are generally better protected when they are sitting in the rear seats of vehicles when there is a crash, so that front seated children are also sub-optimally protected.

Misuse

Restraint misuse is related to the fitting of the restraint to the vehicle and of the child to the restraint. Misuse can take a variety of forms from the less risky, for example, having the internal harness adjusted slightly loosely, to the potentially life-threatening, which includes failing to secure the restraint to the vehicle[21]. Misuse is the most serious form of sub-optimal restraint apart from being unrestrained, and has been associated with greater risk of injury or death, particularly in more severe crashes[13, 19, 21, 29].

Concern about the effects of misuse of restraints has led to various studies designed to gauge how widespread misuse practices are and estimate the impact of various types of misuse. In the US, one study reported a very high level of misuse, with nearly 90% of restraints observed to suffer from at least 1 fitting fault[30]. Similarly, a large (n = 2965) multi-state study also found substantial levels of misuse, with only around 20% of the observed child safety seats for 0-4 year olds correctly used[31]. Although the levels of misuse of restraints for older children 18-27 kg was much better at around 50%, few children in this weight range actually used child restraints (6%), with most either secured in adult belts (75%) or unrestrained altogether (19%)[31].

While not as marked, Australian studies show high rates of misuse. One car park survey in 1998 of 1,177 CRS found installation to be incorrect in 39% of the cases, with lack of top tethers forming one third of the faults in capsule installations and incorrect adult belt-threading a similar proportion in forward-facing CRS installations[32]. Other State-based studies have found fitting errors in 21% to 73% of restraints for children up to age 4 years[33]. Though BPBs have been found to be less prone to poor fitting[32], it should be noted that these surveys were carried out on parked cars without children in the seats, and are likely to underestimate the real level of misuse.

Surveys of parents suggest that these high rates of misuse may be due in part to the widely-held perception that fitting child restraints is an easy task[33, 34]. Perhaps as a result, only a small percentage of parents avail themselves of the advice and services offered by restraint fitting stations or specialists. It is likely that few parents really understand the forces involved in a crash, the necessity for tight coupling of passengers to the vehicle or the critical nature of even small amounts of slack in the restraint system to the protection offered by the restraint. These factors may be exacerbating parental complacency or overconfidence of their ability to adequately fit restraints. So, too, experience with earlier children, where restraint use has not resulted in any ill consequences, may indirectly reinforce parental unsafe behaviour or beliefs that such details are unimportant.

Vehicle and restraint design play parts in the propensity for a restraint to be misused. Though there have been many advances over the decades of child restraint use making them easier to use and harder to misuse by provision of features such as single adjustment points on CRS, there is still room for improvement. Particular problems include the degree of compatibility between rear vehicle seat design and restraint geometry, seat belt geometry, and the relative degree of difficulty of anchoring the restraint correctly to the vehicle. Some progress towards addressing these issues has been made. Recent revision of AS1754 to include a simulated door in side impact testing has meant more stringent requirements for side impact protection of CRS and high-backed BPBs[1].

Two further amendments to the Standard are also being considered. The first would require provision of alternative anchorage systems such as ISOfix and LATCH[35]. If approved, this could see restraints manufactured with the ability to be fully rigidly attached to vehicle bodies. Australian testing has demonstrated that fully rigid anchoring, where both the vehicle and the restraint have rigid attachments, significantly improves the side impact protection offered by CRS when compared with semi-rigid anchorage or the current flexible anchorage[23, 36]. Fully rigid anchorages may also offer improved performance for high-backed BPBs in side impacts, provided the design allows for retention of the child's head under impact conditions[27], as discussed above.

The second amendment under consideration is to include booster seats for larger children[35] (as currently available in the US) which may go some way towards bridging the gap in protection for those children too large for boosters but as yet too small for seat belts.

Inappropriate restraint use

Because of the high protection they offer when used properly, traffic and safety organisations recommend that parents keep children in each type of dedicated child restraint until the child outgrows it. However, a mounting body of evidence suggests that children are moved prematurely or "graduated"[12] to the next restraint type before they reach maximum size for the smaller restraint. Premature graduation includes children moved to booster seats or adult seat belts before they reach the weight/height limits for forward-facing CRS and children who are moved into adult seat belts while they are still able to use booster seats. This is termed inappropriate restraint and may present nearly twice the risk of injury to children involved in crashes than those who are appropriately restrained[37].

Studies in the US have repeatedly demonstrated that children of booster seat size (4-8 years old approximately) are at great risk of premature graduation into adult seat belts rather than being placed in size-appropriate BPBs[37-41]. In addition, the older the child, the greater the risk of inappropriate restraint use, with 6 year olds only half as likely as a 4 year old to use a booster, and 8 year olds almost never using them[39].

It appears that this pattern of BPB use among children of appropriate age is similar in Australia. An observational survey found similar levels of seat belt use among children aged 4-7 years, with 58% using the belt alone compared with 36% of children this age secured in a BPBs[33]. Results from an unpublished intercept interview survey of parents (n = 371) carried out at the Centre for Accident Research and Road Safety-Queensland suggest that more than 50% of Australian children are using adult belts regularly by the time they are 6 years old.

Risks of front seating

As early as 1977 studies demonstrated that passengers in the rear seat are at significantly reduced levels of risk for injury or death than those who sit in the front seats of vehicles[42]. More recent figures based on analyses of large USA crash databases such as FARS, National Automotive Sampling System and the General Estimates System provide further evidence for the associated dangers of front seating. Analyses of these databases for 1998-2002 revealed that a much higher percentage of restrained children seated in the front seat were fatally injured when compared to children seated in the rear seat[43]. When children were unrestrained, whilst the relative protection from sitting in the rear is reduced, children were still at reduced risk of fatality when sitting there rather than the front seat.

Similarly, using FARS data for 1988-1995, in vehicles without a front passenger airbag, restrained rear-seated child passengers were found to be about 35% less likely to be killed[44] than front seated children. Other analyses have demonstrated increased protection for rear seated children regardless of whether they were restrained[42, 43], though the addition of a restraint enhanced the protection[43, 45].

As well as being at lower risk of death, rear-seated children are also at less risk of serious injury than front seated children[8, 37, 46], though the effect of seating is not as great as that of appropriate restraint use[37]. However, these effects are interactive in nature: children appropriately restrained in the rear seat were found to be at least risk of injury[37].

The in-depth Australian study of children presenting to an emergency department cited previously[13] displays similar patterns to those reported above: front seated children were about two and half times more likely to be injured and to suffer more severe injuries than rear-seated children.

Crash data analysis can provide information on where those passengers who were injured or killed were sitting. Similarly, studies of children presenting to emergency departments has given valuable insight into the nature and extent of injury after crashes as well as some gauge of the extent to which children are uninjured from involvement in crashes[13]. However, in terms of estimating the extent to which rear seating may benefit children, some measure of exposure, or the proportion of children who actually travel in the front seat is needed. This has generally been gauged using observational studies, where researchers directly observe vehicles and their passengers from roadsides or locations where numbers of child passengers are likely to be high. One study of this nature carried out in Queensland in 2005 has estimated that around 60% of vehicles carrying child passengers 12 years and under had a child sitting in the front seat[47]. Proportions in the USA are estimated to be much lower at around 40%[48], and in one comparative study conducted in European as well as US cities, children were only observed in the front seat in 9-22% of European vehicles compared with 25-27% of US vehicles[49].

Several factors are thought to influence the rate of front seating. In Australia, exposure for younger children may be reduced by the requirement for top tethers on forward-facing CRS, since the anchor points are almost always in the rear of the vehicle. Another influence may be the presence of passenger-side airbags, which in the US experience were found to represent greater risk of injury and death to children[17]. However, in Australia passenger side airbags have not been mandated for new vehicles, but may be provided as an optional feature by manufacturers. There are also critical differences in the style of airbags fitted to vehicles on the Australian market: Australian airbags are designed to work with restrained passengers and hence fire later and with less force than the earlier airbags designed to protect unrestrained passengers. They also have larger vents making the overall cushioning softer[50]. These features resulted in an assessment by the Federal Office of Road Safety (FORS)[50] that the phenomenon of airbag-induced death or injury to children would not be seen in Australia, and this prediction appears to have been borne out. However, NSW has legislated against the use of any child-specific restraint in the front seats of vehicles where a passenger airbag is designed to deploy[51].

Another factor that may influence where parents seat their children is the level of perceived risk parents associate with having a crash generally, and more specifically, the risk of injury associated with sitting in the front in the event of crash. In studies related to why caregivers appear complacent about the misuse of child restraints, Will and Geller[52] suggest that aspects of the driving situations, such as its voluntary nature and everyday occurrence, coupled with fundamental cognitive characteristics of being human, such as optimism bias, fundamental attribution error and belief in a 'just world' lead to underestimation of risks associated with driving. People are also generally poorly equipped to assess risk accurately and may have trouble translating the meaning of risk assessment communicated to them by experts[53].

Better awareness or assessment of risk may lead to more safety conscious behaviours. In a qualitative exploration of barriers to booster seat use, parents who were more aware of the risks of crashes to their children were also more concerned to protect them through use of booster seats and by seeking information than were parents who were less aware[54]. All in all, parents seating their children in the front seat may be either unaware of the increased risk, or wrongly believe that a crash will not affect them or their children.

Discussion and Conclusions

It seems that a number of issues specific to enhancing protection of children travelling in cars are still deserving of attention. While in Australia we seem to have progressed well in protecting our youngest passengers through the use of infant restraints and legislation to maximise use, many of our toddlers and primary school aged children are not optimally protected when they travel. Improvements for the protection of these children can come from a number of directions.

Firstly, it would seem that parents need better education on what constitutes optimal protection and how best to achieve it for their own children. For parents, the message to buckle children up appears to be overshadowing any messages about the critical nature of fit or the need to place children as far away as possible from the site of potential crashes. Moreover, the evidence above suggests that while almost all parents know when to use infant restraints and most know when to move their children into forward-facing CRS, there is a gap in understanding about what the next stage should be and when it should occur. This is complicated by the emphasis on weight/mass limits provided by restraint manufacturers for forward-facing restraints and BPB. Thus there is a need to enhance parental risk perception and to draw attention to the other dimensions of booster and belt fit such as seated height, body width and leg length and to encourage better choices. A more active form of reaching parents may be needed to achieve this, with parents given advice specific to their circumstances.

Secondly, restraint design offers avenues to improve protection. BPB seats dedicated to protect larger children are urgently required. Design needs to address side impact protection as well as risks of the child slipping out below the belt (submarining). While currently harnesses are designed to meet the needs of these children, they are not always a valid option because some larger children are too wide to wear them without neck contact with the straps and they offer no protection against submarining or side impact. Better design of restraints for younger children is also needed so that they include head protection in side impacts and ways of minimising incorrect use. One suggestion has been to include a visual indicator for the user that shows correct instalment[55]. In addition, there is room for research on vehicle performance with restraints, methods of securing restraints to vehicles, as well as on the dynamics of crash effects on children using these restraints. As called for by others[13] this may involve development of more biofidelic child dummies as well as dummies of older children. It may also require more attention to vehicle-restraint compatibility.

Thirdly, changes to legislation can both guide parents as to what restraints to use as well as draw their attention to critical safety dimensions. In this respect, legislation could mandate the use of dedicated child restraints for children aged 10 years and under. While cost may appear to be a barrier to this sort of move, evidence cited above shows that most parents are already using CRS for children between 6 months and 2 years old (and these are usually more expensive than other types), and many use boosters beyond this. It is the discontinuation of use at ages earlier than advisable that appears to be at issue rather than the outlay to buy a restraint. There is also a clear need to emphasise, and indeed mandate, rear seating for all children under age 12 wherever possible. This is a zero-cost, no-technology avenue to reducing risk particularly for our primary-school aged children. These children are the least well protected by existing legislation and restraint design and the most likely to be placed at additional risk by front seating. Clear guidelines for parents would help reduce these risks. Such changes to legislation may be more successful in a climate where parents are both well-informed of the need for, and positively disposed towards, the changes. This may mean education interventions as an early step, supported by evidence of parental attitudes and opinions about issues of child occupant safety.

Finally, as well as research on crashes, we need to know more about the human side of the use of restraints and what factors influence the decisions parents make about protecting their children in cars. For instance, we know little about whether parents are ignorant of the risks of premature graduation to larger restraints or whether other considerations govern this behaviour. We also know very little about parents' knowledge of other child protection issues or what it is that is of most concern to them about protecting their children when travelling. Information of this sort would be a good first step to best practice in education and intervention efforts

References

1. Standards Australia CS-085. Australian New Zealand Standard: Child restraint systems for use in motor vehicles AS/NZS 1754:2004, Sydney, Standards Australia/Standards New Zealand, 2004.

2. Watson W., Ozanne-Smith J., and Lough J. Consumer-product injuries to children, Melbourne, MUARC, No. 168, 2000.

3. ATSB. Road deaths Australia: 2004 statistical summary, Canberra, Australian Transport Safety Bureau, June 2005, 2005.

4. ATSB. Serious injury due to road crashes, Canberra, Australian Transport Safety Bureau, November 2004, 2004.

5. NRMA, Road safety milestones. 2nd ed, Sydney, National Roads and Motorists' Association (NRMA); 1988.

6. RTA, Australian Road Rules Part 16 : Rules for persons travelling in or on vehicles, Roads and Traffic Authority, NSW. Available at: http://www.rta.nsw.gov.au/rulesregulations/downloads/p16.pdf, Accessed 2 August, 2005.

7. VicRoads, Infant restraints: babies up to 6 months, VicRoads. Available at: http://www.vicroads.vic.gov.au/VRNE/vrne5nav.nsf/LinkView/771D7D2E680A6AAACA256FEB00029F75206E045CFDF46299CA256FD300241C2D, Accessed 12th December, 2005.

8. Corneli H.M., Cook L.J., and Dean J.M., Adults and children in severe motor vehicle crashes: A matched-pairs study, Annals of Emergency Medicine, Vol.36, No. 4, 2000, pp.340-345.

9. Halman S.I., Chipman M., Parkin P.C., and Wright J.G., Are seat belts as effective in school age children as in adults? A prospective crash study, British Medical Journal, Vol.324, 2002, pp.1123-1125.

10. Tyroch A.H., Kaups K.L., Sue L.P., and O'Donnell-Nichol S., Pediatric restraint use in motor vehicles collisons, Archives of Surgery, Vol.135, No. 10, 2000, pp.1173-1176.

11. Durbin D.R., Elliot M.R., and Winston F.K., Belt-positioning booster seats and reduction in risk of injury among children in vehicle crashes, JAMA, Vol.289, No. 21, 2003, pp.2835-2840.

12. Winston F.K., Durbin D.R., Kallan M.J., and Moll E.K., The danger of premature graduation to seat belts for young children, Pediatrics, Vol.105, No. 6, 2000, pp.1179-1183.

13. Brown J., Bilston L.E., McCaskill M., and Henderson M. Identification of injury mechanisms for child occupants aged 2-8 in motor vehicle accidents: Final project report to MAA NSW, Sydney, Motor Accidents Authority NSW, June, 2005.

14. AAP, Car safety seats: a guide for parents, American Academy of Pediatrics. Available at: http://www.aap.org/healthtopics/carseatsafety.cfm, Accessed 27th September, 2005.

15. CDC, Stature for age percentiles, Centre for Disease Control and Prevention, USA. Available at: http://www.drhull.com/EncyMaster/growth_charts/boys_ht_2-20_yr.PDF, http://www.cdc.gov/nchs/data/nhanes/growthcharts/set2/chart%2008.pdf, Accessed 15 March 2005, 2005.

16. Brown J., Griffiths M., and Paine M. Effectiveness of child restraints: the Australian experience, Australian New Car Assessment (ANCAP), June, 2002.

17. NHTSA. The performance and use of child restraint systems, seatbelts, and air bags for children in passenger vehicles: Volume 1: Analysis, Washington, DC, NHTSA, September, No. NTSB/SS-96/01 Notation 6739, 1996.

18. NHTSA, Revised estimates of child restraints effectiveness, NHTSA. Available at: http://www-nrd.nhtsa.dot.gov/pdf/nrd-30/NCSA/RNotes/1996/childest.pdf, Accessed 25th September, 2005.

19. Arbogast K.B., Durbin D.R., Cornejo R.A., Kallan M., and Winston F.K., An evaluation of the effectivenessof forward facing child restraint systems, Accident Analysis & Prevention, Vol.36, No. 4, 2004, pp.585-589.

20. Lumley M., 'Child restraint tether straps-a simple method of increasing safety for children', Proceedings of the 2nd Child Occupant Protection Symposium, SAE, 1997.

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

22. Brown J., Bilston L.E., and McCaskill M., 'Injury implications of inappropriate use of adult seatbelt systems for children aged 2-8', Australasian Road Safety Research, Policing and Education Conference, Sydney, 2003.

23. Bilston L.E., Brown J., and Kelly P., Improved protection for children in forward facing restraints during sideimpacts, Traffic Injury Prevention, Vol.6, No., 2005, pp.135-146.

24. Johnston C., Rivara F.P., and Soderberg R., Children in car crashes: Analysis of data for injury and use of restraints, Pediatrics, Vol.93, No. 6, 1994, pp.960-965.

25. Kahane C.J. Lives saved by the Federal Motor Vehicle Safety Standards and other vehicle safety technologies, 1960-2002: Passenger cars and light trucks, Washington, DC, Evaluation Division, National Centre for Statistics and Analysis, NHTSA, October, 2004.

26. Royal Automobile Club Victoria (RACV), Booster Seat, RACV. Available at: http://motoring.racv.com.au/peacemind/safety/chidren/booster_seat.cfm, Accessed 6th October, 2005.

27. Huot M., Brown J., Kelly P., and Bilston L.E., Effectiveness of high back belt positioning booster seats in side impacts, Traffic Injury Prevention, Vol.6, No. 2, 2005, pp.147-155.

28. Child Injury Research and Engineering Network (CIREN), CIREN program report 2002, NHTSA. Available at: http://www-nrd.nhtsa.dot.gov/departments/nrd-50/ciren/NetworkReport/childrens.html, Accessed 30 September, 2005.

29. Gotshall C.S., Eichelberger M.R., Morrissey J.R., Better A.I., Reardon J., and Bents F., 'Injury patterns associated with child restraint misuse', 41st STAPP Car Crash Conference, SAE, 1997.

30. Eby D.W., and Kostyniuk L.P., A statewide analysis of child safety seat use and misuse in Michigan, Accident Analysis & Prevention, Vol.31, No. 5, 1999, pp.555-566.

31. Decina L.E., and Knoebel K.Y., Child safety seat misuse patterns in four states, Accident Analysis & Prevention, Vol.29, No. 1, 1997, pp.125-132.

32. Paine M., and Vertsonis H., 'Surveys of child restraint use in NSW', 17th International Technical Conferences on the Enhanced Safety of Vehicles, Amsterdam, 2001.

33. RACQ. Child restraint advice and fitting service in Queensland, Brisbane, Royal Automobile Club of Queensland, May, 1999.

34. RACV. Child restraint issues in Victoria, Melbourne, Royal Automobile Club Victoria, 2000.

35. Standards Australia, Child restraint standard tightened, SA. Available at: http://www.standards.org.au/cat.asp?catid=47&contentid=6&News=1, Accessed 2nd February, 2006.

36. Charlton J., Fildes B., Laemmle R., Smith S., and Douglas F., 'A preliminary evaluation of child restraint crash performance with three anchorage systems in a Holden Commodore', Road Safety Research, Policing and Education Conference, Perth, Western Australia, 2004.

37. Durbin D.R., Chen I.G., Smith R., Elliott M.R., and Winston F.K., Effects of seating position and appropriate restraint use on the risk of injury to children in motor vehicle crashes, Pediatrics, Vol.115, No. 3, 2005, pp.e305-309.

38. Durbin D.R., Kallan M., and Winston F.K., Trends in booster seat use among young children in crashes, Pediatrics, Vol.108, No. 6, 2005, pp.109-112.

39. Ebel B.E., Koepsell T.D., Bennett E.E., and Rivara F.P., Too small for a seatbelt: Predictors of booster seat use by child passengers, Pediatrics, Vol.111, No. 4, 2003, pp.323-327.

40. Eby D.W., Bingham C.R., Vivoda J.M., and Ragunathan T., Use of booster seats by Michigan children 4-8 years of age, Accident Analysis & Prevention, Vol.37, No. 6, 2005, pp.1153-1161.

41. Ramsey A., Simpson E., and Rivara F.P., Booster seat use and reasons for nonuse, Pediatrics, Vol.106, No. 2, 2000, pp.20-25.

42. Williams A.F., and Zador P., Injuries to children in automobiles in relation to seating location and restraint use, Accident Analysis & Prevention, Vol.9, No. 1, 1977, pp.69-76.

43. Starnes M., Child passenger fatalities and injuries, based on restraint use, vehicle type, seat position, and number of vehicles in the crash, Washington, D.C, National Highway Traffic Safety Administration, April, 2005.

44. Braver E.R., Whitfield R., and Ferguson S.A., Seating position and children's risk of dying in motor vehicle crashes, Injury Prevention, Vol.4, 1998, pp.181-187.

45. Glass R.J., Segui-Gomez M., and Graham J.D., Child passenger safety: decisions about seating location, airbag exposure, and restraint use., Risk Analysis, Vol.20, No. 4, 2000, pp.521-527.

46. Smith K.M., and Cummings P., Passenger seating position and the risk of passenger death or injury in traffic crashes, Accident Analysis & Prevention, Vol.36, 2004, pp.257-260.

47. Lennon A., 'Where do children sit in Australian passenger vehicles? Results of an observational study.' Australasian Road Safety Research, Policing and Education Conference, Wellington, NZ, 2005.

48. Ferguson S.A., Wells J.K., and Williams A.F., Child seating position and restraint use in three states, Injury Prevention, Vol.6, 2000, pp.24-28.

49. Segui-Gomez M., Glass R.J., and Graham J.D., Where children sit in motor vehicles: a comparision of selected European and American cities, Injury Prevention, Vol.4, 1998, pp.98-102.

50. FORS, Airbags and the risk of serious injury to children and small adults: Why it shouldn't happen in Australia, Federal Office of Road Safety. Available at: http://www.atsb.gov.au/road/pdf/mgraph13.pdf, Accessed 4 July, 2005.

51. NSW Parliament, Clause 46, Road Transport (Safety and Traffic Management) (Road Rules) Regulation 1999. 14 Dec 2005. Available at: http://www.legislation.nsw.gov.au/viewtop/inforce/subordleg+623+1999+FIRST+0+N/?autoquery=(FragmentSGML%3D((%22part%2016%22)))%20AND%20((RecordType%3D%22ACTFRAG%22%20and%20Repealed%3D%22N%22)%20OR%20(RecordType%3D%22SRFRAG%22%20and%20Repealed%3D%22N%22))&dq=Document%20Types%3D%22Acts,%20Regs%22,%20Exact%20Phrase%3D%22part%2016%22,%20Search%20In%3D%22Text%22&fullquery=(((%22part%2016%22))), Accessed 31 January, 2006.

52. Will K.E., and Geller E.S., Increasing the safety of children's vehicle travel: from effective risk communication to behavior change, Journal of Safety Research, Vol.35, 2004, pp.263-274.

53. Lundgren R., and McMakin A., Risk communication. 3rd ed, Columbus, Batelle Press, 2004.

54. Simpson E.M., Moll E.K., Kassam-Adams N., Miller G.J., and Winston F.K., Barriers to booster seat use and strategies to increase their use, Pediatrics, Vol.110, No. 4, 2002, pp.729-736.

55. Griffiths M., Brown J., and Paine M., Safety innovations for Australian child restraints, Melbourne, RACV, June, 2004.