Improving child restraint design – upcoming changes in restraint standards and remaining challenges

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Abstract

The Australian/New Zealand child restraint Standard, AS/NZS 1754 is recognised as one of the most rigorous worldwide, and there are major changes being currently being introduced to accommodate larger and older children in child restraints. This paper outlines these changes and explains the rationale behind the changes. How these relate to proposed legislation changes is also presented. Key changes include the provision of booster seats for children up to 8-10 years of age, and weight up to 36kg, increased from 26kg in the current Standard; increases in weight limits for forward-facing seats; additional side impact testing requirements; and the phasing out of booster cushions. Future challenges for the Standard such as specialist anchorage systems (e.g. ISOFIX/LATCH) and improved labelling and ease of use requirements will also be discussed.

Introduction

The performance of dedicated child restraints in Australia is governed by two standards, AZ/NZS 1754 and its sister AS/NZS 3629.1. This is a mandatory standard in Australia, while New Zealand accepts restraints tested to alternative international standards in addition to these. This paper reviews the current Standard, outlines the areas of the current Standard where enhancements are possible, and presents a number of recently proposed changes together with the principles behind their development Future challenges and remaining issues are also outlined.

Brief History[1]

The first Australian standard for child restraints, AS E46, was issued in 1970. The development of this Standard directly addressed inadequacies of devices that were being used to carry children in cars at that time. The key requirements of this standard were related to structural integrity and labeling. Restraint types for three size ranges of children were included. These were infant carriers for children from 0-9kg; chair/harnesses for children from 9-18kg and harnesses for children 18-36kg. This first version of the standard also required child restraints to be secured at three attachment points. AS E46 was extensively rewritten and released in 1975 as AS1754 (1975). This revision added dynamic performance requirements to improve the level of protection being provided in crashes, and extended the restraint type designations covered by the standard from 3 to 6 types. These basically included infant restraints, forward facing and rear ward facing child restraints and harnesses. There was no provision for booster seats.

Initially, restraint type designations were devised on the basis of how children were being carried in cars. Infants from birth to approximately 6 to 9 months of age were normally carried in a recumbent or semi-recumbent positions; over 6 to 9 months until 3 ½ to 4 years it was thought that children could be carried in a seating position if suitably supported, but were unlikely to be able to sit still for long if left alone; and over 3 ½ to 4 years children could be carried on the vehicle seat without support. Weight ranges corresponding to these age ranges were used to provide guidelines for restraint designers. Type designations therefore included mass limits and age based guidelines. In latter versions of the Standard age based guidelines were dropped from the type designations.

Booster seats were introduced into the standard in 1978. Their primary purpose at this time was as a device that would allow small children to see out of the vehicle window. Overtime, their potential benefit in providing a transitional form of restraint between forward facing child restraints and adult seat belts became clear. Initial definitions for this type of restraint were for carrying children between 9 and 38kg. There have been a number of changes to this range in subsequent versions of the Standard. Currently the range is 14 to 26kg.

[1] The history of child restraint development in Australia is reviewed by Lang et al (2002)

The inclusion of the requirement for three point anchorage in the Australian Standard since its inception has particular historical importance. This requirement, together with its matching Australian design rules (ADR34, in 1974), ensured the provision of standardized tether anchorage locations in sedans, and is the basis for the unique long standing widespread use of top tethers in Australia.

Key Features of the Current Standard

The current Australian and New Zealand Standard has provision for several classes of restraints. These include rear facing infant restraints (Type A), forward-facing toddler restraints (Type B), rear facing toddler restraints (Type D), seat belt converters (Type C), and booster seats (Type E). Restraints may combine these types, converting from one type to another. Currently, the design requirements for these seats are based largely on weight ranges: 0-9 or 12kg for infant restraints, 8-18kg for toddler restraints, and 14-26kg for booster seats.

Key design features of restraints specified by AS/NZS 1754 include the requirement for top tether straps (Types A, B, D, and boosters over 2kg) to control forward excursion of the restraint, a single point of harness adjustment (Types A,B,D) to simplify harness tightening, double crotch straps (Types A,B,D) to prevent loading of the genital region and submarining. An ancillary benefit of the top tether requirement was the almost universal installation of child restraints in the rear seat. Requirements for booster seats under the standard are much less prescriptive.

Dynamic testing of restraints under the current AS/NZS 1754 include frontal, side, rear and inverted protocols. Table 1 below outlines which tests are required for which restraints. The frontal test is conducted at 49km/hr, the side and rear impact tests at 32km/hr and the inverted test at 16km/hr. The side impact test is conducted either with or without a door structure – the latter allows for determining whether the head of the dummy is adequately contained within the restraint.

Restraint Type	Frontal	Side Impact with door	Side Impact without door	Rear	Inverted
Type A Infant restraints	9mo or 18mo dummy	9mo or18mo dummy	TARU ejection dummy	TARU ejection and 9mo or 18mo dummy	TARU ejection dummy
Type B toddler restraints	9mo dummy and 6yo dummy	9mo dummy	9 mo dummy		
Type C and E converters	3yo and 10yo dummy		3yo dummy		
Type D Toddler restraints	9mo dummy and 6yo dummy	9mo dummy	9 mo dummy	6 yo dummy	
Type E booster seats	3yo, 6yo, 10yo dummy	3yo dummy (not cushions)	3 yo dummy	6 yo dummy with spacer	

Table 1: Current Dynamic Test Requirements

Currently, restraints must include instructions on restraint use in the packaging, a prominent label to warn parents not to leave child unattended in the restraint, and some warnings on use of the restraint. The restraint itself must be marked with the weight range for which the restraint is suitable, illustrated instructions for use, including harness adjustment, and situations in which the restraint must not be used.

Scope for improvement of the current standard

Despite its reputation for being one of the most rigorous child restraint standards internationally,

there are a number of areas where enhancements to the current requirements would significantly improve the level of protection provided to Australian children in crashes.

1. No support for dedicated lower anchorage systems for child restraints (ISOFIX/LATCH). The European union countries have adopted a standard for rigid attachment of child restraints into vehicles, ISOFIX, using a pair of U-shaped bars fixed into the join between the rear seat cushion and seat back. Restraints have latches that clip rigidly onto these bars and firmly attach the restraint to the car, not requiring the use of a seat belt to secure the restraint. North America have adopted an alternative flexible system, which uses the same anchorage points in the vehicle, but secures the restraint using lengths of seat belt webbing, either attached to either side of the restraint, or looping through the back like a lap-only belt. These must be used with a top-tether, hence the name Lower Anchors and Tethers for Child restraints (LATCH). The original intention of these systems was to simplify child restraint installation and reduce installation misuse due to incorrect seat belt routing or excessive slack. Local research has shown that ISOFIX in particular has the potential to improve performance in side impact crashes (Kelly et al, 1995; Brown et al, 1997; Bilston et al, 2004; Brown et al 2004; Charlton et al, 2004; Bilston et al, 2005). Neither system is currently supported in AS/NZS 1754,

2. Limited control over internal restraint geometry to match child anthropometry. Currently, there are requirements for restraints to "accommodate" specific dummies, which ensures that restraints are usually wide enough to accommodate the target age ranges, and there are controls over harness slot heights to provide suitable harness positioning over the shoulders. However, there is no requirement for restraint back height to ensure that suitable head protection in rear impacts is available, and indeed there is evidence that current restraint heights may not be sufficient for the target age ranges, encouraging premature graduation from one restraint type to another (Bilston et al, 2007). This has been noted to be a particular problem for polystyrene booster seats and some older "compact" convertible rear/forward-facing seats.

3. Overlap in weight ranges between forward-facing toddler restraint and booster seats. There is 4kg overlap in the weight ranges for Type B (8-18kg) and Type E (14-26kg), which has had the unintended effect of encouraging premature graduation to booster seats by children as young as 2 years old, as soon as they reach 14kg (Edwards et al, 2006; Bilston et al, 2006). It has been suggested that recommending restraint use by age would be a more effective method of matching restraints to children than the current weight-based classes (Anderson et al, 2007).

4. Upper weight limit for boosters. The current upper weight limit for boosters specified in the Standard is 26kg. This equates approximately to the 50th percentile for 8 year olds, but many children reach 26kg well before turning 8. This limit was originally designed to limit the overall boosted height of the child to reduce the risk of head strikes on the roof. However, there is now substantial evidence that acceptable adult belt fit is not achieved for children until 11-13 years of age (approximately 145cm in height), and this limit leaves children over 26kg without a suitable restraint.

5. Side impact tests are only performed using the smallest relevant dummy, not the largest relevant dummy. For example, forward-facing restraints (Type B) are currently only tested with the 9 month dummy in side impact with the door. Recent studies have shown that this does not ensure that head contact with the door is prevented for the 3 year old dummy in these restraints. Requiring restraints to be tested with a dummy at the upper end of the recommended size range would address this issue.

6. Booster cushions are exempt from side impact test with the door. Not surprisingly, booster cushions (i.e. booster seats without any side structures) do not provide lateral protection or postural support for children.

7. Booster seat performance tests do not relate to how well these restraints position the belt, either statically or dynamically. The primary benefit of a booster seat, when used with a 3-point belt, is to position the sash belt over the centre of the shoulder and across the bony parts of the torso, and

the lap belt low across the upper thighs, thus preventing seat-belt related abdominal, lumbar spine and cervical spine injuries. There are no requirements in the Standard that address the ability of a booster to do this. Recent results from the Australian Child Restraint Evaluation Program (CREP), demonstrated that many currently approved booster seats do not perform well in this regard, despite meeting the current standard (Brown et al, 2007) and this is consistent with a couple of recent high-profile cases in which serious abdominal injuries occurred in children using booster seats locally, and also reported overseas (Jermakian et al, 2007).

8. Scope for improved anti-misuse measures. Field studies have indicated that child restraint misuse is a common problem. While some forms of misuse tend not to have great consequences for injury outcome, some forms of misuse can substantially reduce the protective capacity of the restraints. These include errors in restraint installation such as tether or seat belts being excessively slack or not used, and errors in placing the child in the restraint, such as slack or unbuckled harnesses etc. In addition to alternative methods of securing restraints such as ISOFIX or LATCH, there is scope to strengthen the already existing anti misuse features (such as the single point of harness adjustment) by making harness adjustment easier, providing indicators of harness slack or non-use, and more clearly defining belt routing, particularly in convertible restraints where there may be more than one belt route. More visible labels warning against common high risk types of misuse, and provision of information in pictogram form which may improve comprehension for non-English speakers are also desirable.

9. Confusion over which restraints are suitable for children of different ages. This was partially addressed in point 4 above. The current focus on weight ranges for restraints, while essential to provide engineering design specifications, is confusing for families. Recent research has shown that many parents do not understand what restraint their child should be using, and in many cases do not know their child's weight and height. The addition of recommended age ranges, plus closer specification of the geometry of the restraints (see #2 above) to ensure that the majority of children who are within the recommended age ranges actually fit in the restraints could clarify this for parents. This also links into recently proposed changes to the Australian Road Rules, which suggests that restraint use by children be mandated by age.

Proposed Changes

Some of the issues outlined in the previous section have been begun to be addressed in a recent draft edition of AS/NZS. Key changes in this draft include:

1. New restraint class of boosters to accommodate older children. The most substantial change in the draft edition is the development of a new class of booster seats (Type F) to accommodate children from 4-10 years (18-36kg). Key aspects of this new restraint class include more rigorous controls on seat belt positioning (including dynamic position) to prevent submarining and ensure the seat belt fits snugly across child's torso; external geometry requirements to ensure that the overall boosted height of the child does not exceed that of an average adult (to limit the change of head strikes on the roof), control over the external geometry of the restraint to make it easier to fit into the rear seat of cars alongside other restraints, and provide access to the seat belt buckle; and a requirement for lateral postural support of the torso.

2. Geometry requirements to ensure adequate height and harness slot locations for target age ranges. All restraint types now have to meet minimum internal seat back height requirements to ensure that toddler restraints will provide rear head support for children up to their 4th birthday, and booster seats for children up to the 9th birthday. For toddler restraints, there are slightly revised shoulder slot locations to match.

3. Changed weight ranges to reduced premature graduation to boosters. The weight ranges for toddler restraints (Types B,D) are proposed to change to 8-20kg and booster seats (Types E,D) will commence at 18kg, to reduce the number of children who are prematurely graduating to booster seats in the 14-18kg range.

4. Addition of age ranges to type designations and labels. Approximate age ranges have been added to restraint labels, packaging and instructions to simplify restraint selection for parents.

5. Belt path colour coding. To make it clearer where the seat belt should go in restraints, and to clarify which path to use when, colour-code belt paths for different restraint types have been introduced. This means that a convertible rear/forward-facing restraint will have the belt path for rear-facing mode marked in blue, and the path for forward-facing mode will be marked in orange. Booster seat belt paths will be marked in yellow.

6. Addition of bigger dummies in side impact test. Toddler restraints (Type B,D) will now be tested in side impact with a door using a 3 year old dummy boosted slightly to match a 4 year old child. The new booster seats (Type F) will be tested with both the 3 year old dummy and the 10 year old dummy.

7. Removal of booster cushions. The removal of the exemption of booster cushions from the side impact test will effectively mean they cannot comply with the new standard.

8. Controls on tether location on restraint. There are new requirements for whether the tether attaches to the restraint, to make sure it is attached on the upper back of the restraint, as locations lower down reduce tether effectiveness.

9. Controls on seat belt length needed to install restraint. There have been reports of problems installing some restraints in vehicles due to inadequate seat belt length. A new procedure has been developed that will ensure that all restraints should be able to be installed in a vehicle with the minimum legal seat belt length.

Implications for Legislation and Restraint Guidelines

A number of the specific items outlined above will facilitate the return of age-based restraint recommendations, and even legislation. The introduction of age ranges on the packaging and labeling of restraints (#4 above) will provide parents with clearer guidelines about when to use specific restraints for their children. The National Transport Commission recently released a draft regulatory impact statement and draft model legislation that would require the use of a rearward-facing infant seat until at least 6 months, a forward or rearward facing safety seat with inbuilt harness until 4 years, and a booster seat until 7 years of age. That report also foreshadowed the desirability of raising the age for safety seat use to 5 years and requiring booster seats up to 145cm in height once suitable restraints are available. For such age-based child restraint legislation to be practical, restraints to suit all children within the regulated ages must be widely available, and clear messages about which restraint to use for children of specific ages must be provided. The specification of restraint geometry in the revised standard (#2 above) has been done with the potential legislative changes in mind. The newly specified restraint geometry should accommodate children up to the 95th percentile in seated height to use a Type B or D child restraint up to their 5th birthday, and a booster seat up to their 9th birthday. Increases in upper weight limits (#3) will also assist in accommodating a wider range of children in restraints, although a proportion of children on their 5th birthday will exceed the 20kg weight limit on forward-facing restraints. Importantly, the introduction of the new class of booster seats for older children will allow changes to legislation to require booster use beyond the 7th birthday once these restraints become more widely available.

Future Challenges

If finally accepted, these changes will improve the protection afforded by Australian child restraints, and address many of the issues outlined above. However, there are a number of remaining issues not addressed by this new draft Standard. These include:

1. ISOFIX/LATCH. This issue remains outstanding. Part of the problem with this issue has been that the child restraint standard must match an Australian Design Rule to specify the in-vehicle

anchorage points, and there is a need to ensure that the adoption of any version of this system does not result in a degradation in the level of protection currently provided. Issues being worked through include the desire to harmonise vehicle standards internationally; the location and number of these in-vehicle anchorage (two pairs or three in the rear seat), the strength of these anchorages and the implications for tether anchorage locations; and choice of restraint attachment type (rigid or flexible). There have also been a number of reports from other countries where these systems have been adopted that indicate that rather than reducing misuse, some versions of these systems are increasing misuse problems. The challenge to the Australian Standard is to incorporate the features of ISOFIX/LATCH that will improve the side impact protection offered by Australian restraints without degrading current levels of protection in other impact types, and ensuring the propensity for misuse is minimized.

2. Type C and Type E converters. These are add-on child harnesses that provide dual shoulder restraint (Type C) and other forms of belt positioning device (Type E). Currently requirements for these devices are ill-defined and have limited performance criteria. For example, there is no requirement that either of these devices keep the lap belt from riding up into the abdomen or prevent submarining. Better performance requirements for these devices are required.

3. Integrated child restraints in vehicles. A number of overseas vehicle designs incorporate integrated child restraints, most commonly integrated booster seats. These are not covered under either the current child restraint standard or an Australian Design Rule. The status of these devices needs to be clarified, and if possible, performance requirements for these restraints be developed.

4. Enhancing requirements related to reducing the propensity for misuse. While the current draft is starting to address this important issue with belt path colour-coding and improved labelling, there is scope for further improvement, as noted above.

Conclusions

The draft revised AS/NZS includes some substantial changes, particularly the development of booster seats for larger children (Type F). It also tightens the requirements for side impact performance and restraint geometry. Performance requirements for booster seats have been tightened significantly also. The changes also clear the path for age-based restraint selection instead of weight-based recommendations. This ties into changes to the Australian Road Rules which are currently being finalized, which will mandate restraint use by age. However, there is still work to be done to incorporate dedicated attachment systems for restraints and reduce the propensity for restraint misuse.

Please note that this paper outlines changes that are included in a DRAFT edition of AS/NZS 1754, and it may change prior to issuing of the revised Standard.

Acknowledgements

The authors would like to thank the other members of CS085 working group for discussions about various aspects of the Standard – past, present and future. Lynne Bilston is supported by an NHMRC Senior research fellowship, and Julie Brown is supported by a grant from the Australian Research Council and partner funding from the Motor Accidents Authority of NSW and the Roads and Traffic Authority of NSW.

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