Best Practice Guidelines for the Safe Restraint of Children Travelling in Motor Vehicles

TECHNICAL REPORT

Kidsafe
Child Accident Prevention Foundation of Australia

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1 Contributors

These guidelines were jointly developed under the auspices of Kidsafe Australia and Neuroscience Research Australia. An expert working committee (the Technical Working Group), chaired by Professor Lynne Bilston was formed in October 2018 to guide, advise and author an updated edition of the Best Practice Guidelines on the Safe Restraint of Children Travelling in Motor Vehicles, first developed in 2013.

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2 List of abbreviations and acronyms

ATD	anthropomorphic test dummy
AIS	Abbreviated Injury Scale
AS/NZS	Australian Standard/New Zealand Standard
CDC	Centers for Disease Control
CRS	Child Restraint System
FARS	Fatal Accident Reporting System
FFCR	Forward Facing Child Restraint
HBB	High Back Booster
ISS	Injury Severity Score
MAIS	Maximum Abbreviated Injury Scale
MVC	Motor Vehicle Crash
NASS	National Automotive Sampling System
NHTSA	National Highway Traffic Safety Administration
OR	Odds Ratio
RFCR	rear facing child restraint
RR	relative risk

3 Introduction

3.1 Overview of literature review process

The overall review process was that of a literature review conducted systematically to address the research question of **"What constitutes current best practice in the use and installation of restraints for the prevention of serious injuries and fatalities to children as passengers of motor vehicles in the event of a crash?"**

The aim of the review was to make specific recommendations about each type of restraint used by children in order that those people (and organisations) who provide advice to parents and carers of children have clear evidence-based advice on the use of restraints for children from 0-16 years of age.

The literature search and assessment involved the following steps (which are described in detail in the sub-sections below).

1. We conducted a search for all articles related to the effectiveness of occupant restraints (using common keywords and synonyms) in protecting children in the event of a motor vehicle crash.
2. Articles examined were limited to those available in English and which examined outcomes relating to the prevention of injuries to the child occupant. Educational program effectiveness studies were excluded.
3. As advice to parents and carers concerning child restraint use and installation needs to be quite specific (covering the fit between the child and the restraint, the transition from one restraint to the next as the child grows, and issues relating to the use of restraints and their installation) a framework for the classification of the evidence was developed in order to group the articles by the specific topic they covered. Many studies addressed multiple areas and the technical group advised that this approach would capture all available studies without repeating the same search strategy for each specific sub-topic and without missing articles by selecting too specific search terms (e.g. 'Restraint installation' a specific topic within the broader topic of child restraints, does not pull up studies that actually cover evidence relating to the installation of restraints as the focus of some articles may have been on airbags and forward facing restraints and 'restraint installation' may not be a key word used by the authors, while 'child restraint' may).
4. The inclusion and exclusion criteria (identified below) were applied to each article identified through the search by a review of the abstract or if in doubt, by a review of the full article.
5. Those included were reviewed and a summary table was developed for each, covering
    a. the type of study,
    b. country in which it was conducted,
    c. level of evidence it provided (NHMRC, 2009)
    d. details of the research methodology,
    e. key findings,
    f. comments and limitations, including comments on bias where relevant.
6. The summary of each article was copied under the topic heading in the framework to which it applied. Many articles provided findings relevant to several topics, so the summary for these articles was included as many times as relevant
7. Evidence statements for each topic were developed based on the findings from set of studies for that topic and the relevant recommendation regarding best practice in this area was developed or refined, based on the findings. The summary tables were used to draw together the number of studies providing evidence, the strength and direction of the findings, and the overall level of evidence.
8. Where there were no or very few robust studies which addressed specific key elements about child restraint use and installation choices, the technical group have identified consensus-based recommendations to provide the suggested best practice based on their collective knowledge of the research in this field.

3.2 Topics and questions

To guide the development of the framework and the review of the articles identified, a list of topics and questions were developed, as follows:

- What are the safest **types of child restraints** (forward facing, rear facing, booster seats and adult seat belts) for different ages/sizes of children?
- What evidence is there for the safety of different **seating positions** for children within the vehicle, and how is this influenced by the presence of airbags
- What evidence is there regarding the injury outcomes associated with **incorrect installation of a child restraint** in a vehicle or **incorrect securing of a child within a restraint** for children travelling in motor vehicles?
- How should we assess whether a child is ready to **transition to the next stage of restraint**?
- How do we provide optimal passenger safety for children in **non-typical vehicles** including taxis, public transport, troop carriers and non-passenger vehicles, when using "Dickie seats" (extra seats installed after vehicle manufacture), and integrated child restraint systems?
- What evidence is there on the **effectiveness of common types of accessories** such as child safety harnesses, belt positioners, buckle covers, padding, pillows and cushions, belt tensioners and extenders?

These research questions were developed to address the major decision points for parents and carers concerning the safe transport of children in cars, and that would address the key risk factors for injury to children as occupants of motor vehicles involved in crashes. From these questions, the framework for the review was developed, as shown below:

Appropriate Restraint Use

Rear Facing Child restraints
Forward facing child restraints
Booster seats
Adult seat belts
Special vehicles and other situations
Child restraint accessories and other special devices

Seating Position

General seating position recommendations
Child restraint position
Seating children and using child restraints in airbag-equipped seating positions

Correct Use of Child Restraints

Restraint installation
Dedicated child restraint anchorage-equipped restraints
Correctly securing the child in the restraint
Restraint/vehicle compatibility
Use of restraint Fitting Stations

3.3 Type of review conducted

As described above, the search and review of the literature was one review conducted systematically. As noted above, the approach differs from a traditional systematic review because many studies in this field cover multiple topics. Searches using keywords focused on a specific question often fail to identify all relevant studies for that particular question as these more specific keywords are often not indexed or noted as a keyword by the authors. To address this, we conducted a broad literature search using the keywords and strategies below to identify as many studies related to child passenger safety as possible, and then each study was examined to see whether it applied to a specific topic, as well as being assessed for quality. The following parameters of the review were used.

3.4 Search strategy

The literature was searched using the following methods: a search of electronic databases PubMed and the Australian Transport Research Index (ATRI) and Cochrane reviews using key terms relating to the research questions until no new articles emerged. Those selected were cross-checked against major literature reviews, undertaken by some members of the technical writing group and other narrative reviews in that were identified in the literature search. Specifically, the reference lists of the following studies:

- Asbridge, M., Ogilvie, R., Wilson, M., Hayden, J., 2018. The impact of booster seat use on child injury and mortality: Systematic review and meta-analysis of observational studies of booster seat effectiveness. Accid Anal Prev. 119, 50-57.
- Ishikawa, T., Oudie, E., Desapriya, E., Turcotte, K., Pike, I., 2014. A systematic review of community interventions to improve Aboriginal child passenger safety. Am J Public Health. 104 Suppl 3, e1-8.
- Brown, J., McCaskill, M.E., Henderson, M. and Bilston, L.E. (2006), Serious injury is associated with suboptimal restraint use in child motor vehicle occupants. Journal of Paediatrics and Child Health, 42: 345-349. doi:10.1111/j.1440-1754.2006.00870.x

References from these reviews that did not come up in the main databases were also examined. No formal date cut points were set for the evidence search, but many older studies were excluded because the restraints being studied are not available in the current Australian context (see below). Research into child restraints tends not to pre-date the 1980s and all articles that meet the inclusion criteria in terms of study methodology and relevant content have been included for each of the databases searched. The relevance of the restraint types studied included restraints currently legal to be used in Australia, has been assessed on a case-by-case basis. Due to that nature of the review, which had multiple research questions, no single search was done resulting in a defined number of articles. It was a free-text search using each of the terms identified in the TR search strategy in various combinations, until no new relevant articles emerged. We acknowledge that this does not make it possible to repeat the exact same search, but we are confident that the approach has identified all relevant articles for the review, from these three databases.

Members of the technical drafting group also provided a small number of additional references during drafting that were not identified in the initial searches. These were assessed using the same criteria as all other studies. In practice, none of these met our inclusion criteria. One or two useful background references for describing basic restraint physics for the introduction were suggested, but these are not part of the evidence statements.

3.5 Keywords

For the 2013 version of these guidelines the keywords below were searched in the following combinations:

Child/paediatric/pediatric/anthropometry/shoulder height/size/age

WITH

Child restraint/safety seat/booster seat/adult seat belt/seat belt/forward facing/rear facing/rearward facing/ISOFIX/top tether/LATCH/belt positioning

WITH

Effectiveness/injury/risk

For this 2019 update, the terms used were limited to the terms below to ensure the maximum number of potentially eligible articles were identified, and to avoid research that was not relevant.

Child

WITH

Child restraint/safety seat/booster seat/seat belt/ISOFIX/LATCH

WITH

Effectiveness/injury/risk

Variants of these terms were also tried (e.g. plurals)

Variants of these terms were also tried (e.g. plurals, different spelling etc)

Searches were not limited by specific population subgroups, in order to maximize coverage. Studies applying to specific subgroups only, such as Aboriginal and Torres Strait Islanders, culturally and linguistically diverse people, and the socioeconomically disadvantaged were identified in the article review stage.

For example, Pubmed searches of index terms starting with “child restraint” resulted in following search, and were then limited to the relevant dates, and combined with the other terms noted above:

("child restraint"[All Fields] OR "child restraint designs"[All Fields] OR "child restraint device"[All Fields] OR "child restraint device use"[All Fields] OR "child restraint devices"[All Fields] OR "child restraint effectiveness"[All Fields] OR "child restraint installation"[All Fields] OR "child restraint installations"[All Fields] OR "child restraint law"[All Fields] OR "child restraint law exemptions"[All Fields] OR "child restraint laws"[All Fields] OR "child restraint legislation"[All Fields] OR "child restraint misuse"[All Fields] OR "child restraint practices"[All Fields] OR "child restraint safety"[All Fields] OR "child restraint seat"[All Fields] OR "child restraint seat use"[All Fields] OR "child restraint seats"[All Fields] OR "child restraint system"[All Fields] OR "child restraint system crs"[All Fields] OR "child restraint system harness design"[All Fields] OR "child restraint system misuse"[All Fields] OR "child restraint system use"[All Fields] OR "child restraint systems"[All Fields] OR "child restraint systems/adverse effects"[All Fields] OR "child restraint systems/classification"[All Fields] OR "child restraint systems/economics"[All Fields] OR "child restraint systems/microbiology"[All Fields] OR "child restraint systems/parasitology"[All Fields] OR "child restraint systems/standards"[All Fields] OR "child restraint systems/statistics and numerical data"[All Fields] OR "child restraint systems/supply and distribution"[All Fields] OR "child restraint systems/trends"[All Fields] OR "child restraint systems/utilization"[All Fields] OR "child restraint systems in automobiles"[All Fields] OR "child restraint systems utilization"[All Fields] OR "child restraint systems, child passenger safety"[All Fields] OR "child restraint usage"[All Fields] OR "child restraint use"[All Fields] OR "child restraint use laws"[All Fields] OR "child restraint use legislation"[All Fields] OR "child restraints"[All Fields])

Similarly, Pubmed searches of index terms starting with “booster seat” resulted in following search being executed:

("booster seat"[All Fields] OR "booster seat aged children"[All Fields] OR "booster seat design"[All Fields] OR "booster seat education"[All Fields] OR "booster seat effectiveness"[All Fields] OR "booster seat law"[All Fields] OR "booster seat laws"[All Fields] OR "booster seat legislation"[All Fields] OR "booster seat misuse"[All Fields] OR "booster seat non use"[All Fields] OR "booster seat questionnaire"[All Fields] OR "booster seat usage"[All Fields] OR "booster seat use"[All Fields] OR "booster seated"[All Fields] OR "booster seated children"[All Fields] OR "booster seats"[All Fields])

NOT (("child restraint"[All Fields] OR "child restraint designs"[All Fields] OR "child restraint device"[All Fields] OR "child restraint device use"[All Fields] OR "child restraint devices"[All Fields] OR "child restraint effectiveness"[All Fields] OR "child restraint installation"[All Fields] OR "child restraint installations"[All Fields] OR "child restraint law"[All Fields] OR "child restraint law exemptions"[All Fields] OR "child restraint laws"[All Fields] OR "child restraint legislation"[All Fields] OR "child restraint misuse"[All Fields] OR "child restraint practices"[All Fields] OR "child restraint safety"[All Fields] OR "child restraint seat"[All Fields] OR "child restraint seat use"[All Fields] OR "child restraint seats"[All Fields] OR "child restraint system"[All Fields] OR "child restraint system crs"[All Fields] OR "child restraint system harness design"[All Fields] OR "child restraint system misuse"[All Fields] OR "child restraint system use"[All Fields] OR "child restraint systems"[All Fields] OR "child restraint systems/adverse effects"[All Fields] OR "child restraint systems/classification"[All Fields] OR "child restraint systems/economics"[All Fields] OR "child restraint systems/microbiology"[All Fields] OR "child restraint systems/parasitology"[All Fields] OR "child restraint systems/standards"[All Fields] OR "child restraint systems/statistics and numerical data"[All Fields] OR "child restraint systems/supply and distribution"[All Fields] OR "child restraint systems/trends"[All Fields] OR "child restraint systems/utilization"[All Fields] OR "child restraint systems in automobiles"[All Fields] OR "child restraint systems utilization"[All Fields] OR "child restraint systems, child passenger safety"[All Fields] OR "child restraint usage"[All Fields] OR "child restraint use"[All Fields] OR "child restraint use laws"[All Fields] OR "child restraint use legislation"[All Fields] OR "child restraints"[All Fields])

Similar index terms and keyword searches were conducted for the ATRI database, using the same key words above.

Note that we searched both databases using each of the terms (single and plural) in all combinations until no new relevant articles appeared.

3.6 Databases

The electronic databases most relevant to this topic, the Australian context and yielding peer-reviewed publications that were search were PubMed and ATRI (Australian Transport Index) as well as the Cochrane database of systematic reviews. These databases were chosen for consistency with the 2013 edition of the Guidelines, and for comprehensive coverage of the national and international injury, road safety and transport literature. PubMed offers comprehensive coverage of the peer reviewed medical and epidemiological literature, while ATRI covers both Australian and international transport literature, including both domestic and international conferences and non-medical outlets not covered in Pubmed.

Hand searching of reference lists of included articles was conducted to check for any articles not captured by the search terms above and not referenced in the searched databases. None were found that met the inclusion criteria.

3.7 Inclusion and exclusion criteria

Peer reviewed studies that were included were those where:

- The outcomes measured were fatal or non-fatal injuries to children (0-16 years of age) as a result of being a passenger in a motor vehicle crash
- The impact on child injury outcomes (or the likelihood of child injury outcomes) was assessed for the restraint types in question or their use, and factors that were found to influence these outcomes

Or

- Controlled laboratory studies which simulated motor vehicle crashes and the protective effect of different types of restraints and different ways in which restraints are used or misused for the purposes of testing the potential for injury to children

Excluded were:

- Individual case reports
- Studies where none of the included restraint types were applicable to the Australian context
- Articles, reports or conference papers that were not peer-reviewed
- Studies focused on educational programs to encourage restraint use
- Relevant systematic and Cochrane reviews were also considered.

3.8 Language of publication

Articles included were limited to those available in English.

3.9 Search timeframe

For the 2013 guidelines, all studies published up until the end of April 2013, that met the above criteria (using the terms for 2013) were included. No earliest publication date for scientific articles was formally set, but child restraints did not become common until the mid 1970s, and early evidence about child restraints is of limited applicability in the current time because designs have changed markedly. Evidence for seat belts from earlier times remains relevant. Applicability of studies and specific restraints were assessed individually. See also section 3.11 for a discussion of limitations of evidence relating to studies not similar to current Australian restraint designs.

For this update, the relevant search terms (noted above) for all studies published from 1 January 2012 through 30 April 2019 when the literature search was also completed. The year 2011 and the first four months of 2012 were included in both reviews to capture publications in this period that might not yet have been on the relevant search engines when the earlier review was conducted.

3.10 Methods of assessment of evidence

For each topic under the framework identified in section 3.2 above, the included articles were reviewed for the combined level of evidence they offered for each of five elements:

- Evidence base - based on the number of studies and their level of evidence
- Consistency - the extent to which the findings were in the same direction
- Public health impact - the change in risk of serious or fatal injury associated with the factor being examined
- Generalisability - the extent to which the findings from the collection of studies could be generalised to other population groups
- Applicability – the extent to which the study was applicable to the current Australian context

For each topic, relevant articles were summarised in a table covering the study type, level of evidence, including an assessment of bias, country in which the study was conducted, methodology, major findings, and comments on the limitations of the study or other relevant factors to the context of the study. NHMRC levels of evidence were assigned to each study in these tables. Where there were questions over the quality of ratings, the methodological advisor provided advice and clarification. A formal assessment of bias was not conducted, but study design and analysis factors that suggest selection bias in populations studied (e.g. only studying hospitalized children for example makes a study biased towards more severe injuries), confounding, missing information and detection bias are noted in the comments section where relevant. In the case of laboratory crash testing studies, bias is largely associated with the representativeness of the chosen test protocol and of the crash test dummy used. These issues are also considered in the generalizability assessment.

Evidence Base

Excellent	One or more level I studies with a low risk of bias or several level II studies with a low risk of bias
Good	One or two level II studies with a low risk of bias or a SR/several (=2 or more) level III studies with a low risk of bias
Satisfactory	One or two level III studies with a low risk of bias, or level I or II studies with a moderate risk of bias
Poor	Level IV studies, or level I to III studies/SRs with a high risk of bias

Consistency

Excellent	All studies consistent
Good	Most studies consistent and inconsistency may be explained
Satisfactory	Some inconsistency reflecting genuine uncertainty around clinical question
Poor	Evidence is inconsistent
Not applicable	Only one study

Public Health Impact

If odds ratios or relative risks were reported, the following were applied if the majority of the reported findings fell into these ranges:

Excellent	Very large (OR>1.5)
Good	Substantial (OR=1.3-1.5)
Satisfactory	Moderate (OR=1.1-1.3)
Poor **Unknown**	Slight or restricted (OR<1.1) No odds ratios available

Generalisability

Excellent	Population/s studied in body of evidence are the same as the target population for the guideline. In this context, interpreted as the majority of studies are representative of the population of children using these restraints
Good	Population/s studied in the body of evidence are similar to the target population for the guideline. In this context, interpreted as the majority of studies are similar to the population of children using these restraints
Satisfactory	Population/s studied in body of evidence differ to target population for guideline but it is sensible to apply this evidence to target population. In this context, interpreted as some studies are representative of the population of children using these restraints and/or these studies are likely to apply to the broader population of child restraint users.
Poor	Population/s studied in body of evidence differ to target population and hard to judge whether it is sensible to generalise to target population. In this context, interpreted as the majority of studies are not representative of the population of children using these restraints, or it is unclear if the results generalize more broadly beyond the study population.

Applicability

Excellent	Directly applicable to Australian context. In this context, interpreted to mean that studies were conducted on Australian children using Australian restraints and/or in Australian vehicles.
Good	Applicable to Australian context with few caveats. In this context, interpreted to mean that most studies were conducted on Australian children, using Australian restraints, and/or laboratory studies using Australian restraints, or in vehicles identical or very similar to Australian vehicles.
Satisfactory	Probably applicable to Australian context with some caveats. In this context, interpreted to mean that studies included overseas restraints and/or vehicles that are somewhat similar, to those used in Australia, but with some possibly relevant differences
Poor	Not applicable to Australian context. In this context, interpreted as the studies were of restraints or vehicles that are not found in Australia.

These tables were used to draw together the number of studies providing evidence, the strength and direction of the findings, and the overall level of evidence. These were then discussed in detail by the Technical Drafting Group, and an overall ranking of the specific piece of advice was made (Recommendation/Consensus-based recommendation/consensus-based recommendation). For recommendations, the following grades were used to rank the evidence, based on the NHMRC definitions.

Overall Evidence grades

Grade	Interpretation	How it was determined
A	Excellent Evidence: body of evidence can be trusted to guide practice	Either excellent or good components
B	Good evidence: body of evidence can be trusted to guide practice in most instances	A mix of excellent and good with some satisfactory
C	Some evidence: body of evidence provides some support for recommendations(s) but care should be taken in its application	The best component is good with some satisfactory and poor components
D	Weak evidence: body of evidence is weak and recommendations must be applied with caution	The components are satisfactory or below

The NHMRC evidence grading system applied, as outlined above, to a given recommendation, based on the summarised evidence around each question or practice being recommended, was ultimately identified, based on the evidence rankings, as being a: Recommendation; Consensus-based recommendation; or Practice points, using the following criteria:

- RECOMMENDATION - Where there is at least one study providing evidence. Quality of the evidence was graded A-D as detailed above.
- CONSENSUS BASED RECOMMENDATION - Expert opinion or poor quality evidence only - where acceptable quality research is currently lacking but there is agreement by the technical drafting group on a recommended best practice, the recommendation will be included together with a statement that evidence is currently limited to expert opinion.
- PRACTICE POINTS - Guidance on topics that are not within the scope of the guidelines and literature review.

3.11 Limitations of review

3.11.1 Lack of evidence

There are many areas of child restraint use and effectiveness for which there is no or very little rigorous peer reviewed evidence available for an evidenced-based recommendation. In part this is linked with the fact that the design of child restraints and of vehicles is constantly changing and newer technologies have not yet been the subject of large scale population-based studies that are needed to observe their impact in real crash situations. Such studies take long periods of time because of the relative rarity of child passenger injuries and the persistence of older vehicles and restraint technologies in the fleet, leading to small numbers in large surveillance systems.

Furthermore, there are many areas, particularly less common situations, or particular cultural groups, for which data on injury outcomes in the event of a crash have not yet been the focus of studies or numbers of cases have not been high enough to obtain reliable estimates. Where there is a lack of evidence, the Technical Drafting Group has developed "consensus-based recommendations" which are advice on best practice that stems from the wide cross-section of experience of the members of the Technical Drafting Group and current recommendations. It was considered important in this context to include this guidance classified as "consensus-based recommendations" in the final document, even though evidence is very limited, because of the need to provide carers and road safety professionals with clear and consistent guidance on these topics, while noting that the evidence base for these practices is not strong.

3.11.2 Limitations of the evidence available

The evidence presented has a paucity of studies which are usually in clinical research held as gold standard, including systematic reviews and randomised controlled trials (RCT). The latter is to be expected in this field (as in other areas of injury prevention research (Smith and Pell, 2003)) as there are obvious ethical reasons for not randomly assigning children to one type of child restraint or another (or none at all) in order to observe the outcome in terms of injury or fatality to the children in a crash situation. As a result, "B" (or "good") is the highest ranking of studies available in this field, as represented in the evidence tables under 'evidence base'. The vast majority of field studies are 'natural experiments', or observational studies where cases are based on real-world crashes and the restraint type or use has been chosen, generally by the parent or carer, prior to the crash event. There are some biases inherent in this type of research in that parental choices of child restraints may be linked with other factors that might influence the findings such as age of vehicle, speed at the time of crash, correctness of use of the restraint, and potentially biases in reporting of restraint status of the child by the parent/driver after the crash event (Streff and Wagenaar, 1989).

The studies available span several decades and multiple countries and, as a result, there is heterogeneity of the studies conducted in terms of the types and designs of restraints, vehicle safety equipment, local laws and recommendations covering restraint use by child passengers. This limits the validity of conducting a meta-analysis on any of the devices being investigated. Furthermore, some of the findings need to be considered with caution when the studies are from other countries or times when designs may be different than currently available and used in Australia. These constraints are identified in the evidence table with each recommendation.

In some areas, the evidence is a mix of laboratory and field studies, which can serve to strengthen our confidence in any observed or expected injury outcome. However, laboratory studies are limited in the number of different restraint models and crash types tested, as well as the sizes of the child dummies used and the biofidelity of the dummies and the representativeness of the test protocol to real world crashes. These studies are not able to provide odds ratios as field studies can. As a result, in many areas our understanding of the public health impact is limited.

3.11.3 Specific issues in this context

There are several aspects of research in injury prevention generally, and child restraint use in particular, that impose specific constraints in the undertaking of a systematic review of the literature. As Smith and Pell (2003) note, randomised controlled trials are not an ethical option in many areas of injury prevention, including in restraint use. Legal requirements for use of specific restraints in vehicles also precludes study of some forms of restraint use, including non-use of restraints. As a result, the majority of the evidence available on the effectiveness of child restraints falls into two groups: analysis of large injury or crash surveillance databases with or without additional survey and observational data, and laboratory crash testing data. The limitations of field data are the lack of control of the crash, vehicle, restraint and other variables. In laboratory studies there are limitations associated with the small number of restraint- makes and models tests, vehicle types simulated, and child dummies. The laboratory crash studies do not fit neatly into the NHMRC evidence grading scheme, but provide a good basis for comparative safety of different restraint options in this area, and are considered in the road safety field more broadly to be high quality evidence. While there are limitations in the biofidelity of crash test child dummies, they are also the clearest direct comparisons of restraint options, whereas field crash studies rarely provide directly comparable children, restraints and crash circumstances for comparison, and there is rarely sufficient data for effective statistical control of all relevant variables. However, the combination of the field and laboratory studies provides good evidence on the effectiveness of restraint types and restraint uses where the numbers of studies available are reasonable and where factors that may contribute to bias have been well controlled for in the analysis.

Because the available literature is based on rare events (serious including fatal injuries to children as passengers in the event of a motor vehicle crash) and has been conducted in many different countries with different restraints, laws and vehicle fleets, few studies are conducted under similar enough conditions or with similar enough populations and restraints to allow pooling of data for formal meta-analysis.

Many studies of child occupants include aspects relevant to multiple research questions (e.g. appropriate restraint use AND incorrect restraint use) and are not indexed by specific keywords that allow a formal systematic review using specific keywords to identify all the relevant literature for a given topic. As a result, the approach taken was a comprehensive review of peer-reviewed literature on the effectiveness of child restraints relevant to the current Australian context, using as search terms the key words in many combinations, followed by detailed review to draw together the studies that covered findings relevant to specific research questions.

There are limitations to the applicability of many of the older studies and those conducted in other countries to the current Australian context, due to changes in the design and regulation of child restraints. Mandatory product safety laws in place in Australia mean that our child restraints are not designed or anchored to the vehicle in the same way as most of the other countries from which studies are available. This was taken into account in the analysis of the literature available, particularly large US studies which include largely untethered child restraint designs (although tethers are used in newer restraints in the US, few have been included in analyses published to date). It was not within the scope of these guidelines to examine restraint designs that are not available in Australia (or that are likely to become available in the immediate future).

While the overall public health impact of various types of restraints, or indeed any safety device that requires a level of compliance, is dependent upon the level of compliance with recommendations. Nor did the literature review include studies that focused on educational and other interventions to increase adherence with child restraint best practice, although these are relevant for implementation. Exposure to particular restraint practices is influenced by local context, socioeconomic status, access to information, public health campaigns, advice given, vehicle and restraint manufacturer instructions etc. The focus of the review was on the effectiveness of the restraint if used, and if used correctly. The intention of these guidelines is to provide the best available advice to carers of children travelling in motor vehicles on which restraints to use, and when and how to use them correctly. Furthermore, the current review did not investigate issues beyond the safety of the child in the event of a crash, such as driver distraction, or crash risk for different types of restraints.

It is also noteworthy that for some practices, there are no formal studies available, and recommended practice is based on knowledge of the fundamental physics of car crashes, biomechanics, and restraint design principles. These principles are very well established and form the basis of the design of motor vehicle safety systems worldwide. Such recommendations are clearly identified in the guidelines document as not being evidence-based recommendations but “consensus-based recommendations” developed based on consensus opinions of the Technical Drafting Group. They are important for providing clear and consistent guidance on these issues.

4 Evidence statements

Note: Numbering follows the numbering in the main guidelines document to minimize confusion in cross-referencing.

6.1 *Appropriate choice of restraints*

This section makes best practice recommendations for what type of restraint to use at what age, and when to transition from one restraint to another and lays out the evidence base for each piece of guidance.

Prior to the introduction of the 2010 edition of AS/NZS 1754, restraint types were recommended based on the weight of the child. In recent years, appropriate restraint use for children has been defined on the basis of their age rather than their weight, as many parents do not accurately know their child's weight beyond infancy (Bilston *et al.*, 2008). While age is a useful, practical guide (Anderson and Hutchinson, 2009) (consistent with the National Road Rules) a system of shoulder height markers that better reflect the adequacy of the size match between a child and a given child restraint have recently been developed (Brown *et al.*, 2010a) and implemented in the mandatory Australian Standard for child restraints, AS/NZS 1754(2010). On the basis of restraint design principles (Eppinger, 1993) this is considered to represent the 'best' parameter for determining restraint fit and thus performance in a crash. For older restraints that are labelled with weight ranges rather than ages or shoulder height, the equivalent size to the shoulder heights are given in the relevant sections below. Since Australian restraints are tested with dummies that are significantly heavier than the maximum weight range, if the child still fits in the restraint harness exceeding the nominated weight range by a small amount (1-3kg) is unlikely to pose a significant risk to the structural integrity of the restraint in a crash. Since the crash forces in booster seats are carried by the seat belt, exceeding the weight limits should not pose a significant risk provided the child fits well within the booster seat.

Optimal protection for child passengers is obtained when the following recommendations below are followed.

Recommendation 1.1	**The use of any restraint is preferable to not using a restraint.** ✋
Overall Evidence Grade	**A**

Table 1: Evidence statement supporting recommendation 1.1

Evidence statement	**Restraint use decreases the risk of fatal and serious injuries to child occupants in the event of a motor vehicle crash**	
Grade	**A**	
Component	**Rating**	**Notes**
Evidence base	Good	Eighteen level III-2 studies and three level III-3 and two level IV were identified that provide evidence on the effectiveness of child restraints. These were mostly retrospective cohort studies based on large datasets and

		nested in-depth case reviews, with some potential for selection bias towards more injured children and more seriously injured children in samples.
Consistency	Excellent	Studies, regardless of currency or geographic setting, have consistently shown that any form of approved restraint offers greater overall protection (injury reduction) than no restraint. No studies report opposing findings for overall restraint use. Specific restraints can be associated with some specific types of injuries, such as soft tissue injuries associated with lap only belts.
Public Health Impact	Excellent	Available studies have found a reduction of serious injuries or death by 30-96%, with greater gains reported in more recent studies (with restraints of improved design) and when there is a good fit of the restraint to the child.
Generalisability	Good	While there are many studies with consistent findings on a range of restraint types, findings from more recent studies have greater generalisability due to ongoing changes in vehicle and restraint designs. Findings are based on child anthropometry, so findings should be generalisable without regard to population/ethnic groups.
Applicability	Excellent	Some studies are from overseas with different designs of restraint, but their results are consistent with Australian studies.
Other factors		Numerous laboratory studies of simulated crashes have confirmed these field studies. The current law requires all vehicle occupants to be restrained.
References		(Kahane, 1986; Partyka, 1988; Agran *et al.*, 1992; Henderson, 1994; Johnston *et al.*, 1994; Cuny *et al.*, 1997; Isaksson-Hellman *et al.*, 1997; Tyroch *et al.*, 2000; Valent *et al.*, 2002; Durbin *et al.*, 2005; Elliott *et al.*, 2006; Du *et al.*, 2008)

There are numerous studies, largely based on retrospective data reviews of various populations from within Australia and several other countries, which have consistently shown that restrained children are better protected against fatal and serious injuries compared to unrestrained children. While there is potential for some selection bias in the study samples, as cohorts under investigation may not include occupants of vehicles that are uninsured, or are limited to certain types of injuries or levels of injury severity, the number of studies with consistent findings provides an overall excellent evidence base for this recommendation. Furthermore, laboratory studies simulating crashes with restrained and unrestrained anthropomorphic test dummies clearly support these field study findings in terms of the estimated injury likelihood. While different types of restraints are associated with different levels of protection (depending upon the size of the child), overall the evidence indicates that a child wearing an Australian Standard approved restraint has a significantly lower (30-96% lower) risk of serious injury or death in the event of a motor vehicle crash than an unrestrained child.

Table 2: Summary of articles providing evidence for recommendation 1.1

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
(Agran *et al.*, 1992)	Cohort study - review of data	III-2	USA	Review of data from surveillance system from 38 hospitals (inc. trauma centres and HMOs) and the coroner's office - followed by interview with parents (n=755 4-9 yr. olds for which data were complete) and 726 10-14 year olds.	Injury severity: AIS and ISS.	Restraints (adult seat belts) were noted as either lap and shoulder, lap-only, or none. Restrained children (10-14 years) experienced significantly fewer intracranial, soft tissue, and facial injuries and more spinal strains than unrestrained children. The mean ISS was lower for restrained children in all locations than unrestrained. Poor fit of adult seat belts for young children has been implicated.	Data based on self-reporting by parents. Lack of accurate data on severity.

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
(Caskey *et al.*, 2018)	Data review of crash surveillance database, frontal tow-away crashes	III-2	USA	Children aged 5-12, the second row of seats, involved in frontal crashes over an eight year period (2008-2015), who were unrestrained, in a booster seat and seat belt or seat belt alone. The National Automotive Sampling System-Crashworthiness Data System (NASS-CDC) was used to identify cases. Excluded were roll-overs, vehicles older than 2000, and other restraint types. Regression analysis was used to identify the influence of the restraint type on injury risk was assessed while controlling for child occupant, vehicle characteristics and crash severity.	Injury frequency and severity: moderate to severe (≥ AIS 2) compared to less than moderate.	The proportion of unrestrained children involved in crashes was 9.6% (95% CI, 0.0-13.5) compared with the belts only group at 2.5% (0.2-4.2) and the booster user group at 0.5% (0.0-0.9). Compared to children in booster seats, those in a lap sash belt only were fives time more likely to be injured and unrestrained children were 19 times more likely to be injured. After controlling for other factors, unrestrained children were found to be 60.7 times more likely to be moderately to severely injured than those using a lap and shoulder belt.	While children 5-12 years old were included in the analysis there were few older children in booster seats, which may have contributed to the lack of significant difference in injury severity of boosters compared to lap sash belt only. Results are limited to frontal crashes only.
(Cuny *et al.*, 1997)	Cohort study - review of data	III-3	FRA	Data sources (from 4 months during 1995-6) were police crash records together with medical records; 1327 children under the age of 10 were included.	Injury severity: AIS and MAIS.	Rear facing CRS reduced the proportion of serious injuries (MAIS= 2+) by 88%, forward facing by 71% and booster seats by 31%. Findings suggested that misuse of CRSs results in the same proportion of serious injuries as no restraint.	One page article - methods section is too brief to know how misuse of CRS was measured, how subjected were included in the study or how estimates of proportion of injuries increased under different scenarios was calculated. It is assumed that no restraint was the index measure.
(Du *et al.*, 2008)	Matched cohort study	III-2	USA	1517 children in 705 crashed vehicles - outcomes variable of death within 30 days of the crash. At least one child killed in crash - study compared other children in the same crash.	Death within 30 days of the crash.	A reduction in the risk of death was associated with restraint use (RR=0.33) but there was no significant difference in the effectiveness of different restraint types. Compared to inappropriate restraint use, appropriate restraint use was linked with a reduction in risk of death (RR=0.46).	Sample size limitations may have been linked with not being able to find difference in effectiveness of restraints by age group. While matched design, confounders - like location of child who died to intrusions during crash.
(Durbin *et al.*, 2005)	Cross-sectional study using a child specific crash surveillance system	III-2	USA	Children 0-16 in 15 states who were involved in a MVC over a four year period (Dec 1998-Nov 2002) - cars 1990 or newer. Over sampling of children presenting for medical treatment. Data from telephone interview with driver or proxy were included. Seating row and restraint use (correct and incorrect - with CRS or booster seat use for children <9 was classified as "correct"). Approx. 18000 children were included in the sample. Weighted logistic regression was used.	Injury status and by severity (AIS<2 and 2+).	The highest risk of injury was to unrestrained children in the front seat, followed by unrestrained in the back seat. After adjusting for age of child and type of vehicle seating row and restraint status were both independently associated with injury risk. Inappropriately restrained children were at nearly twice the risk of injury as appropriately restrained children. Furthermore, children without a restraint had over 3 times the risk (OR: 3.2; CI: 2.5-4.1) of injury.	Age appropriate restraint use and second (or third) row seating work synergistically to achieve greater safety. Restraint use and seating position relied on driver reporting of this information. Study did not cover vehicles older than 1990 nor uninsured vehicles.
(Elliott *et al.*, 2006)	Cohort study - review of data	III-2	USA	Data from 2 databases (one of fatalities and one a sample of non-fatal crashes) involving children in two-way crashes occurring between 1998 and 2003. Vehicles selected for inclusion were those that were non-drivable following the crash. 9246 children were included.	Fatal vs. non-fatal injuries.	Compared to adult seat belts, child restraints (when not seriously misused) were associated with a 28% reduction in the risk of fatality among children 2-6 years - after adjusting for driver survival status, vehicle type and year, age of driver and passenger, and seating position.	Child restraint systems included rear-facing and forward facing car seats, and shield and belt-positioning booster seats. Potential for misclassification of restraint type by police.
(Ernat *et al.*, 2016)	Retrospective medical record review	III-2	USA	A total of 97 patient records were included in the analysis of restraint type by injury sustained. Cases were admitted to a level 1 trauma centre between 2003 and 2011 and included all children between 0 and 10 years treated for spinal injury due to a MVC.	Rates of injury as well as injury type and location	It was shown that 52% were either in the wrong restraint for their age or in the front seat, a further 26% were unrestrained. Significant differences were found between the injuries by the restraint type used, and the age of the child. Proper use of child restraints was significantly	The study did not differentiate between type of restraint (booster versus FF - CRS or RF - CRS) and no information was available about the speed or direction of impact at the time of the crash. Case

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
				Analysis was initially be restraint type, then by whether it was correctly used.		higher in younger aged children (between 0 and 1 years) compared to older children (between 4 and 5 years). Higher rates of cervical spine and isolated ligamentous injuries were seen among the unrestrained children compared with 2-point (lap sash only) and 3-point (lap and shoulder sash) restrained passengers, when proper 3P restraint use was not taken into consideration. Three-point restrained passengers had higher rates of TL injuries than unrestrained passengers even when isolating the comparison with those using 3P restraints properly.	selection was based on having a spinal injury so being able to assess the impact of restraints on the risk of spinal injury was not done. Did not investigate injuries caused by air bag deployment.
(Henderson, 1994)	Data review of injuries resulting in hospital attendance or fatality.	III-2	AUS	Cases were 247 children aged <15 attending hospital following a MVC. Interviews with a parent, inspection of the vehicle and reconstruction of the crash event using the EDCRASH program to obtain estimates of speed, change in velocity and deceleration that is likely to be more accurate that reported during interview or from records. Restraint type was recorded. Vehicles were 1966-93.	Injury severity (AIS >2) and fatal injuries.	Side impact was the crash type most likely to result in a significant injury (34% of case children sustained an injury of AIS 2 or greater). Few infants were in capsules (n=6, 2.6%). Injuries by restraint type were summarised by possible mechanism. Lap-sash belts appeared to offer good protection but were only available in outboard seats. A higher proportion of unrestrained children had a serious injury or fatality (26.3% fatally injured, 42.1% suffered an injury of AIS 2 or greater), as compared with restrained children ($p<0.01$). A high proportion of the cases were in four-wheel drive cars and multi-passenger vehicles. Importance of seating position was highlighted. Concludes that restraints specifically designed for children are most protective and adult seat belts do not offer protection from side-impacts. Some indications that many children were moved out of a CRS too early.	Provides an overview of the types of restraints available. Study population not necessarily representative of all crashes in which children are injured and does not represent those in which an injury was prevented. Strength of study was in understanding the crash event, not just the proportion of children injured and injury severity by each restraint type. Small numbers in some restraint types e.g. capsules and forward facing restraints limits conclusions.
(House *et al.*, 2012)	Prospective observational study of children injured in crashes	III-2	USA	Prospective observational study of children aged 4-8 taken to ED due to MVC. Doctors classifying injury severity were blinded to restraint status of child. Restraint use was classified as no restraint, adult seat belt, or booster seat.	Injury severity classified as minor, moderate or severe. Also examined booster seat use (three groups: booster, seat belt or no restraint)	In the sample, 58 were in booster seats, 73 in seat belts and 28 unrestrained. There was no significant difference between restraint type or restraint use and injury severity outcomes, although there was a trend towards unrestrained being associated with more severe injury. Most injuries were minor with only 16 being moderate or major, and 2 fatalities. Decreasing booster seat use was observed with increasing age.	Strength of study was it was prospective and so not subject to recall biases and not limited to only serious injuries as can occur with retrospective reviews. Sample size was not sufficient to make conclusions; of 168 presentations, 9 had no restraint status recorded so were excluded from analyses.
(Isaksson-Hellman *et al.*, 1997)	Cohort study - review of data	IV	SWE	Volvo crash surveillance database for the period 1976-1996 and includes 4242 child occupants involved in crashes. Details of the vehicle, and follow-up survey to obtain details on the crash and medical records of injuries. Injury risk was the number injured divided by the number of occupants for each group.	Injury severity: none or MAIS, 1, 2 3+.	Children in an adult seat belt showed a higher number of minor and serious injuries than those in a CRS. Compared to no restraint wearing an adult seat belt was found to reduce the proportion of children with serious injury (MAIS 2+) by 59%, belt positioning booster reduced it by 76%, and rear facing CRS reduced it by 96% (forward facing not reported). Analysis suggests that optimal safety is not achieved unless the child is in the appropriate restraint for their age and size.	Vehicles were limited to Volvos - but this does allow for more uniform comparison of the effectiveness of different restraint types. Large proportion of unknown restraint type. Confidence intervals are not reported and even though there are several breakdown categories reported (severity of injury, type of restraint, direction of impact, body location of injury etc.) Results have too few numbers to be

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
							significant. No multivariate analysis.
(Johnston *et al.*, 1994)	Cross-sectional case series - data review	III-2	USA	Probability sample of police reported crashes in 26 states - over a 2 year period. Selected crashes in which there was one or more child under 15 as a passenger (n=16,685) reviewed police data on type of restraint and whether child was injured. 10,098 children with known restraint use.	Injury outcomes to children as passengers in MV crashes by restraint use. No attempt was made to classify injury severity.	Compared to children who were "optimally restrained", children who were sub-optimally restrained had a slightly higher risk of injury, but those unrestrained were at 2.7 times the risk. Compared to children in the back seat, children in the front seat have 1.5 times the risk of injury. The use of a car seat reduced injuries by 60% for 0-14 year olds, while a lap-sash harness was only 38% effective in reducing injuries for 5-14 year olds.	For children aged 0- 4 (preschool), optimal use was defined as police reported use of a child safety seat. For the 5 to 14 year old children, shoulder belt combination, as that is the current recommendation. Any other restraint usage inducing lap belt or shoulder belt alone was considered sub-optimal.
(Kahane, 1986)	Multi-pronged. In depth review of sequential sample of crashes.	III-2	USA	Statistical analyses of the US Fatal Accident Reporting System and State accident data; analyses of sled test and compliance test results, and observational surveys of restraint system usage and misuse. Sequential sampling (n=) in a sample designed to be representative of population (quota for age groups etc). In depth investigation of these events and factors linked with injury outcomes.	Fatal and serious injuries in real crashes, injury producing contact (notably of the head) and deceleration forces in sled test crashes.	Correctly used forward facing CSSs reduce the risk of death and injury by approximately 71% compared with unrestrained children.	Authors note that restraint wearing changes each year – in terms of proportion correctly restrained. Restraint types are also very different from this period and US restraints do not included top tether straps. Study of limited current value except that provides evidence that any restraint is better than none, or a poorly used/fitted restraint.
(Loftis *et al.*, 2017)	Retrospective medical record review	III-2	USA	Retrospective medical review Jan 2007- July 2014 of all children presenting to Level 1 trauma centre following motor vehicle crash; of the 976 patients, 238 had unknown restraint status so analyses were conducted on 729 patients.	Injury coded using ICD-9 with diagnoses 800-959.9 grouped to 27 diagnoses and mortality.	Children aged 9-12 years were most common age group unrestrained. Of all 729 children, 254 (34.8%) were unrestrained; 231 (31.7%) were improperly restrained. No statistical difference in mortality and any restraint status (p=0.159). Unrestrained children more likely to have intrathoracic injury (24% versus 13.5% of those properly restrained; p=0.01); open head wounds (38.2% versus 25.8%; p=0.01) and open upper extremity wound (5.1% versus 0.8%; p=0.02)	Excluded 25% or original cohort due to unclear restraint use status; all cases were result of severe crashes so restraint status not recorded for those with minor injuries - only those with severe injury so likely underestimation of true effect.
(Ma *et al.*, 2012)	Cross-sectional study, restraint use by injury outcome	III-3	USA	Retrospective cross-sectional study from police reported MVCs involving children from 0-12 years in the US from 1996 to 2005. Children were grouped into 4 age groups: 0- <1 year, 1-3 years, 4-7 years and 8-12 years. Logistic regression on these grouping with appropriate restraint use, inappropriate use and non-use (which included whether in the correct restraint and seating position for age). Potential confounders considered included characteristics of the child passenger, driver, vehicle and crash.	Non-fatal and fatal injuries.	A total of 7633 cases were included. Children with no restraint use experienced a significantly higher prevalence of fatal injury than children who were appropriately restrained in all age groups: <1 year olds had an estimated 23 times the risk odds of fatal injury were significantly greater among unrestrained children among all age groups (children aged <1 year old OR=23.79, 95%CI=1.20-472.72; 1-3 years OR=21.11, 95%CI=4.39-101.57; 4-7 years OR=16.24, 95%=2/76-95.54; and 8-12 years OR=9.81, 95% CI 2.05-46.90). Children aged 1 to 3 years who were inappropriately restrained had 6.28 times the odds of being fatally injured compared with those who were appropriately restrained after adjustment for potentially confounding factors. Children in this age group who were restrained	Vehicles and restraints in this study are now 13-20 years old so current models of both may have quite different injury risks associated with them. Due to data limitations the authors were not able to determine if the restraints were correctly installed.

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
						and in the rear seat but inappropriately restrained had approximately 12 times the odds of dying compared with children with appropriate restraint use. The odds of a non-fatal injury for front seated infants appropriately restrained were reduced by 74% compared with rear-seated appropriately-restrained infants.	
(Ma *et al.*, 2013)	Retrospective matched longitudinal study using a crash surveillance system	III-2	USA	Examined cases of children involved in crashes 1998-2009 identified on the National Automotive Sampling System (NASS) Crashworthiness Data System (CDS). Children were aged between 0 and 10 years and were not seated in the front seat of the vehicle. A matched analysis design was employed comparing those within the 4-7 year age group (the age range required by law), with those outside that range. A total of 2,476 children were in the sample. Restraint use was grouped as not restrained, lap sash belt only, or backless or high-back booster seat. Children were matched on child age, vehicle body type and sampling weight.	Any injury (examined by AIS 1+ and AIS 2+, as well as sever injury of ISS > 8), fatal injury and regional body injury.	Children with combined seat belts and booster seats were 27% less likely to have any injury than those with no restraints, (RR = 0.73, 95% CI = 0.55 to 0.96). No association was observed for any injury or for severe and fatal injury, when comparing children with combined seat belts and booster seats with children restrained by seat belts alone. Those in a booster seat were significantly less likely to have a head injury, face injury, upper body injury and lower extremity injury when compared to children with no restraints. However, they had more than a three-fold risk of a neck injury (AIS 1+) but no difference in the risk of moderate neck injury (AIS 2+).	Cases were limited to those involved in tow-away crashes. And information was not available on the proper use of restraints for many of the cases. The retrospective data means that several potential confounders were not available for many cases.
(Partyka, 1988)	Retrospective review of crashes using a matched pairs technique	III-2	USA	FARS surveillance system - covering the period 1982-87 in which there were 7060 vehicles included on the reporting system. Looking at children under 5 years of age, matched pairs - based on restraint usage by driver and child occupant and fatality ratios were calculated.	Fatal vs. non-fatal injuries.	Based on the fatality ratios it was estimated that children were 50% less likely to be killed if they were in a child restraint. When fatality ratios were applied to front versus rear seating of the child who is restrained, it was found a 33% reduction in chance of a fatal injury of the child is in the back seat. The effectiveness of a CRS was 52% in avoiding a fatal injury after controlling for seating position. Effectiveness of restraints: for infants in CRSs was 69%, toddlers (1-4 years) in CRSs: 47% and toddlers in adult belts: 36% reduction in risk.	Old study - many changes to recommended restraints since 1980's. Assumptions are made about correct restraint use, and that driver fatality was indicative of the risk of fatality for the child occupant.
(Sauber-Schatz *et al.*, 2014)	Retrospective longitudinal study based on the Fatal Accident Reporting System examining the impact of restraint use (unrestrained versus restrained) on child fatalities (0-12 years)	IV	USA	Occupant fatalities from 2002-2011 for children aged 0-12 years grouped as <1, 1-3, 4-7, 8-12 years. Data included use of restraint and ethnicity	Fatalities	Motor vehicle occupant death rates among children aged 0–12 years decreased by 43% from 2002 to 2011 (from 2.2 deaths/100,000 to 1.2 deaths/100,000). From 2002–2003 to 2009–2010, the proportion of unrestrained child deaths decreased significantly among children aged 0–12 years (by 18% for 1-3 year olds; by 39% for 4-7 year olds and by 24% for all children 0-12 years). Fatality rates decreased over this time, One-third of children (0-12 years) who died in 2011 were unrestrained indicating there were still many potentially preventable deaths. White children were more likely to be restrained compared with either black children or Hispanic children.	Data are limited to police reports with inaccuracies possible. Other factors such as safer vehicles, improved roads and emergency services could have contributed to the reduction in fatalities over this time. Possible conservative estimate as 7% of deaths in 2007 up to 29% of deaths in 2010 had no restraint use status recorded.
(Sauber-Schatz *et al.*, 2015)	Retrospective medical record review	III-3	USA	Surveillance system linking police and hospital records (probabilistic linkage) for motor vehicle crashes in 11 states, from 2005-2008. The database includes 50 crash related variables and 18 health outcomes.	Injuries by body region and whether hospitalised	Across all age groups unrestrained children had the highest percentage of injuries for each body region. Children optimally and sub optimally restrained had minor differences in body region injured, by age group. Children who were	Data were limited by not being able to distinguish if children were correctly restrained or the restraint was correctly installed, and booster use for children over 8

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
				Sample was children aged 1-12 who were involved in a motor vehicle crash. Child ages were grouped 1-3, 4-7, 8-12. Restraint use was classified as optimal, sub-optimal or unrestrained. Optimal and sub-optimal were only crudely defined as in a child restraint or booster seat if aged 1-7 as optimal and in an adult seat belt as sub-optimal, and 8 -12 years was just in an adult seat belt or not (booster seats were not coded for this age group).		unrestrained had approximately 7 times the risk of traumatic brain injuries than those who were restrained – either optimally or sub-optimally. Children in each age group who were optimally restrained were significantly less likely to have a neck, back or abdominal injuries or to be hospitalised than those who were unrestrained. Sitting in the back seat was found to be protective for children 8-12 years old. By age group: the odds of children aged 1–3 year having neck, back or abdominal injuries who were optimally restrained was 63% less than children who were not restrained, with the true effect being between 68% and 59% (OR= 0.37; 95% CI = 0.32–0.41); similar results shown for TBI (OR = 0.13; 95% CI = 0.10–0.17) or for being hospitalised (OR = 0.41; 95% CI = 0.38–0.45). Children aged 4-7 years optimally restrained versus not restrained had significantly lower odds of TBI (OR = 0.10; 95% CI = 0.08–0.12)	could not be determined. Data for children aged <1 year unable to be used due to coding issue (missing ages also coded as 0 years)
(Stewart *et al.*, 2013)	Medical record review of children aged <18years presenting to hospital trauma centres in USA Ontario following MVCs. Population separated into children requiring child/booster seats and adolescents requiring lap/sash belts alone.	III-2	Canada	Review of medical records, or coroners' reports, of children 0-17 years presenting to one of two Ontario trauma centres as a result of injuries from a motor vehicle crash. Cases were included if seated in the rear seat, and analysis compared two age groups (0-8 years required to be in a child restraint or booster and 9-17 years required to be in a lap-sash belt) for injury outcomes. Records were cross-linked with police records for 54% of cases where this was available.	Serious injuries examined by ISS, fatalities, body location	There were 36 children aged 0-8 years and 70 children aged 9-17 in the sample. Significant differences were found between the two age groups on some body regions. The adolescents (9-17 year olds) had significantly higher proportion and more severe injuries to the abdominal region, the child group (0-8 years) had a higher proportion with severe head injuries (78% c.f. 38%, p <0.001). Findings may be associated with the fact that only 55% of the younger group were appropriately restrained. Lack of age-appropriate restraint resulted in a 3.5-fold increase in odds of severe head injury (p=0.029). Among the older group, there was more than double the number of unrestrained, rear occupants with a severe head injury compared with restrained (56% vs. 22%; p=0.004). For severe abdominal injury, as age and use of age appropriate restraint increased so too did the odds of severe abdominal injury (OR=3.8; p=0.034). Also found that children in the centre rear position had 6.6 times the risk of severe head injury - which may be associated with the hard centre console and the lack of a universal anchorage in the centre position.	Data are not representative of all crashes, as they exclude those with no or non-serious injuries as well as those where the child died at the scene and was not transported to hospital. Details of the collision type (from police records) were not available for 46% of cases. Comparing the two types of restraints had its limitations as there are many other factors associated with the two different age groups of the children that may have influenced the outcomes. Data were not available on change in velocity and amount of intrusion, which is important to the biomechanical analysis of injury tolerance.
(Stewart *et al.*, 2014)	Retrospective review of State Dept of Transportation and State Health Data	III-2	USA	Retrospective analysis of scene crash data from Colorado State Department of Transportation (2007–2011) and State Department of Public Health data (2000–2011) regarding infants who presented to a trauma centre after MVC.	Head injuries	Properly restrained infants were 12.7 times less likely to present to a trauma centre after an MVC (OR = 12.7, CI 95% 5.6–28.8, p b 0.001). TBI was diagnosed in 73/119 (61.3%) infants; 42/73 (57.5%) properly restrained, and 31/73 (42.5%) improperly/unrestrained (p = 0.34). Average head abbreviated injury scale was similar for properly restrained (3.2 ± 0.2) and improperly /unrestrained infants (3.5 ± 0.2, p = 0.37).	Improper restraint use is not defined in the paper, but appears to be related to appropriate use of an infant restraint.

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
(Tyroch *et al.*, 2000)	Retrospective record review	III-2	USA	Review of medical records of all children (0-6 years old) presenting to ER at 2 hospitals (include minor or no injuries) (n=585). Autopsy records of pre-hospital deaths (n=14) for same period also reviewed - 82 months. Injury severity examined by restraint type.	Injury Severity Score (ISS), injury type.	With the exception of spinal fractures, the restrained group showed a reduction in severe injuries for every anatomic site. The mean ISS (3 for restrained c.f. 8 for unrestrained) and the number of children with severe injuries (ISS ≥16, 21 vs. 38) was lower in the restrained group, even when stratified with respect to child safety seat and seat belt use (P<.001) Percentage of uninjured children was higher in the restrained group (36% vs. 18%). The fatality rate was significantly lower in the restrained group.	Did not know if restraints were used properly. Crashes which did not result in children presenting to the hospital were not included.
(Valent *et al.*, 2002)	Retrospective record review	III-2	USA	Five year period (95-99) for review of National Automotive Sampling System data files were used. Crashes were police reported tow-away collisions.	Injury severity (AIS >2).	After controlling for sex, age, seating position, vehicle and crash types compared with children using no restraint system, properly restrained children had significantly lower overall injury risk (RR, 0.37; 95% CI, 0.20–0.69). Significant risk reductions were also found for injuries to the head (RR 0.18; 95% CI, 0.10–0.35), thorax (RR, 0.35; 95% CI, 0.13–0.93) and lower extremities (RR, 0.26, 0.12-0.57) as well as for mortality (0.26, 0.12-0.59).	Study looked at risk of injury to specific body areas. Found many children not restrained at all. Some misreporting of seat belt use might be expected. Study did not collect data on whether harness, shield or tether was used.
(Wolf *et al.*, 2017)	Ecological study - retrospective longitudinal study using a crash surveillance system	III-2	USA	A state-by-state analysis of factors associated with crashes involving children less than 15 years of age for the period 2010-2014 in the USA, using the Fatality Analysis Reporting System (FARS). Factors considered were state policies as well as characteristics of the vehicle, driver and passenger. Based on recommended restraint type for children, analysis was by 5 age groups (0-2, 3-5, 6-8, 9-12, and 13-14 years of age)	Age-adjusted, MVC-related mortality rate (AAMR) per 100 000 children and percentage of children who died of those in fatal MVCs	There were 18,116 children recorded in the FARS database as being involved in a fatal crash during the five year period. Findings indicated that the strongest predictor of fatal injury for children was use or non-use or inappropriate use of a restraint (p<0.01). It was revealed that 20% of children were not restrained or not appropriately restrained at the time of the crash. There was considerable state variation on this aspect, from 2% in New Hampshire to 38% in Mississippi. For each 1% increase in the percentage of children who were unrestrained or inappropriately restrained, the AAMR increased by 0.038 (95% CI 0.020-0.057). Projected that potential 10% absolute improvement in child restraint use would decrease the national age-adjusted MVC-related mortality rate from 0.94 to 0.56 per 100 000 children. Over 5 years, this translates to >1100 paediatric deaths averted, or nearly 40% of the deaths observed over the 2010-2014 period.	FARS database is limited to crashes with a fatality so the study did not include crashes in which no occupant was killed. Analysis did not include SES of the driver, nor level of enforcement at the state level. Did not separate analysis for unrestrained and improperly restrained. Also excluded children in an unenclosed passenger or cargo area, the vehicle exterior, or a trailing unit (all of which the child was likely unrestrained).

Consensus Based Recommendation 1.2	**Restraints of any type should never be used to restrain two or more passengers at the same time.** ✋

This consensus-based recommendation is based on expert opinion, taking into account the following considerations. Sharing of a restraint by two or more occupants is thought to compromise the safety of both occupants, but there have been no formal studies of this practice. Currently the law prohibits the sharing of seat belts and this position is supported by the Technical Drafting Group on the basis of the likelihood of a restraint not being properly fitted for either of the occupants if seat belts are shared. Furthermore, there is an increased opportunity for head injuries if children's heads contact each other during a crash if there is not adequate distance between them as vehicle occupants. This practice point is based on expert opinion only as there is limited field data available. Additional research could include testing studies of injury risk for multiple users of a single restraint.

Consensus Based Recommendation 1.3	**Parents/carers are encouraged to exhaust all options for restraints in the child's current or 'recommended' category before transitioning them to the next category of restraint, except for the cases noted in recommendations 1.6 and 1.8.**

This consensus-based recommendation is based on expert opinion, taking into account the following considerations. Within a given restraint category, there is considerable variation in the size of children accommodated by specific makes and models of restraints (e.g. Bilston & Sagar, 2007), and when a child exceeds the size limits of one particular model of restraint, there may be other restraints available in that category that accommodate that child's size, which would provide better protection than progressing to the next category of restraint. E.g. some rearward facing infant restraints accommodate children only up to 70cm in length (approximately 6-9 months of age), while others accommodate children in rearward facing positions up to 80cm in length (approximately 12 months of age or even beyond). Similarly, some booster seats only accommodate children up to an approximate height of 128cm (Type E) or 138cm (Type F), while others accommodate children well beyond these minimum heights, reducing the potential 'gap' between a booster seat and achieving good seat belt fit in a vehicle (see recommendation 1.9 and practice point 5). There are two exceptions to this recommendation. Rear facing restraints that accommodate children up to approximately 2-3 years of age (Type A4) are also available, but there is currently no evidence to support a recommendation to either encourage or discourage the use of these restraints compared to properly used FFCRs for children who have outgrown a Type A2 rear facing restraint (see Consensus Based Recommendation 1.6). Secondly, FFCRs with internal harnesses that accommodate children up to approximately 8 years of age (Type G) are available, but there is currently no evidence to support a recommendation to either encourage or discourage the use of these restraints compared to well-fitting high back booster seats (see Consensus Based Recommendation 1.8). To date, there is little information regarding the relative performance of similar restraints at the transition margins between restraint types. Further research could clarify this issue.

Consensus Based Recommendation 1.4	**Children using convertible restraints should use the restraint in the mode designed for younger children for as long as they fit in that mode rather than transitioning to the mode designed for older children as soon as they reach the minimum size for the older mode.**

This consensus-based recommendation is based on expert opinion, taking into account the following considerations. Convertible restraints that combine two (or more) restraint types in a single restraint should be converted from one mode to another when a child transitions from one restraint category to the next. There are no studies that specifically compare the safety performance of convertible restraints to single-mode restraints, nor of the relative safety of children near the transition size in the two operating modes of the restraint. Further research could clarify this issue. In newer restraints, shoulder height markers typically indicate the minimum size at which a child can transition from one mode to the next (e.g. from rearward facing to forward facing, or from FFCR mode to booster seat mode). In older restraints, which may be labelled with weight ranges rather than ages or shoulder height markers, when to make this transition is less clear. Consistent with other recommendations for when to make these transitions (see recommendations 1.5, 1.7) the restraint mode designed for younger children is recommended for use for as long as the child fits in the restraint in that mode.

6.1.1 Rearward facing child restraints (RFCR)

Recommendation 1.5	**Children, from birth, should use rearward facing child restraints for as long as they fit within them.** ✋ • **For restraints certified to AS/NZS 1754(2004) or earlier which do not have shoulder height markers, the sign of the child having outgrown the restraint is when the child's shoulders are above the top shoulder harness strap slot for rearward facing use.** • **For restraints certified under AS/NZS 1754(2010) or later, the sign of the child having outgrown the restraint is when the child's shoulders are above the upper shoulder height marker for rearward facing restraint use.**
Overall Evidence Grade	**B**

Table 3: Evidence statement supporting recommendation 1.5

Evidence statement	**Rear facing restraints are very effective in reducing injuries to infants if used correctly**	
Grade	**B**	
Component	**Rating**	**Notes**

Evidence base	Good	Four studies of level III-2 evidence, one of level III-3 and two level IV, mostly retrospective cohort studies based on large datasets and nested in-depth case reviews, provide an excellent level of evidence for this recommendation. As for all field studies, there is some potential for selection bias in study samples.
Consistency	Excellent	Of the six studies that qualified for inclusion, four concluded that rear facing restraints are the safest for children until this style of restraint is outgrown. One study of fatalities only (Du *et al.*, 2008) found that the fatality risk was not significantly different between restraint types.
Public Health Impact	Excellent	Studies presenting Odds Ratios reported reductions of serious injuries or death for infants and young children in rear-facing restraints in the order of 88-96% compared with no restraints, and significant gains compared to adult seat belts or even forward facing restraints for children under 2 years.
Generalisability	Excellent	Studies were based in five different countries, including Australia, and mostly large population groups, so generalisability is considered to be very good.
Applicability	Good	Several studies are from overseas with different restraint designs than those allowed in Australia including 3 without top tether straps (McMurry *et al.*, 2018). Some older studies report findings relating to velcro-style infant capsules which are no longer manufactured for Australian use, but in all, a range of designs of RFCRs in use in a number of different of countries, including in Australia, have been shown to offer the greatest protection against injury for infants.
Other factors		The risk of crashing, linked with driver distraction if a child's face cannot be seen easily by the driver due to being faced in the other direction, is not yet known.
References		(Weber *et al.*, 1993; Henderson, 1994; Cuny *et al.*, 1997; Isaksson-Hellman *et al.*, 1997; Arbogast *et al.*, 2002; Durbin *et al.*, 2005; Henary *et al.*, 2007)

Field studies indicate that RFCRs offer 88-96% reduction in the risk of fatal and serious injuries to properly restrained infants compared to no restraint. A US study based on a large cohort of child passengers aged 0-23 months involved in all types of crashes reported children in this age group were 70% more likely to incur a serious injury if in a FFCR than a RFCR (Henary *et al.*, 2007). This paper was retracted (Henary et al., 2018) and re-analysis of the original study data (1988-2003) and a larger dataset (1988-2015) found no statistically significant difference in injury rates between RFCR and FFCR users under 2 years of age (McMurry et al., 2018). These US based studies include a large number of untethered restraints (forward and rearward facing) that are not used in Australia, and is thus of limited applicability. There is no evidence of serious neck injuries in correctly used Australian forward facing restraints for children over 6 months of age. Currently data are not available on the actual optimum age/size until which RFCR are most effective, however on balance, the evidence suggests that children should stay rearward facing as long as they fit within a rearward facing restraint. Further research is required on this issue.

Many current Australian rearward facing restraints, specifically Type A2 infant restraints and A2/B convertible restraints cater for and should be used for children up to at least 12 months of age, and longer for smaller children. Newer Type A4 restraints accommodate children to remain rear facing up to approximately 2.5 years of age. It is well recognised that geometric fit is a key determinant of restraint effectiveness (Eppinger, 1993). Ergonomics for restraints are based on AS/NZS 1754 (Standards Australia and Standards New Zealand, 2010) and an Australian study of anthropometric measures (Bilston and Sagar, 2007) together with US ergonomic data (Snyder *et al.*, 1975; Snyder *et al.*, 1977). Children are, on average, heavier and slightly taller than in the 1970s (Loesch *et al.*, 2000), and some children can be outside these typical ranges.

In some convertible child restraints certified to AS/NZS 1754 (2004) or earlier editions of the standard, the maximum shoulder harness strap slot that is suitable for rearward facing use may not be clearly identified on the restraint or in the instructions. In this case, the child's supine length (height) is a suitable way of determining when the child is too large for the RFCR. For A1 restraints, nominally suitable for children up to 9kg or 6-9 months of age, the child restraint is suitable for rearward facing use up to a supine length of 70cm, and for Type A2 restraints, nominally suitable for children up to 12kg or 12 months of age, this length is 80cm (Standards Australia and Standards New Zealand, 2013). Type A4 restraints are nominally suitable for children up to 30 months, and while no maximum height is nominated, these restraints all have shoulder height markers to guide selection. Restraints certified to the Australian Standard prior to AS/NZS 1754 (Standards Australia and Standards New Zealand, 2010) are labelled with child weight ranges rather than shoulder height markers. These weight ranges are not based on evidence, but rather are historical estimates for the age ranges that were recommended in earlier versions of the child restraint standard. Also, there is no field or laboratory testing evidence of a risk of structural failure in Australian child restraints, even in crashes well above the severities used in standards or consumer testing. Taken together with the restraint design principles that best protection is achieved by matching the geometry of the restraint to a child's anatomy, these factors suggest that there is minimal risk associated with the use of child restraints by children with weights that exceed the nominal weight ranges by a small amount (1-3kg). Further research could clarify this issue.

There is currently no research comparing the relative safety performance of different classes of Australian restraints within the rear facing category. i.e. comparing the safety performance of Type A1, Type A2, Type A4, and convertible restraints incorporating one of these in addition to a forward facing mode. It should be noted that optimal safety not only requires the child to use a size-appropriate restraint, but also for that restraint to be installed correctly and the child to be correctly secured within the restraint, and there is some evidence that convertible restraints are more likely to be used incorrectly than single-mode restraints (Brown *et al.*, 2010b). This issue requires further research.

Table 4: Summary of articles providing evidence for recommendation 1.5

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
(Arbogast *et al.*, 2002)	A stratified cluster sample study using a child specific crash surveillance system	III-2	USA	Data was collected from a large scale, population based, child-specific crash surveillance system. Analysis was conducted on children aged 12 to 47 months using forward facing restraints. Drivers of case vehicles were given telephone interviews; and investigations of the crash scene and vehicle were conducted within 24 hours of notification.	Injury severity and distribution (AIS).	43 children using a FFCR experienced injuries of AIS 2 or greater. 96% of the injuries were to the head, spine and extremities. Looseness of the vehicle seat belt and child restraint harness were shown to be contributing factors to injury risk. 11% of children received an injury to the neck, spine or back. Injury to the cervical spine during a crash occurred due to the interaction between large head accelerations and the underdeveloped biomechanical structure of the spine. It is suggested that rear-facing restraints use should be extended as they distribute crash forces across the entire torso, thereby protecting the neck.	Limitations of the study include use of car models from 1990 onwards, thereby excluding uninsured and older vehicles. Additionally, information was collected via a telephone interview, thereby introducing potential recall biases. Few tethered restraints in database of crashes, so of limited applicability to Australian restraints
(Cuny *et al.*, 1997)	Cohort study - review of data	III-2	France	Data sources (from 4 months during 1995-6) were police crash records together with medical records; 1327 children under the age of 10 were included.	Injury severity: AIS and MAIS.	Results indicate that RFCRs reduced the proportion of serious injuries (MAIS= 2+) by 88%, forward facing by 71% and booster seats by 31%. Findings suggested that misuse of CRSs results in the same proportion of serious injuries as no restraint.	One page article - methods section is too brief to know how misuse of CRS was measured, how subjected were included in the study or how estimates of proportion of injuries increased under different scenarios was calculated. It is assumed that no restraint was the index measure.
(Durbin *et al.*, 2005)	Cross-sectional study using a child specific	III-2	USA	Children 0-16 in 15 states who were involved in a MVC over a four year period (Dec 1998-Nov 2002) in cars 1990 or newer. Over-sampling of	Injury status and by severity (AIS<2 and 2+).	The highest risk of injury was to unrestrained children in the front seat (8.7%), followed by unrestrained in the back seat (3.5%). After adjusting	Age appropriate restraint use and second (or third) row seating work synergistically to achieve greater safety. Restraint use

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
	crash surveillance system			children presenting for medical treatment. Data from telephone interview with driver or proxy were included. Seating row and restraint use (correct and incorrect - with CRS or booster seat use for children <9 was classified as "correct"). Approx. 18000 children were included in the sample. Weighted logistic regression was used.		for age of child and type of vehicle, seating row and restraint status were both independently associated with injury risk. Compared to appropriately restrained children, inappropriately restrained children were at nearly twice the risk of injury as (OR: 1.8; 95% CI: 1.4 – 2.3), and unrestrained children were at more than three times the risk of injury (OR: 3.2; 95% CI: 2.5– 4.1). Seating row had less of an effect than restraint status, with front seat use increasing injury risk by 40% as compared to rear seat use (OR: 1.4; 95% CI: 1.2–1.7). Unrestrained children, compared with those appropriately restraint, in the front seat had 4.3 times greater risk of injury.	and seating position relied on driver reporting of this information. Study did not cover vehicles older than 1990 nor uninsured vehicles.
(Henary *et al.*, 2007) (RETRACTED)	Data review from crash surveillance system	III-2	USA	870 children 0-23 months old in a FFCR or RFCR old involved in a crash identified on the US NHTSA database 1988-2003 were included. Only those in restraints and not misusing them were included. Crash severity was estimated from vehicle mass and change in velocity, direction of force was utilised to create a variable 'proximity' indicating if child was on the same or other side than the intrusion.	Injury severity (ISS < 9 or 9+) and mortality.	THIS STUDY WAS RETRACTED IN 2017 DUE TO ERRORS IN ANALYSIS. FINDINGS EXCLUDED FROM EVIDENCE BASE. See (McMurry *et al.*, 2018)	Reference remains for reference only. Results not be considered.
(Henderson, 1994)	Data review of injuries resulting in hospital attendance or fatality.	III-2	Australia	Cases were 247 children aged <15 attending hospital following a MVC. Interviews with a parent, inspection of the vehicle and reconstruction of the crash event using the EDCRASH program to obtain estimates of speed, change in velocity and deceleration that is likely to be more accurate that reported during interview or from records. Restraint type was recorded. Vehicles were 1966-93.	Injury severity (AIS >2) and fatal injuries.	Side impact was the crash type most likely to result in a significant injury (34% of case children sustained an injury of AIS 2 or greater). Few infants were in capsules (n=6, 2.6%). Injuries by restraint type were summarised by possible mechanism. Lap-sash belts appeared to offer good protection but were only available in outboard seats. A higher proportion of unrestrained children had a serious injury or fatality (26.3% fatally injured, 42.1% suffered an injury of AIS 2 or greater), as compared with restrained children (p<0.01). A high proportion of the cases were in four-wheel drive cars and multi-passenger vehicles. Importance of seating position was highlighted. Concludes that restraints specifically designed for children are most protective and adult seat belts do not offer protection from side-impacts. Some indications that many children were moved out of a CRS too early.	Provides an overview of the types of restraints available. Study population not necessarily representative of all crashes in which children are injured and not those in which an injury was prevented. Strength of study was in understanding the crash event, not just the proportion of children injured and injury severity by each restraint type. Small numbers in some restraint types, e.g. capsules and forward facing restraints -limits conclusions.
(Isaksson-Hellman *et al.*, 1997)	Cohort study - review of data	IV	Sweden	Volvo crash surveillance database for the period 1976-1996 and includes 4242 child occupants involved in crashes. Details of the vehicle, and follow-up survey to obtain details on the crash and medical records of injuries. Injury risk was the number injured divided by the number of occupants for each group.	Injury severity: none or MAIS, 1, 2 3+.	Over the 20 year period there has been a marked decline in the risk of serious injury to children, particularly those under 3 years of age. Children in an adult seat belt showed a higher number of minor and serious injuries than those in a CRS. Compared to no restraint, RFCRs were found to reduce the proportion of children with serious injury (MAIS 2+) by 96%. Analysis suggests that optimal safety is not achieved unless the child is in the appropriate restraint for their age and size.	Vehicles were limited to Volvos - but allowed for more uniform comparison of the effectiveness of different restraint types. Large proportion of unknown restraint type. Confidence intervals are not reported even though there are several breakdown categories (severity of injury, type of restraint, direction of impact, body location of injury etc.) Results have too few numbers to be significant. No multivariate analysis. Significant differences to Australian restraint designs.

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
(McMurry *et al.*, 2018)	Re-analysis of data review from crash surveillance system by Henary 2007	III-3	USA	Review of cases of children 0-23 months for 1988-2015 on the US National Automotive Sampling System Crashworthiness Data System (NASS-CDS) database. Examined seat orientation (RF or FF) and injury outcome. Excluded those impacted by airbag deployment and roll-overs.	Injuries to children (ISS of 9 or greater or were fatally injured) plus individual injuries of AIS 2+ by body region.	Overall, there was a low injury rate of children up to 2 years of age identified on the NASS-CDS database. Both 0-year olds and 1-year-olds in all data year groupings experienced lower (but not statistically different) rates of injury when restrained in RFCRS compared with FFCRS.	Insufficient sample size for reasonable statistical power or for meaningful regression controlling for covariates
(Weber et al., 1993)	Spinal cord injury accident case review, full-scale crash reconstruction, and sled simulation	IV	Canada and USA	Transport Canada investigated a collision between two cars. This collision was then reconstructed using two vehicles. Finally, a 6-month dummy was used to determine kinematics and biomechanical responses to the crash.	Laboratory testing of head accelerations, neck loads and moments, dummy motions and head displacement.	Case child (6 months old) suffered a spinal cord contusion which resulted in paraplegia following a crash in a FFCR. Following sled testing, it was found that harness tightness (slack vs. tight), back angle, and tether (present vs. absent) made little different to the forces and moments experienced by the neck of the dummy (average force of over 1200N). Rear-facing restraints appear to significantly reduce the forces experienced by children under 1 year old in the event of a crash.	A limitation of this study is that no sled-tests were conducted to determine the response of a 6 month old dummy using a rear-facing restraint under similar crash conditions.

Consensus Based Recommendation 1.6	**Restraints designed for extended rearward facing use up to approximately 2-3 years of age are now available (Type A4). These are an acceptable alternative to use of a forward facing child restraint for children who fit within them.** • **For these restraints, the sign of the child having outgrown the restraint is when the child's shoulders are above the upper shoulder height marker for rearward facing restraint use.**

This consensus-based recommendation is based on expert opinion, taking into account the following considerations. There is currently no field or laboratory testing experience with these new restraints, which differ substantially in design from overseas restraints for extended rearward facing use, however these restraints will be required to pass similar performance tests as for rearward and FFCRs in Australia and are likely to offer good protection. There is currently no evidence to support a recommendation to either encourage or discourage the use of these restraints compared to properly used FFCRs for children who have outgrown a Type A2 rear facing restraint. Further research is required to assess their performance and any potential benefits compared to FFCRs.

6.1.2 Forward facing child restraints (FFCR)

Recommendation 1.7	**Children should use forward facing child restraints with an inbuilt 6-point harness (Type B) system from the size that they outgrow their rearward facing infant restraint, until their shoulders are above the maximum allowable height for their forward facing restraint.** ✋ • **For restraints certified to AS/NZS 1754(2004) or earlier, which do not have shoulder height markers, the sign of the child having outgrown the restraint is when the child's shoulders are approximately 2.5cm above the top shoulder harness strap slot for forward facing use.** • **For restraints certified under AS/NZS 1754(2010) or later, the sign of the child having outgrown the restraint is when the child's shoulders are above the upper shoulder height marker for forward facing restraint use.**
Overall Evidence Grade	**A**

Table 5: Evidence statement supporting recommendation 1.7

Evidence statement	***FFCRs are highly effective in preventing injury.***	
Grade	**A**	
Component	**Rating**	**Notes**
Evidence base	Good	Nine studies from Australia and internationally provide evidence that forward facing restraints are more effective than adult seat belts for children up to 6 years of age.
Consistency	Excellent	Findings are in the same direction for all studies. Studies that provide risk estimates show that the benefit of FFCR is greater for younger children (2-3 years) than older children – however all children less than 6 were found to be safer in FFCRs than in adult seat belts.
Public Health Impact	Excellent	From 71-88% reduction in risk of serious injury was found if using a properly fitted child restraint compared to an adult seat belt for children aged approximately 2-6 years of age.
Generalisability	Good	Studies are from a variety of countries, including Australia, and findings are consistent. The appropriateness of the fit of the child in the restraint is important to the restraint's effectiveness. There are limitations to the generalisability of older studies as children may, overall, be heavier than several decades ago, and studies have not been conducted on specific ethnic groups where children may be outside the size-for-age ranges used in anthropometric studies.
Applicability	Good	In addition to the directly relevant studies, there are a number of older studies and international studies which examine FFCRs designs not currently used in Australia, particularly forward facing restraints without top tethers, that

		are of limited relevance to currently used Australian restraints. However, their findings are similar to the Australian studies.
Other factors		
References		Evidence includes field data (Henderson, 1994; Cuny *et al.*, 1997; Winston *et al.*, 2000; Arbogast *et al.*, 2004; Brown *et al.*, 2005; Brown *et al.*, 2006b; Zaloshnja *et al.*, 2007) and laboratory testing (Brown *et al.*, 1995; Bilston *et al.*, 2005)

Current Australian forward facing restraints, particularly Type B restraints and B/E convertible restraints used in forward facing restraint mode, cater for 95% of children up to their 4th Birthday (Bilston and Sagar, 2007). There are numerous studies from Australia and internationally that provide evidence that FFCRs, particularly those with top tether straps, as required in Australia, better protect children up to the age of 6 (and in some studies, older) than an adult seat belt during a crash. Laboratory studies have some limitations due to the biofidelity of the anthropomorphic test dummies (ATD) and a limited number of restraint types tested. However, these studies strongly show that FFCRs are effective in reducing contact between the child and other objects in the event of a crash, and head accelerations and neck forces that are associated with head and spinal injuries, respectively. Field data, based on surveillance systems capturing large numbers of events in a variety of restraint and collision types, from other countries and some within Australia support the laboratory findings.

FFCRs offer optimal protection for children who fit within them (Brown *et al.*, 2006b; Zaloshnja *et al.*, 2007; Brown and Bilston, 2009). Laboratory studies with 3 year old ATD in FFCRs and boosters indicate that the risk of death or serious injury is likely to be lower in the child restraint than the booster (Brown and Bilston, 2006b; Bilston *et al.*, 2007).

Restraints certified to the Australian Standard prior to AS/NZS 1754(2010) are labelled with child weight ranges rather than shoulder height markers. These weight ranges are not based on evidence, but rather are historical estimates for the age ranges that were recommended in earlier versions of the child restraint standard. Also, restraints are tested with crash test dummies that are larger and heavier than the maximum nominal weight (for FFCRs, this is a 23kg 6 year old test dummy), and there is no field or laboratory testing evidence of a risk of structural failure in Australian child restraints, even in crashes well above the severities used in standards or consumer testing. Taken together with the restraint design principles that best protection is achieved by matching the geometry of the restraint to a child's anatomy, these factors suggest that there is minimal risk associated with the use of child restraints by children with weights that exceed the nominal weight ranges by a small amount (1-3kg).

Table 6: Summary of articles providing evidence for recommendation 1.7

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
(Arbogast *et al.*, 2004)	Cross sectional study, insurance records	IV	USA	Completed surveys on 1207 children aged 12-47 months involved in crashes from 15 states (selected from database of insurance records) over period of 3.5 years of children (booster seat and forward facing restraint).	Injuries defined as minor (<2) or serious (2+) based on telephone survey with parents and use of AIS. This was combined with data on severity of crash to determine a restraint effectiveness estimate.	The risk of serious injury was 78% lower for FFCRs than adult seat belts (OR=.22, CI= .11-.45 $p<0.001$) and 79% lower for risk of hospitalisation (OR=.21, CI=0.09-.5, $p<0.001$). No difference in restraint types in preventing minor injuries.	Limitations in sampling - those captured by insurance claims. Recall bias possibilities with telephone interviews after the incident.
(Bilston *et al.*, 2005)	Laboratory testing - simulated side-impact, instrumented dummies and high-speed cameras	III-2	Australia	Two differently designed FFCR were tested (older and newer style) - all with top tethers in place. Different belt routing positions were tested and head injury criteria plotted via sensor outputs.	Contact between dummy's head and thorax and the door - using chalk paint and review of high-speed camera footage.	Findings indicated that anchorage points have profound effect on head protection for side-impact. Completely rigid lower attachment of restraints offers greater potential for reductions in head injury risk, than anchorage systems. The addition of energy absorbing material in the side structure of restraint systems is effective when the head is fully contained within an adequately designed side wing structure. For restraints anchored by seat belts and loop style semi rigid anchorage straps, belt routing has the potential to significantly affect occupant head excursion.	Test dummies, while most advanced available, were not designed for side-impact tests.
(Brown *et al.*, 1995)	Laboratory study - sled testing	III-2	Australia	Using a dummy to simulate a 6 month old, 3 models of forward facing 6-point harness CRS were tested. Two had high mounted tethers, and one low. Several sensors were used to detect forces and moments on key body locations. Crash events were captured on a high-speed camera. 12 separate tests were conducted.	Upper and lower neck lumbar forces and moments. Loads and acceleration on head, chest and pelvis.	Restraints with the high mounted tether tended to have lower head acceleration, and lower neck axial loads. It appeared that the lower tethered restraint performed not very differently to a restraint just anchored by a 3-point belt.	Only one kind of low mounted restraint was used. Collisions types limited to frontal.
(Brown *et al.*, 2005)	Review of medical record data crash investigation and interview with the driver.	III-2	Australia	152 Children aged 2-8 presenting to 1 of from 2 paediatric hospitals in Sydney, as a result of a MVC. Drivers were interviewed and an inspection of the vehicle before repair, where possible. Results indicate optimal restraints for 2-4 year olds were FFCR with a 6-point internal harness, for 4-6 year olds: belt positioning booster seat with lap-sash belt, and for 6-8 year olds: an adult lap-sash belt. Crash impact parameters were calculated, age and height and weight were collected. Data from Henderson's 1994 study was analysed.	Injuries - by AIS code.	Only 18% of children were optimally restrained. A non-significant difference between the proportion of sub-optimally restrained who were injured (76%) and those optimally restrained (61%) - but when examining only serious injuries the difference was significant (29% versus 0% respectively). Younger children who are inappropriately restrained are at higher injury risk than older children.	Sample was from paediatric teaching hospitals so biased towards the more serious injuries. Cross validation of findings done on several factors. Optimal restraint was adapted from the American Academy of Paediatrics guidelines (2005). Misuse was not able to be included, except where gross misuse was evident as noted on the ambulance form or medical record. Fewer children unrestrained (3%) than 10 years earlier in the Henderson study (11%).
(Brown *et al.*, 2006a)	Retrospective case review, portion with in-depth investigation including laboratory simulation of main use errors.	III-2	Australia	Review of 152 children aged 2-8 years and restraints involved in crashes and presenting to a paediatric emergency department. Assessment of restraint use, quality of restraint, data on heights and weights from interview or medical records - or age-based estimates. Comparisons made between appropriate and inappropriate use and fit for size. Also 6 sled crash tests were done to simulate outcomes in optimal and sub-optimal restraint use	Correct/incorrect use of restraint (appropriateness of restraint for child and correct use). Laboratory testing of head accelerations, neck loads and moments, dummy motions and head displacement.	Of the 142 cases for which quality of restraint use was known, 82% were sub-optimally restrained - with 78% using inappropriate restraint for size. An injury AIS 2+ (serious was incurred by 0% of those who were appropriately restrained and 28% of those inappropriately restrained (not significant after controlling for crash severity); and moderate injuries were incurred by 22% and 57% ($p<0.05$) respectively. Incorrect use was associated with 6 times the risk of life-threatening injury after controlling for crash severity. Laboratory testing confirmed that excessive torso and head movement occurs with incorrect belt	Quality assessments not made blind to the injury outcome. Convenience sample of children presenting to hospital - excludes minor injuries and deaths. Limited data available as used case review only - not collected systematically.

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
						use. Results suggest that incorrect use of a restraint is potentially more serious in terms of risk of injury than using the incorrect restraint for size.	
(Cuny *et al.*, 1997)	Cohort study - review of data	III-2	France	Data sources (from 4 months during 1995-6) were police crash records together with medical records; 1327 children under the age of 10 were included.	Injury severity: AIS and MAIS.	Results indicate that rear facing CRs reduced the proportion of serious injuries (MAIS= 2+) by 88%, forward facing by 71% and booster seats by 31%. Findings suggested that misuse of CRSs results in the same proportion of serious injuries as no restraint. Children in vehicles where the driver was at fault in the crash were more likely to be unrestrained and more likely to be seriously injured.	One page article - methods section is too brief to know how misuse of CRS was measured, how subjected were included in the study or how estimates of proportion of injuries increased under different scenarios was calculated. It is assumed that no restraint was the index measure.
(Henderson, 1994)	Data review of injuries resulting in hospital attendance or fatality.	III-2	Australia	Cases were 247 children aged <15 attending hospital following a MVC. Interviews with a parent, inspection of the vehicle and reconstruction of the crash event using the EDCRASH program to obtain estimates of speed, change in velocity and deceleration that is likely to be more accurate that reported during interview or from records. Restraint type was recorded. Vehicles were 1966-93.	Injury severity (AIS >2) and fatal injuries.	Side impact was the crash type most likely to result in a significant injury (34% of case children sustained an injury of AIS 2 or greater). Few infants were in capsules (n=6, 2.6%). Injuries by restraint type were summarised by possible mechanism. Lap-sash belts appeared to offer good protection but were only available in outboard seats. A higher proportion of unrestrained children had a serious injury or fatality (26.3% fatally injured, 42.1% suffered an injury of AIS 2 or greater), as compared with restrained children ($p<0.01$). A high proportion of the cases were in four-wheel drive cars and multi-passenger vehicles. Importance of seating position was highlighted. Concludes that restraints specifically designed for children are most protective and adult seat belts do not offer protection from side-impacts. Some indications that many children were moved out of a CRS too early.	Provides an overview of the types of restraints available. Study population not necessarily representative of all crashes in which children are injured and not those in which an injury was prevented. Strength of study was in understanding the crash event, not just the proportion of children injured and injury severity by each restraint type. Small numbers in some restraint types, e.g. capsules and forward facing restraints -limits conclusions.
(Winston *et al.*, 2000)	Retrospective review of data from crash surveillance system + interview	III-2	USA	Sentinel surveillance from insurance claims in 15 states in the USA, follow-up telephone interview with parents. Automated sampling process to select participants.	Crashes requiring medical treatment to child occupants 0-15 years.	11,123 cases for a one year surveillance period were included 8334 interviews completed. Young children in seat belts were 3.5 times more likely to incur a significant injury and 4.2 times more likely to incur a head injury than those in a child restraint. The risk of significant injury was greater for children aged 2-3 than those aged 3-5 years if wearing an adult seat belt compared to a dedicated child restraint. Recommend that stay in CR until at least 4 years and 18 kg.	Real-world study, and as result a certain level of misuse of restraints that could not be controlled for. Restraint use was self-reported during the interview after the crash.
(Zaloshnja *et al.*, 2007)	Cohort study - review of data	III-2	USA	Reviewed 7 years of data of crashes that involved a tow-away and examining the restraint being used by children aged 2-3 years (as all being of a size suitable for child restraints). Data on 409 children were available and compared child restraint with lap-sash belt.	Any injury (vs. none).	Child seat provided significantly better protection than the lap–sash belt (82% reduction in risk of injury after controlling for vehicle and crash characteristics including crash severity). Protective value of the CR was greatest in roll-over events (OR = 5.79for seat belt). This study suggests that child safety seats are more effective than lap- safety belts for children aged 2 to 3 years seated in the rear.	As child seat types not described, results did not cover severity of injury by restraint type – and were likely to be different than Australian types. Limited to 2-3 year old children and no information on correct use of restraint.

Consensus Based Recommendation 1.8	**Restraints designed for extended forward facing use with an inbuilt 6-point harness for children up to approximately 8 years of age are now available (Type G AS/NZS 1754). These are an acceptable alternative to use of a booster seat for children who fit within them.**

This consensus-based recommendation is based on expert opinion, taking into account the following considerations. There is currently no peer reviewed published field or laboratory testing experience with such restraints, either in Australia or overseas, however these restraints will be required to pass similar performance tests as for FFCRs in Australia and are likely to offer good protection. There is currently no evidence to support a recommendation to either encourage or discourage the use of these restraints compared to well-fitting high back booster seats for children too large for Type B FFCRs. Further research is required to assess the performance and any potential benefits compared to booster seats.

Recommendation 1.9	**Once a child has outgrown their forward facing child restraint, they should use a booster seat (Type E or Type F in AS/NZS 1754) until they can no longer fit within it or can achieve good seat belt fit as assessed by the '5 step test' in the vehicle they are riding in. Most children up to 10-12 years of age will require a booster seat to obtain good belt fit.** ✋
Overall Evidence Grade	**B**

Parents and carers are recommended to exhaust all booster seat options before using a seat belt alone for a child who cannot achieve good seat belt fit. Good seat belt fit depends on the match between the child and the vehicle seat and seat belt geometry. Vehicle seats and seat belts vary considerably, but good seat belt fit in most vehicles is generally not achieved for most children until approximately 10-12 years of age. There remains a potential gap in optimal protection for children who have outgrown currently available booster seats (Type E, Type F) but still cannot achieve good seat belt fit in some or all vehicles, as assessed by the 5 step test.

Table 7: Evidence statements supporting recommendation 1.9

Evidence statements	***1. Booster seats mitigate the risk of serious injuries to children too small for adult seat belts and poor lap belt fit is associated with increased risk of abdominal and head injuries.*** ***2. Poor shoulder belt fit is associated with increased risk of neck injuries*** ***3. Poor shoulder belt fit is associated with increased risk of spinal injuries*** ***4. Children do not get good adult belt fit until they can sit upright (not slouching) with the lap belt low and firm across the iliac spines of the pelvis and shoulder belt in centre of shoulder*** *(see corresponding references – note references span multiple ages)*	
Grade	**B**	
Component	**Rating**	**Notes**
Evidence base	4-8 year olds: Good 8-12 year olds: Satisfactory	Studies are quite heterogeneous in terms of the age groups, crash conditions and restraint types examined which makes defining the precise transition age or size problematic. A mix of field data (10 studies and one systematic review) and laboratory studies (3 studies) provide good evidence for this recommendation for children aged 4-8 years, showing that lap-sash adult seat belts are less effective than booster seats or child restraints for children due to poor fit which results in poor distribution of restraint forces on the child in the event of a crash. One systematic review (Asbridge *et al.*, 2018) found no benefit of booster seats over seat belts in terms of injury or mortality, and noted the poor quality of many studies, including failure to adjust for important confounders. There is limited field data for injuries to booster seat users vs. seat belt users specifically for children over 8 years of age or older. The evidence base for older children is less direct, and relies on studies of poor seat belt fit, and field data that shows that children in this age group sustain similar abdominal injuries to younger children in seat belts (Miller *et al.*, 2002; Campbell *et al.*, 2003) and an apparent reduction in injury risk (but numbers are too small for statistical analysis). One field study showed an increased risk of spinal injuries for children aged 8-12 in adult seat belts compared to adults (Brown and Bilston, 2009).
Consistency	4-8 year olds: Satisfactory 8-12 year olds: Satisfactory	Results on booster seat effectiveness largely find a benefit in injury reduction, but the data is not completely consistent. While two studies (Miller *et al.*, 2002; Rice *et al.*, 2009) found that for 4-7 year olds in the rear seat there was no safety advantage of booster seats than adult seat belts for fatalities, and one study found no protective effect for injury (Ma et al., 2013) most other studies that included injuries as well as fatalities reported that younger children (albeit age groups varied in different studies) are less well protected in adult seat belts than in booster seats. One meta-analysis found no benefit of booster seats over seat belts (Asbridge *et al.*, 2018). For older children, while evidence is largely limited to anthropometric studies, three studies such indicated that a good seat belt fit is not achieved until the child is approximately 10-12 years of age, and in some cases older depending on the child and the vehicle (Klinich *et al.*, 1994; Huang and Reed, 2006; Bilston and Sagar, 2007).
Public Health Impact	Excellent	Studies assessing the relative risk of injury found a significant reduction in serious injury risk or fatality (approx. 30-80% reduction) for younger children (approx. 4-8 years) in belt-positioning booster seats compared to adult seat belts when controlling for age. For older children, only one study employing field data was identified and it concluded that an increased risk of spinal injuries extends to children up to 12 years of age if they are using a seat belt rather than a

		booster seat in the event of a serious crash (Brown and Bilston, 2009). Some studies include a mix of children across these two age groups.
Generalisability	Good	Large databases from field studies from a few different countries provide a good level of generalisability of the available evidence. Studies include field injury data, ergonomic studies of booster seat and seat belt fit (largely based on measurements of child size). Thus, the findings should be able to be generalised to all children where such sizes can be determined, regardless of ethnic or cultural backgrounds. There is a paucity of evidence for older children, however, the ergonomic principles can be expected to be relevant to this age group.
Applicability	Good	Booster seats and vehicle seat belt systems are very similar internationally to those in Australia, and international studies are thus directly applicable to the Australian context for younger children. However, the international studies likely include a larger proportion of booster cushions, which are being phased out in Australia, due to changes in AS/NZS 1754 in 2010. Six studies from Australia (three within the last five years), with consistent results with overseas studies, indicate a good level of the applicability of the findings to the current Australian context. Only one field study (Brown and Bilston, 2009) provides outcome data on children up to 12 years of age, although one US-based study includes a small number of children aged 8-10 years (Ma et al., 2013). Two of the anthropometric studies which consider child sizes un to around 150cm tall, are relatively recent. One U.S. study examined data from 56 different vehicles (Huang and Reed, 2006) and one Australian study examined data from 51 vehicles (Bilston and Sagar, 2007), so, their findings are applicable to the Australian context. However, no data are available for more recent vehicle models.
Other factors		There are limitations to the testing of dummies in a slouched position, which may mean laboratory data underestimates rather than overestimates the relative risk.
References		1. (Isaksson-Hellman *et al.*, 1997; Winston *et al.*, 2000; Miller *et al.*, 2002; Durbin *et al.*, 2003; Brown *et al.*, 2005; Charlton *et al.*, 2005; Brown and Bilston, 2006a; Miller *et al.*, 2006; Arbogast *et al.*, 2007; Bilston *et al.*, 2007; Arbogast *et al.*, 2009b; Brown and Bilston, 2009; Kirley *et al.*, 2009; Rice *et al.*, 2009) 2. (Bilston *et al.*, 2007) 3. (Brown *et al.*, 2005; Brown and Bilston, 2009) 4. (Klinich *et al.*, 1994; Huang and Reed, 2006; Bilston and Sagar, 2007)

This recommendation is based on evidence from a mix of study types including crash or injury surveillance data supplemented with data from interviews with the driver of the motor vehicle together with in-depth crash analysis and laboratory studies. Available field studies available are quite heterogeneous in the populations studied (including the age of children included) and their methodologies, so precise size or age cut-off at which booster seats are no longer required are not well defined to date. There may be a gradually decreasing risk as the child grows from age 4-12 and seat belt fit improves, but currently there isn't strong evidence about the injury risks for different age or sized children too small to obtain good seat belt fit without a booster seat. Anthropometric data (Klinich *et al.*, 1994; Huang and Reed, 2006; Bilston and Sagar, 2007) demonstrated the physical mismatch between child anthropometry and rear seat cushions and seat belt geometry in vehicles.

The evidence suggests that children should not use an adult seat belt alone until they can achieve good rear seat (i.e. they can sit upright without slouching) and seat belt fit. Good seat belt fit can help prevent the risk of 'submarining' (where the child slides underneath the lap belt), or 'seat belt syndrome' (SBS) (injuries to the lumbar spine or abdominal region, or neck injuries from the sash belt). This requires that the child's thighs are long enough to allow them to sit comfortably with their lower back against the back of the seat, and their knees bent in front of the front edge of the seat AND the sash part of the seat belt should pass across the middle of the shoulder, not across the neck. These are the elements of fit summarised in the "5 step test". A minimum standing height (typically in the range of 145-150cm, although 135cm is used in some locations in Europe) is sometimes recommended as a transition point to adult seat belts, rather than the more comprehensive "5 step test" recommended here, and the suitability of standing height as a transition marker for adult seat belt fit was a topic of debate, particularly among input from the project steering committee, largely due to the relative simplicity of communicating a specific standing height as a transition compared to the "5 step test". However, the evidence base for a specific standing height as the safe transition point is limited. There is considerable variation in rear seat and seat belt geometry in passenger vehicles (Bilston and Sagar, 2007) and in the proportions of leg and torso size in children of similar standing height (Bilston and Sagar, 2007), and thus standing height is not considered to be a good metric for assessing suitability of seat belt fit for a specific child in a particular vehicle. Moreover, the use of a specific standing height as a minimum requirement for adult seat belt use can create confusion for parents and carers, because there remains a gap in restraint availability for children who have outgrown currently available booster seats (Type E, Type F in As/NZS 1754) but still cannot achieve good seat belt fit in some or all vehicles. Specifically, Type E and Type F booster seats are not required to (and do not) accommodate all children up to the commonly quoted standing height of 145-150cm for transition to adult seat belt use, making this an unsuitable metric for transition. Finally, there is some evidence that parents and carers often do not accurately know their child's height and/or weight, but do know their age (Bilston *et al.*, 2008), so a statement of expectation that good seat belt fit is unlikely to be achieved before the age range of 10-12 years (Bilston and Sagar, 2007) is included to set reasonable expectations for the minimum age that a child can achieve good adult seat belt fit, and a time at which the "5 step test" can reasonably be used to test for good seat belt fit. Further research is required on how best to communicate good seat belt fit requirements for the transition to adult seat belts, including the "5 step test".

Recent international studies provide a mixed picture of booster seat effectiveness, with some demonstrating benefit and others not finding benefit in preventing injuries compared to seat belts. There is one meta-analysis (Asbridge *et al.*, 2018) which did not find a benefit of booster seats over seat belts alone, but the authors noted the poor quality of included studies, heterogeneity of booster seats used, and that studies generally did not address the quality of belt fit achieved by boosters used. Many of these studies include low back boosters now only rarely used in Australia. There is little evidence addressing the direct link between booster design and the belt fit achieved and injury outcome. There is a need for research to examine booster seat effectiveness in the Australian context.

With evidence that poor seat belt fit is associated with an increased risk of serious abdominal injuries (OR = 1.7-4.2) combined with the evidence on the requirements for a good adult seat belt fit for children (i.e. typically up to and including 10-12 years of age) it is likely that children are better protected in crashes if they are in a booster seat until they can achieve a good fit in an adult seat belt.

Restraints certified to the Australian Standard prior to AS/NZS 1754(2010) are labelled with child weight ranges rather than shoulder height markers. These weight ranges are not based on evidence, but rather are historical estimates for the weights that match age ranges that were recommended in earlier versions of the child restraint standard. Also, restraints are tested with crash test dummies that are larger and heavier than the maximum nominal weight (for Type E booster seats, this is a 32kg 10 year old test dummy, and for Type F booster seats, this is a 36kg 10 year old dummy), and there is no field or laboratory testing evidence of a risk of structural failure in Australian child restraints, even in crashes well above the severities used in standards or consumer testing. In addition, the primary restraint forces in booster seats are borne by the seat belt rather than the booster itself. Taken together with the restraint design principles that best protection is achieved by matching the geometry of the restraint to a child's anatomy, these factors suggest that there is minimal risk associated with the use of booster seats by children whose weight exceeds the nominal weight range by a small amount (1-3kg), if the child still fits well into the booster seat and cannot achieve good seat belt fit without a booster.

Table 8: Summary of articles providing evidence for recommendation 1.9

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
(Anderson *et al.*, 2017)	Retrospective longitudinal study using a crash surveillance system	III-2	USA	Analysis of police attended crashes involving children 8-12 years of age in Washington state, USA (2002-2015). Children were those travelling as passengers and using either a booster seat or only a seat belt. Data on 75,859 children were analysed. Logistic regression analysis used to assess the impact of the booster seat compared to the seat belt alone on the level of injury. Adjusted models included consideration of individual-, vehicle-, and crash-level variables.	Injury status and by severity according to the KABOC scale which assesses none or non-evident, incapacitating or fatal	Steep increase in use of booster seats among 8-12 year olds over the surveillance period, with 2% using them in 2002 and 14% in 2015. The use of a booster compared to seat belt alone was associated with a 19% reduction in the odds of any injury after adjusting for other factors (OR=0.814, 95% CI=0.749, 0.884). When examining the findings by sub age groups, using a booster was seen to be associated with a 13% reduction in chance of any injury for 8-9 year olds (OR=0.869, 95% CI=0.818, 0.923) and a 33% reduction among 10-12 year olds (OR=0.675, 95% CI=0.505, 0.902). Boosters, compared to seat belts alone were not found to be associated with a difference in risk of fatal or incapacitating injury, for all age groups combined nor when analysed by the two sub age groups.	Used the KABOC scale for injuries: quite crude and determined by police: non-evident (none or minor), incapacitating, fatal. Measures of the height and weight of the children were not available, so this may have been a factor in whether older children wear boosters and the potential added protection they may offer.
(Arbogast *et al.*, 2007)	Retrospective data review - child injury surveillance system	III-2	USA	Abdominal injuries (n=21) compared to those without abdominal injuries (N=16) in children 15 years or less. Detailed case review of those under 12 sustaining an abdominal injury (AIS >2) from a frontal crash. A second group with similar crashes but without severe abdominal injury were reviewed.	Abdominal or chest wall injury, other injuries.	Seat belt loading directly over the injured organs was responsible for the majority of the abdominal injuries. The loading was attributed to either poor seat belt positioning, poor child posture or misuse of the shoulder belt.	Convenience sample from insurance database from 15 states plus DC. Mechanism of injury was inferred from analysis after the crash.
(Arbogast *et al.*, 2009a)	longitudinal cohort study	III-2	USA	Review of insurance claims of children 4-8 years seated in the rear seat in MVC - data from 16 states plus DC for 8 year period + interview with parents selected via a stratified cluster sample. Interviews were conducted on approx. 35000 children from 530,000 involved in crashes.	Level of medical treatment following the crash: no treatment, physician's office or emergency department only, admitted to hospital or death) Injury severity of AIS 2 or higher.	1.15% of all children in the sample incurred an injury of a severity rating of AIS 2 or higher. The risk of this level of injury was almost half of that for children in booster seats compared to those in a seat belt (OR=0.55, CI= 0.32-0.96) Children in side impact crashes benefited the most from booster seats, showing a reduction in injury risk of 68% for near side impacts and 82% for far-side impacts. No significant difference in the risk of injury between the children in backless versus high-back boosters (OR: 0.84; 95% CI: 0.44 –1.61). Head injuries were the most common - and abdominal injuries were mostly associated with seat belt use - not boosters.	Large sample - but limited to one major insurance group - so potentially some biases in sample selection. Further detail provided about the type of injuries incurred. Findings do not suggest type of booster seat significantly alters the risk of injury - important findings as backless boosters are cheaper and generally more acceptable to older children.
(Asbridge *et al.*, 2018)	Systematic review and meta-analysis of observational studies	II	USA	Systematic review of all suitable studies up to December 2016 of observational studies of children aged 4-10 years involved in MVC. Experimental laboratory and simulator studies, and case reports were excluded. A meta-analysis was conducted to determine if sufficiently homogeneous data were available.	Main outcomes included were injury and fatality	Eleven articles were included in the review. In all, no association between booster seats and risk of serious or fatal injuries was identified. Of studies with unadjusted analysis, 2 found booster seats were protective of AIS 2+ injuries compared to adult seat belts; one found they were associated with an increase in the risk of injury, and 4 found no difference. Three studies provided adjusted analysis and all reported boosters as a protective factor against AIS 2+. The meta-analy*sis* (which included 4 studies) revealed no significant difference in risk of AIS 2+ (OR 1.03, 95% CI 0.53–1.99). Null effect was also observed when removing studies with potential high levels of bias, and when limiting the analysis to the 2 studies with adjusted analysis. Similarly, when studies examining fatalities were	Only 4 studies were suitable for inclusion in the meta-analysis, and two of these had small sample sizes. Limited selection of studies by age range of children, not height and weight so may have missed studies showing greater association. Also, whether the boosters were used correctly or not was not examined. Data was from articles that examined crashes from 2002-2009, and there have been improvements in design since that time.

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
						examined there were no significant reduction in risk for those wearing booster seats. Results were mixed for studies examining specific injuries such as head, face and limbs. When reviewing studies that examined types of boosters, only high-back booster seats were fund to have a significant protective effect compared to seat belts. No study found differential effect when considering the age group of the children.	
(Baker *et al.*, 2018)	Observational study of kinematics of children in vehicles under "sharp turning" conditions	III-2	Sweden	Observational study of 18 child volunteers (aged 5-10 years) on a backless booster cushion and a 2-stage integrated booster cushion. Professional driver did sharp turns at 50kph. Seat position was right-side rear seat, and child was restrained by the 3-point seat belt. Video tracking software was used to assess the kinematics of the child.	Shoulder belt (SB) engagement and seat belt to body interaction were assessed.	Booster cushion type and the child's height interacted to influence seat belt to body interaction. On the whole, shorter children on the booster cushion displayed slightly more lateral displacement of the nasion than taller children, although there was not a large range of lateral displacements across all children. The seat belt generally stayed on the shoulder, with 89% of slip-off instances occurring for shorter children on the BC than among taller children. Children loaded the shoulder belt by axially rotating their torso into the seat belt more often on the integrated booster cushion than the booster cushion.	Only one model of booster cushion was used. Other models may change the seat belt position and change the gap between the seat belt and the torso. The study used only 18 children under a known test condition with a professional driver. This is a limitation to the translation of the finding to the unexpected crash situation - as well as to injury outcomes.
(Bilston and Brown, 2007)	Retrospective case review with binomial logistic regression	IV	Australia	Data for children up to 16 years of age attending one of two paediatric hospitals with a spinal injury were collected. 340 children were identified.	Spinal injuries: injury mechanism, type and location on the spine.	Traffic related injuries were found to be the most common cause of injury. More minor neck injuries were reported in the 9-12 age range, and most were associated with sitting in the front seat, and were obtained following whip-lash like movement.	All types of spinal column injury analysed from 2 major children's hospitals. Non-spinally injured controls not included.
(Bilston and Sagar, 2007)	Seat &, seat belt geometry measurements and child anthropometric data	IV	Australia	51 vehicle right rear outboard seating positions were measured from a range of late model (2005/6) vehicles.	Anthropometric measures: seated shoulder height, seated eye height, shoulder breadth; measurements of rear seat geometry - cushion depth, angles etc. for common vehicles models on the Au market.	Findings suggested that for the shortest seat cushion, at 50th percentile a child does not have adequate length for good seated posture until 11.5 years of age, and in average car seat, the average child is 15 before being the right size for good posture. Good geometric fit is important for its influence on graduation from one restraint type to another and premature graduations is associated with lower levels of protection in crashes.	Comparative study of vehicle and restraint geometry with child anthropometry from published data. Assumed that Us child population is good representation of Australian child population. Australian cars and restraints measured.
(Bilston *et al.*, 2007)	Observational study - crash laboratory simulation of real crashes	III-2	Australia	Reconstruction of crashes in which 4 children aged 2-8 were injured and another 4 with minor injuries - assessing child kinematics. Comparison with crashes in which children would not have been injured and with crashes in which the same restraints were correctly worn.	Measurement on dummies of tri-axial head acceleration and upper neck forces and moments - some had tri-axial pelvis accelerations measured instead.	Detailed case by case analysis of real scenario, and when varying factors to do with restraint use in the lab. Results indicate that inappropriate use and misuse of restraint by child occupants can result in unfavourable kinematics - exposing child to high risk of injury.	Dummy sensors were not useful in predicting injury (as evidenced by the injuries sustained in the real situations). Differences in crash factors (not being able to replicate it exactly) may have contributed.
(Brown and Bilston, 2006a)	Laboratory testing - based on real-world crashes	III-2	Australia	152 Children aged 2-8 presenting to a paediatric hospital between July 2003 and January 2005. Cases where good restraint information could be determined were kept, leaving 142. Restraint use was labelled as either appropriate or inappropriate, and correct or incorrect. Laboratory testing of misuse models was performed.	Injuries - by MAIS and ISS codes – in three levels; minor injury (ISS>4), moderate injury (ISS>9), and severe injury (ISS>15).	Incorrectly restrained children were 7 times more likely to sustain life-threatening injuries. There was a higher proportion of abdominal injury among those incorrectly restrained (unadjusted OR for abdominal injury in incorrectly restrained 2.1, CI 95% 0.39-10.7, adjusted OR=1.8, CI 95% 0.34-9.5). Inappropriate restraint use, including premature graduation to an adult seat belt, was seen as the most common form of sub-optimal restraint use.	The field sample may be more biased towards more serious crashes as children were collected following admittance to the emergency department.

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
(Brown and Bilston, 2009)	Retrospective record review	IV	Australia	72 cases of spinal trauma in children under 17 years of age. Data extracted on positioning, type and correct/incorrect use of restraint (recorded by ambulance officer) along with demographics and crash severity (low, med, high). Aged split into below and above 8 years.	Spinal injuries: classified as minor/external and soft tissue damage (approx. AIS=1), and major which were those that posed some risk to the spinal cord or column.	72 cases were identified (58 $\leq$ 12 years of age, 14 >12 years of age). Using logistic regression to adjust for confounders, including crash severity and crash type, age, being less than 12 years was found to be significantly associated with serious spinal injury. Compared to older children, children aged less than 12 years were more likely to sustain serious spinal injury (OR 7.1, 95% CI 1.2 to 42.9).	Convenience sample from 2 paediatric hospitals - not representative of all cases, excludes minor and fatal injuries.
(Brown *et al.*, 2005; Brown *et al.*, 2006a)	Review of medical record data crash investigation and interview with the driver.	III-2	Australia	152 Children aged 2-8 presenting to 1 of 2 paediatric hospitals, as a result of a MVC. Interviews were conducted with the driver and an inspection of the vehicle before repair, where possible. Optimal restraints for 2-4 year olds were: FFCR with a 6-point internal harness, for 4-6 year olds: belt positioning booster seat with lap-sash seat belt, and for 6-8 year olds: an adult lap-sash seat belt.	Injuries - by AIS code.	Fewer children unrestrained (3%) than 10 years earlier in the Henderson study (11%). Only 18% of children were optimally restrained. A non-significant difference between the proportion of sub-optimally restrained who were injured (76%) and those optimally restrained (61%) - but when examining only serious injuries the difference was significant (29% versus 0% respectively). Younger children who are inappropriately restrained are at higher injury risk than older children.	Sample was from paediatric teaching hospitals thus biased towards more serious injuries. Cross validation of findings done on several factors. Optimal restraint was adapted from the American Academy of Pediatrics guidelines (2005). Misuse was not able to be included, except where gross misuse was evident as noted on the ambulance form or medical record.
(Campbell *et al.*, 2003)	Cross-sectional study - review of data	IV	USA	Medical data from one hospital for the period 1999-2001, inclusive, were reviewed for paediatric admissions (aged 4-13 years) for seat belt contusions. Mechanism of injury, seating location, type of seat belt, and treatment.	Abdominal contusion resulting in hospital admission.	There were 46 cases between 4 and 12 years of age, average 7.5 years. Injuries were linked with lap-only belts for 33 cases and lap-sash belts. 48% had surgery, 41% suffered facial injury.	Study was not designed to identify the relative risk of seat belt related injuries to children compared to adults nor compared to children of the same age in child restraints. Main finding was that children up to the age of 12 incur the same abdominal injuries as young children.
(Charlton *et al.*, 2005)	Laboratory - sled testing	III-2	Australia	Two types of booster seats were tested using 3 configurations: lap belt only, harness correctly fitted, and harness incorrectly fitted, as well as no child restraint - just an adult seat belt. The 2 harness types were also tested using ISOFIX and top tether anchors. Hybrid III 6-year-old and 3 year old dummies with sensors were used.	Neck injury values were calculated from axial forces and flexion bending moments.	Results showed that the booster seats offered superior protection compared to adult seat belt, in terms of head acceleration and neck injury values. With the 3 year old dummy the correct use of the harness - with crotch strap in place - was crucial to eliminate submarining (which can cause serious injury to the neck region).	Limited bio fidelity of the dummies (stiffer than real child). Some tests were only performed at relatively low speeds and higher speed testing is needed.
(Durbin *et al.*, 2003)	Cross-sectional study	III-2	USA	Review of insurance claims of children 4-7 years seated in the front and rear seat in MVC - data from 15 states for 3.5 year period + interview with parents selected via a stratified cluster sample. Interviews were conducted on 4243 children from 48257 involved in crashes. In-depth crash investigation was conducted where child was killed or seriously injured. Paired information (2 children in same vehicle) was available for 170 pairs to examine seating position.	Cases were identified via insurance report and where child was medically treated for an injury. Outcome of interest from survey was parent report of clinically significant injuries.	Response rate was 74%. Injuries occurred in 1.81% of all 4-7 year-olds, including 1.95% of those in seat belts and 0.77% of those in belt positioning booster seats. After adjusting for age and sex of child, seating position, driver age, crash severity, and vehicle characteristics, the odds of injury were 59% lower (95% CI = 0.2 to 0.86), in belt positioning booster seats than adult seat belts. Children in belt positioning booster seats had no injuries to the abdomen, neck/spine/back, or lower extremities, while children in seat belts alone had injuries to all body regions. Booster sea use declined with age. There was no injury effect observed in association with airbags.	First real-world evidence that booster seats are associated with significantly reduce risk of injury. Seating position - did not seem to affect injury risk.
(Ernat *et al.*, 2016)	Retrospective chart review of children hospitalised as a result of a motor vehicle crash	III-2	USA	A total of 97 patient records were included in the analysis of restraint type by injury sustained. Cases were admitted to a level 1 trauma centre between 2003 and 2011 and included	Rates of injury as well as injury type and location	It was shown that 52% were either in the wrong restraint for their age or in the front seat, a further 26% were unrestrained. Significant differences were found between the injuries by the restraint type used, and the age of the child. Proper use of child restraints was significantly higher	The study did not differentiate between type of restraint (booster versus FF - CRS or RF - CRS) and no information was available about the speed or direction of impact at the

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
				all children between 0 and 10 years treated for spinal injury due to a MVC. Analysis was initially by restraint type, then by whether it was correctly used.		in younger aged children (between 0 and 1 years) compared to older children (between 4 and 5 years). Higher rates of cervical spine and isolated ligamentous injuries were seen among the unrestrained children compared with 2-point (lap sash only) and 3-point (lap and shoulder sash) restrained passengers, when proper 3P restraint use was not taken into consideration. Three-point restrained passengers had higher rates of TL injuries than unrestrained passengers even when isolating the comparison with those using 3P restraints properly.	time of the crash. Case selection was based on having a spinal injury so being able to assess the impact of restraints on the risk of spinal injury was not done. Did not investigate injuries caused by air bag deployment.
(Huang and Reed, 2006)	Anthropometric analysis	IV	USA	Anthropometric data from several sources was analysed to assess seat fit for children for 56 different late-model vehicles. Using seat cushion criteria details for each vehicle type were determined. Child ages from crash databases were obtained and anthropometric measures inserted.	Match between child thigh sizes and seat cushion lengths.	There were no differences in the distribution of ages by make or model of cars. Findings indicate there is a significant mismatch between thigh length measurements of rear occupants and rear seat cushion lengths – which can encourage slumping among those whose calves hit the seat cushion, bringing their body forward. Slumping is associated with poor fitting of seat belts increasing the injury risk in a crash.	Study is focused on anthropometric analysis – but the understanding of the principles of a good fit between the child size and the seat size is highly relevant. Consistent with Bilston and Sagar (2007) in Australian vehicles.
(Isaksson-Hellman *et al.*, 1997)	Cohort study - review of data	IV	Sweden	Volvo crash surveillance database for the period 1976-1996 and includes 4242 child occupants involved in crashes. Details of the vehicle, and follow-up survey to obtain details on the crash and medical records of injuries. Injury risk was the number injured divided by the number of occupants for each group.	Injury severity: none or MAIS, 1, 2 3+.	Over the 20 year period there has been a marked decline in the risk of serious injury to children, particularly those under 3 years of age. Children in an adult seat belt showed a higher number of minor and serious injuries than those in a CRS. Compare to no restraint, wearing an adult seat belt was found to reduce the proportion of children with serious injury (MAIS 2+) by 59%, belt positioning booster reduced it by 76%, and rear facing CRS reduced it by 96% (forward facing not reported). Analysis suggests that optimal safety is not achieved unless the child is in the appropriate restraint for their age and size.	Vehicles were limited to Volvos - but this allowed for more uniform comparison of the effectiveness of different restraint types. Large proportion of unknown restraint type. Confidence intervals are not reported. Results have too few numbers to be significant. No multivariate analysis.
(Kirley *et al.*, 2009)	Data review from 2 sources: national surveillance system - police attended crashes as well as insurance company database	III-2	USA	All available crashes from 1997-2006 for children aged 3-7 years not in front seats (614 cases drawn randomly to represented nearly 350,000 cases for detailed vehicle inspection and interview). Three restraints types classified as lap-only, booster seat and lap and booster with lap and shoulder belt. Incorrect use, where known or no restraint at all were excluded. Restraint use and injuries determined from telephone surveys on the latter database by a cluster randomised sample and on the police report on eh former.	Injury location and severity - maximum abbreviated injury score (MAIS >2).	Results from both datasets suggest that booster seats with lap/shoulder belts showed the lowest injury rates (.12% and .96% for the two data sets), compared to lap-only belts (1.21% and 1.74%). None of the differences between restraint types and injury was significant on one dataset (police attended) but the difference between booster and lap-belt only was significant for the insurance claims database. Overall conclusion that booster with both shoulder and lap belt is the safest choice, with the use of lap-only belts (with or without a booster) was the least safe.	Booster seats included shield booster seats. A high error rate in reporting of restraint type. Self-reported data for restraint use and injury type and severity - not possible to determine correct use over the telephone. Low number of children in booster seats with lap belt only.
(Klinich *et al.*, 1994)	Anthropometric study	III-3	USA	Comparative study of child anthropometry and belt fit for 155 children aged 7-12 years. Anthropometric analysis of sample of children (volunteers) in 4 different types of booster seats and no booster seat.	Height, weight, sitting height and belt fit using booster seats – contact points with various body parts (face, neck shoulder etc.).	Key finding: Booster seats improve belt fit and posture. The minimum size child for using lap-sash belts alone is a sitting height of 74 cm, standing height of 148 cm, and a weight of 37 kg. Comparing the anthropometric data with earlier studies, authors noted that children for a given height were heavier than 20 years earlier (1970s).	Study is now dated as was based in the US – so some limitations to generalisability to current Australian children and booster seats. Participants were volunteers.
(Lane, 1994)	Case series – review of mass data on casualty related	III-2	Australia	Case series of 48 children aged 0-14 with abdominal or lumbar spine injuries from TAC database, with some analysis	Lumbar spine or abdominal injuries associated with SBS.	Changing design rules and legislation has meant calculating an annual rate of SBS injuries was not possible. Substantially elevated risk of SBS injuries in lap-only belts.	Several assumptions made to calculate the relative risk of lap-belt related injuries including the generalisability

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
	crashes and follow-up interviews			of incidence and relative rates of seat belt syndrome (SBS injuries) in various seating positions. Exposure in different seating positions was estimated by use of survey data.		The increase in risk is by a factor of two (1.57/0.77) compared to a rear-seat lap-sash belt.	of the survey findings – which might be expected to result in an underestimation of the effectiveness of lap-sash seat belts in reducing injuries.
(Ma et al., 2013)	Retrospective matched longitudinal study using a crash surveillance system	III-2	USA	Examined cases of children involved in crashes 1998-2009 identified on the National Automotive Sampling System (NASS) Crashworthiness Data System (CDS). Children were aged between 0 and 10 years and were not seated in the front seat of the vehicle. A matched analysis design was employed comparing those within the 4-7 year age group (the age range required by law), with those outside that range. A total of 2,476 children were in the sample. Restraint use was grouped as not restrained, lap sash belt only, or backless or high-back booster seat. Children were matched on child age, vehicle body type and sampling weight.	Any injury (examined by AIS 1+ and AIS 2+, as well as severe injury of ISS > 8), fatal injury and regional body injury.	Children with combined seat belts and booster seats were 27% less likely to have any injury than those with no restraints, (RR = 0.73, 95% CI = 0.55 to 0.96). No association was observed for any injury or for severe and fatal injury, when comparing children with combined seat belts and booster seats with children restrained by seat belts alone. Those in a booster seat were significantly less likely to have a head injury, face injury, upper body injury and lower extremity injury when compared to children with no restraints. However, they had more than a three-fold risk of a neck injury (AIS 1+) but no difference in the risk of moderate neck injury (AIS 2+).	Cases were limited to those involved in tow-away crashes. And information was not available on the proper use of restraints for many of the cases. The retrospective data means that several potential confounders were not available for many cases.
(Miller *et al.*, 2002)	Cohort study using a crash surveillance system and controlling for crash severity using paired regression.	III-2	USA	Cases were drawn from the National Automotive Sampling System (NASS) Crashworthiness Data System (CDS) from 1993-1999. Additionally, Fatal Analysis Reporting System (FARS) data from the period 1988-1999 was also pooled. Logistic regressions were used to determine the probability of fatal injury for children based on age group (groups were divided into 4-7 year olds, and 8-13 year olds).	Maximum Abbreviated Injury Scores (MAIS) and victim injury costs	Children aged 4-7years have a lower probability of AIS 2-6 injury (OR 0.66, p=0.12) than children aged 8-13 years suggesting they may fare marginally better in both rear and front seating positions. Paired logistic tests do not support the idea that a lap belted 8-13 year old is less likely to be killed or seriously injured than a similarly restrained 4-7 year old. This analysis implies that older occupants (i.e. 8-13 year olds) are still injured due to poorly fitting lap-sash belts.	Use of paired logistic regression reduces the power of the study in comparison to an entire population regression analysis.
(Miller *et al.*, 2006)	Cost-outcome analysis using existing estimates of the probability of injury and effectiveness of booster seats.	III-3	USA	Used data from other studies (Durbin 2003) to provide estimates of severe injury incidence, probability of injury and costs of injury. Also assessed risk reduction offered by booster seats, population estimates and the cost of booster seats (averaging for backless and high back seats).	Cost of treating serious injuries.	Each booster seat was estimated to avert $484 each year in injury costs. Benefit cost ratio of 9.4:1 and the booster seat laws offered return on investment of 8.6:1. Findings accounted for quality of life measures.	Not primary research - Limitations with using data from other studies - and only 1 was available on effectiveness of the booster seats. Some data and cost estimates were old, and multiple assumptions made.
(Reed *et al.*, 2013)	Laboratory test of belt fit with child volunteers	IV	USA	Forty children aged 5-12 in a laboratory study to examine belt fit with and without booster seats (backless and high back) to examine lap and shoulder belt fit. A mock-up of a vehicle rear seat in a laboratory was established to test a variety of back angles, cushion angles, and cushion lengths of booster seats, with and without backs.	Lap and shoulder belt fit.	Shoulder belt fit was impacted by the child's posture, e.g. leaning to the left or right. Lap belt fit was significantly affected by child size, and there was no interaction effect with booster type or even no booster. Cushion angle did not impact lap belt score. There were indications of a reduction in slumping by the child in a booster seat, which alone improves belt fit. Findings suggests that many children using current-production boosters are still obtaining relatively poor lap belt fit.	Only static scenarios were tested, and it was limited to a laboratory setting. Results don't reveal how the booster impacts injury.
(Rice *et al.*, 2009)	Matched cohort study - using fatality database	III-2	USA	Fatality data for 1996-2006 for children aged 4-8 years. Data for 6851 children in 5503 vehicles, 2193 of the injuries were fatal.	Fatal injury.	Proportion of children using a booster seat declined with age. Estimated fatality risk ratios for booster seat use were 0.33 for children aged 4–5 years and 0.45 for children aged 6–8 years (p<0.005), and for seat belt use were similar for the two age groups, 0.37 and 0.39 respectively (p=0.61).	Study assumed that children in the 4-8 age group in child restraints were using a booster seat, while some may have been in child restraints. Data did not allow for comparative

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
						Booster seat RR was lowest for middle-seat positions and in roll-over situations. Seat belts were found to be significantly protective (non-use RR=2.6), as were booster seats - but there was no significant advantage of using booster seats.	effectiveness of types of restraints. Only examined effect on reducing fatalities - not other injuries or severity of other injuries. Booster seats may reduce injuries to the abdomen but not head - i.e. seat belts even if poorly fitted will prevent being thrown from the car.
(Winston *et al.*, 2000)	Retrospective review of data from crash surveillance system + interview	III-2	USA	Sentinel surveillance from insurance claims in 15 states in the USA, follow-up telephone interview with parents. Automated sampling process to select participants.	Crashes requiring medical treatment to child occupants 0-15 years.	11,123 cases for a one year surveillance period were included, 8334 interviews completed. Young children in adult seat belts were 3.5 times more likely to incur a significant injury and 4.2 times more likely to incur a head injury than those in a child restraint. The risk of significant injury was greater for children aged 2-3 than those aged 3-5 years if wearing an adult seat belt compared to a dedicated child restraint. Recommend that stay in CR until at least 4 years and 18 kg.	Real-world study, and as result a certain level of misuse of restraints could not be controlled for. Also, restraint use was self-reported during the interview after the crash.

6.1.3 Booster seats

Recommendation 1.10 Children should not use boosters with just a lap-only seat belt.

Overall Evidence Grade B

Table 9: Evidence statements supporting recommendation 1.10

Evidence statements	***1. Boosters should be used with lap-sash seat belts. Lap-only seat belts allow upper torso excursion and can increase the risk of head contacts that can cause injury*** ***2. Child safety harnesses offer no additional protection over lap-sash seat belts when used with boosters in frontal crashes, and can encourage submarining which is associated with abdominal and lumbar spine injuries*** *(see corresponding references)*	
Grade	**B**	
Component	**Rating**	**Notes**
Evidence base	Good	Two field studies and two laboratory studies provide evidence of the increased injury risk associated with using only lap belts with booster seats. Child safety harnesses with booster seats offer no additional protection in frontal crashes, and can encourage submarining which is associated with abdominal injuries (Suratno *et al.*, 2009a; Brown *et al.*, 2010c).
Consistency	Excellent	Four studies, as noted above, support the use of lap-sash belts with booster seats where possible.

Public Health Impact	Excellent	Of the two studies that provided odds ratios, both reported close to a 60% reduction in serious injuries associated with lap-sash seat belts as opposed to lap-only seat belts used in conjunction with booster seats.
Generalisability	Good	Two USA field studies drawing on very large real-world samples and two Australian studies provide a good level of generalisability for these research findings.
Applicability	Good	While the USA studies may include a large number of events in booster cushions, no longer being sold in Australia, they are still widely used here. The Australian lab studies examined the performance of 17 high back booster seats but with only one dummy size and a replication of events of a small sample of real-world cases of injuries sustained in crashes on high back booster seats, making these findings applicable to the current Australian context.
Other factors		There is limited field data on child safety harness-associated injuries and lap-only belt injuries.
References		1. (Durbin *et al.*, 2003; Brown and Bilston, 2006b, 2009; Kirley *et al.*, 2009) 2. (Suratno *et al.*, 2009a; Brown *et al.*, 2010c)

A mix of laboratory and field studies, albeit only four studies in total, provide a satisfactory level of confidence in the statement that booster seats with lap-sash seat belts are safer than lap-only seat belts (with or without a booster). As Brown et al (Brown and Bilston, 2009) note from their laboratory testing of high back booster seats, booster seats enhance safety when they maintain a good dynamic seat belt position during a crash, so that the seat belt can operate as designed (Brown and Bilston, 2006b). The evidence suggests that when the seat belt is a lap-sash seat belt, the deceleration force immediately after the crash is spread over a larger body area reducing injuries to the abdomen, neck/spine/back compared to a lap-only seat belt.

Child safety harnesses (type C restraints) (see recommendation 3.2 below) provide no benefit over a lap-sash seat belt when used with a booster seat (Suratno *et al.*, 2009a; Brown *et al.*, 2010c) and are widely misused in the field (Brown *et al.*, 2010b) which further degrades their performance and increases the likelihood of abdominal and spinal injuries associated with 'submarining' (Brown *et al.*, 2010c).

Table 10: Summary of articles providing evidence for recommendation 1.10

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
(Brown and Bilston, 2006b)	Laboratory testing - based on real-world crashes	III-2	Australia	Case series of 19 children aged 2-8 years presenting to hospital after being in a MVC. All children had been using a high back booster. Ambulance and hospital notes together with interviews with the driver. Restraint type, impact severity, seating position. In-depth crash investigation. Suboptimal and optimal restraint use was determined. Five crash simulations were conducted, 1x 6 year old dummy and 4 with a 3 year old dummy. Forces measured and high-speed camera used for visual data.	Head accelerations, neck load and moments.	Only 7 (37%) of the 19 children were optimally using booster seats. Findings suggest that incorrect use of high back booster seats could lead to increases in injury risk. For children big enough to be appropriately restrained in a HBB seat there were no serious injuries in this sample.	Further testing in a more representative population-based study is recommended. Sample size was small and crash types, child sizes and booster use were all varied. Simulations were not direct reconstructions of the real-world crashes but "typical" of those observed in the field. There was sub-optimal level of confidence in the simulated crash data particularly regarding crash severity.
(Brown *et al.*, 2010c)	Laboratory testing - simulated front-impact, instrumented dummies and	III-2	Australia	Laboratory simulated frontal crash using a 6 y-o dummy and 3 different restraint systems: correct and incorrect harness use and a lap-sash belt - using two different kinds of booster seats.	Dummy motion, belt loads, neck forces and moments, head and knee moments. Submarining as determined visually.	Results suggested that correctly used harness did not perform any better than the lap-sash belt - either on its own or with two common types of booster seats. Incorrect use of the harness - causing the lap belt to be high and positioned over the abdomen, allowed for submarining to occur. Submarining did not occur when	Some limitations in the use of dummy head and neck responses to simulate real crash scenarios - biofidelity of the dummies is unknown. Only one model of harness was tested, and two booster seat types - other combinations may results in some different outcomes. Real postures of children are

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
	high-speed cameras					the booster was used and the lap belt kept low on either restraint tested.	difficult to simulate in dummies. Submarining was determined visually which may be open to a level of subjectivity.
(Durbin *et al.*, 2003)	Cross-sectional study	III-2	USA	Review of insurance claims of children 4-7 years seated in the front and rear seat in MVC - data from 15 states for 3.5 year period + interview with parents selected via a stratified cluster sample. Interviews were conducted on 4243. In-depth crash investigation was conducted where child was killed or seriously injured. Paired information (2 children in same vehicle) was available for 170 pairs to examine seating position.	Cases were identified via insurance report and where child was medically treated for an injury. Outcome of interest from survey was parent report of clinically significant injuries.	After adjusting for age and sex of child, seating position, driver age, crash severity, and vehicle characteristics, the odds of injury for children aged 4-7 years were 59% lower (95% CI = 0.2 to 0.86), in belt positioning booster seats than adult seat belts. Children in booster seats had no injuries to the abdomen, neck/spine/back, or lower extremities, while children in seat belts alone had injuries to all body regions. Booster seat use declined with age. There was no injury effect observed in association with airbags.	First real-world evidence that booster seats are associated with significantly reduced risk of injury.
(Kirley *et al.*, 2009)	Data review from 2 sources: national surveillance system - police attended crashes as well as insurance company database	III-2	USA	All available crashes from 1997-2006 for children aged 3-7 years not in front seats (614 cases drawn randomly and detailed vehicle inspection and interview were conducted). Three restraints types classified as lap-only, booster seat and lap and booster with lap and shoulder belt. Incorrect use, where known or no restraint at all were excluded. Restraint use and injuries determined from telephone surveys on the latter database by a cluster randomised sample and on the police report on the former.	Injury location and severity - maximum abbreviated injury score (MAIS >2).	Results from both datasets suggest that booster seats with lap-sash belts showed the lowest injury rates compared with children restrained by lap belts only (OR: 0.43; 95% CI: 0.23, 0.83). None of the differences between restraint types and injury was significant on one dataset (police attended) but the difference between booster and lap-belt only was significant for the insurance claims database. Overall conclusion that booster with both shoulder and lap belt is the safest choice, with the use of lap-only belts (with or without a booster) was the least safe.	Booster seats included shield booster seats. A high error rate in reporting of restraint type. Self-reported data for restraint use, injury type and severity - not possible to determine correct use over the telephone. Low number of children in booster seats with lap belt only.
(Suratno *et al.*, 2009a)	Laboratory testing - simulated front-impact, instrumented dummies and high-speed cameras	III-2	Australia	Twelve front impact crashes were simulated using a 6 year old dummy - three different restraint types (seat belt, booster seat and safety harness) and the use and incorrect use and non-use of a harness.	Sensors to detect head, chest and pelvis acceleration, upper neck forces and moments, and chest deflection. Dummy motion was captured with high-speed camera.	Results indicated that in frontal impact at least, child safety harness systems provide no better protection than lap-sash seat belt systems, either with a booster seat or alone. The main danger is "submarining". Misuse of harnesses is common and associated with serious degradation of the protective effect.	Testing was limited to frontal impacts and did not test for the risk of submarining with different speeds at impact. No evidence to support their use particularly in conjunction with lap-sashes and that if too tight - they can result in excessive head excursion.
(Brown *et al.*, 2009)	Laboratory testing - using crash sled, instrumented dummies and high-speed cameras	III-2	Australia	17 different high-back booster seats were tested each with one frontal crash. The dummy (mass of 32kg – which is exceeded the upper limits for Australian Standards for booster seats – selected to represented the worst-case scenario) was instrumented and high-speed cameras were also used.	Upward motion of the lap belt. Dummy response in terms of head excursion, head and neck accelerations.	Variations in results for the different booster seats were primarily linked with the ability of the seat to maintain a good dynamic seat belt fit. Only three out of the 17 devices adequately maintained a good belt fit during frontal testing. The location of the sash belt on the dummies shoulder pre-impact did appear to have an influence on the dynamic sash fit.	Real-world positioning of belts may vary from the dummies in lab tests. Only one dummy size tested (97% upper %lie), may need to test it on smaller dummies. Testing only done on frontal impact.

Recommendation 1.11 High back booster seats are preferred rather than booster cushions.

Overall Evidence Grade B

Table 11: Evidence statement supporting recommendation 1.11

Evidence statement	***Booster seats with high backs and side wings offer greater side impact protection and postural support to keep seat belt in correct position than booster cushions.***	
Grade	**B**	
Component	**Rating**	**Notes**
Evidence base	Satisfactory	Two Australian laboratory studies (level III-2) measuring head and neck accelerations in simulated crashes and one USA lab study assessing seat belt fit only (level III-3) provide evidence of the potential value of HBB in the event of side impact crashes. One study indicated that in US boosters, seat belt fit can be better in some low back boosters (Reed *et al.*, 2009).
Consistency	Satisfactory	Australian studies are consistent. One USA field study (Arbogast *et al.*, 2009b) found no difference between HBB and LBB (but see below for limited applicability of this study for side impact). One study indicated that in US boosters, seat belt fit can be better in some low back boosters (Reed *et al.*, 2009).
Public Health Impact	Unknown	Data identifying the size of the benefit of HBB in the real-world is not yet available.
Generalisability	Good	Evidence includes two lab studies simulating crashes, one lab study measuring seat belt fit only, and one field study conducted in the USA. The generalisability of the studies to date is thus partially acceptable.
Applicability	Good	Australian studies are directly applicable. US booster seats often do not have the side impact protection features required under AS/NZS 1754thus that field study cannot be readily generalised to the Australian context. There are some limitations with the laboratory studies as dummies represent a single child size.
Other factors		
References		(Kelly *et al.*, 1995b; Brown and Bilston, 2006b; Arbogast *et al.*, 2009a; Reed *et al.*, 2009; Bohman *et al.*, 2011; Forman *et al.*, 2011; Stockman *et al.*, 2013a; Holtz *et al.*, 2016)

Currently there is only scant evidence on the comparative real world protection offered by high back booster seats compared to booster cushions. Overseas studies which include high back booster seats are limited to boosters which do not have to meet side the impact requirements of Australian legislation so may not provide head protection that Australian restraints provide. Low back boosters offer no side impact protection or postural support to keep the seat belt in the correct position. For these reasons, they were removed from the mandatory Australian Standard, AS/NZS 1754, in the 2010 edition, and new booster seat designs are required to have a high back, head protection and postural support. Naturalistic driving studies have demonstrated better lateral postural support and belt positioning from high back boosters compared to booster cushions (Bohman *et al.*, 2011; Forman *et al.*, 2011; Stockman *et al.*, 2013b). There are some booster cushions still in use in Australia, and local and international evidence indicates that they may offer benefits over the seat belt alone, but evidence is mixed (see above). Further research is required to establish the impact of these devices on child mortality and morbidity. Type E booster seats accommodate 95% of children up to 7 years of age and Type F booster seats accommodate up to 95% of children up to 10 years of age, based on ergonomic data from USA studies in the 1970s (Snyder *et al.*, 1975; Snyder *et al.*, 1977). Up to date Australian ergonomic data is not available. Children are heavier and slightly taller than in 1970s (Klinich *et al.*, 1994; Bilston and Sagar, 2007; Fitzharris *et al.*, 2008), and particular ethnic groups can be outside these mean sizes at specific ages (e.g. pacific islanders).

Table 12: Summary of articles providing evidence for recommendation 1.11

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
(Arbogast *et al.*, 2009a)	longitudinal cohort study	III-2	USA	Review of insurance claims of children 4-8 years seated in the rear seat in MVC - data from 16 states plus DC for 8 year period + interview with parents selected via a stratified cluster sample. Interviews were conducted on approx. 35000 children from 530,000 involved in crashes.	Level of medical treatment following the crash: no treatment, physician's office or emergency department only, admitted to hospital or death). AIS 2 or higher.	1.15% of all children aged 4-8 involved in the insurance claim crashes incurred a serious injury. The risk of this level of injury was almost half of that for children in booster seats compared to those in a seat belt (OR=0.55, CI= 0.32-0.96) Children in side impact crashes benefited the most from booster seats, showing a reduction in injury risk of 68% for near side impacts and 82% for far-side impacts. Not able to detect a difference in the risk for injury between the children in backless versus high-back boosters (OR: 0.84, 95% CI: 0.44 –1.61). Head injuries were the most common and abdominal injuries were mostly associated with seat belt use - not boosters.	Large sample - but limited to one major insurance group - so potentially some biases in sample selection. Further detail provided about the type of injuries incurred. Findings do not suggest type of booster seat significantly alters the risk of injury - important findings as backless one are cheaper and generally more acceptable to older children.
(Bohman *et al.*, 2011)	Naturalistic driving study monitoring seat belt fit during turns	III-3	Sweden	16 children, aged 4-12, in booster cushion and high back booster with lap sash belt were in a professionally driven car on a closed-circuit track, Shorter children were compared on a booster cushion and a high back booster. Taller children were compared on a booster cushion and without any booster cushion. Short children ranged from 107-123cm (average 117) and tall children ranged from135-150cm (average 144). Belt positioning was observed during two turns in each restraint type. Data from 54 trials were used.	Child kinematics and seat belt in relation to the child's shoulder - - close to neck, mid shoulder or off shoulder, and belt slip during turn manoeuvre (off the shoulder)	For shorter children, when in a booster cushion the shoulder belt tended to slip off the shoulder in 2/3 of the turns - but remained on when in the high-back booster - although the shoulder belt did move towards the edge of the shoulder in half of the trials. The initial belt position tended to be closer to the neck in children using booster cushion compared to high back booster. In the taller children, there was no shoulder belt slip off and the shoulder belt movement was not appreciably different depending upon the restraint type. With no booster, the initial shoulder belt position was closer to the child's neck. With a booster cushion, taller children tended to have shoulder belts move towards the edge of the shoulder during the turn.	Child size variations meant not all children were tested in all restraint conditions and only one of each kind of restraint was tested. Limitations of a trial included children not necessarily being in a natural relaxed posture. No test of significance for any observed differences.
(Brown and Bilston, 2006b)	Laboratory testing - based on real-world crashes	III-2	Australia	Case series of 19 children aged 2-8 years presenting to hospital after being in a MVC. All children in this sample had been using a high back booster. Medical notes and interviews with the driver provided data on restraint type, impact severity, seating position. In-depth crash investigation. Suboptimal and optimal restraint use was determined. Five crash simulations were conducted, 1x 6 year old dummy and 4 X 3 year old dummy. High speed camera for visual data.	Forces measured and head accelerations, neck load and moments.	Only 7(37%) of the 19 children were optimally using booster seats. Findings suggest that incorrect use of high back booster seats could lead to increases in injury risk. For children big enough to be appropriately restrained in a HBB seat there were no serious injuries in this sample.	Further testing in a more representative population-based study is recommended. Sample size was small and crash types, child sizes and booster use were all varied. Simulations were not direct reconstructions of the real-world crashes but "typical" of those observed in the field. There was sub-optimal level of confidence in the simulated crash data particularly regarding crash severity.
(Bilston and Sagar, 2007)	Seat &, seat belt geometry measurements and child anthropometric data	IV	Australia	51 vehicle right rear outboard seating positions were measured from a range of late model (2005/6) vehicles.	Anthropometric measures: seated shoulder height, seated eye height, shoulder breadth; measurements of rear seat geometry - cushion depth, angles etc. for common vehicles models on the Au market.	Findings suggested that for the shortest seat cushion, at 50th percentile a child does not have adequate length for good seated posture until 11.5 years of age, and in average car seat, the average child is 15 before being the right size for good posture. Good geometric fit is important for its influence on graduation from one restraint type to another and premature graduations is associated with lower levels of protection in crashes.	Comparative study of vehicle and restraint geometry with child anthropometry from published data. Assumed that Us child population is good representation of Australian child population. Australian cars and restraints measured.
(Forman *et al.*, 2011)	Naturalistic observational study	III-2	Spain	A naturalistic driving study was conducted with 30 volunteer children aged 7-14 years. The test was conducted for 75 minutes during the night with three different restraint types: high back booster, low back booster, no booster (with 10 children in each group). All children wore a	Lateral head positions and shoulder belt fit	Poor shoulder belt positioning was observed in 78% of the frames examined for the no booster group, 61% of the low-back booster group and 17% of the high-back booster group. The high-back booster group also exhibited statistically significantly reduced head movement. In all, the high back booster seat, as used by	Group assignment was not randomised but based on the child's size. Children were assigned a restraint type based on their size. Variation in belt fit among the test groups was not necessarily a function of the subject anthropometry

				three-point lap/sash belt. The trips were conducted late at night to encourage sleeping by the child. The group each child was assigned to was based on their height and weight, with smaller children (under 32 kg) in the high-back booster seat, children 32kg or over but less than 147cm were in the low-back booster group; children over 147cm (but less than 165cm) were in the no booster seat group. A low-light video camera mounted on the back of the front passenger seat was used to record the child's head movements and shoulder positions. One frame every minute was analysed for each subject.		children aged 7-14 who were under 32kg, offered better fit than the other seats for the children over 32kgs.	(in relation to the geometry of the seats and restraints), but instead was a function of the voluntary motion of the children during travel. Because of the lateral support provided, the children moved less with the high-back booster, resulting in a more consistently appropriate fit of the shoulder belt. The study was designed to assess comfort and belt fit relevant to each size group.
(Holtz *et al.*, 2016)	Review of crash data, booster fitting trial and Numerical simulation aimed at examining crash protection challenges for child in light weight electrical vehicles	IV	Germany	Crash data analysis of injuries sustained by older child occupants in lateral impact crashes. (a)Crash data were examined for 2005–2014 relating to children using booster type CRS (high-back booster and backless boosters), sitting in a passenger car that collided with another car, a duty vehicle or with an object. (b)Mathematical modelling of geometric variations of vehicle types and CRS interactions. Models tested different pulse and intrusion levels. Q6 and Q10 dummies were used to investigate the protection of older child occupants in lightweight vehicles. The simulation data was analysed by assessing the dummy injury metrics against the criteria set by Euro NCAP.	Geometrical interference between the CRS and the car, such as the reduction of CRS height adjustability caused by contact between the CRS and the car body. Resultant outcome was calculated injury risk for children using booster seats in a passenger car in any kind of accident	Examination of crash data limited to presentation of injury outcomes of children using boosters in different types of vehicles. From fitting trials percent of cars within each vehicle type observed to have geometrical issues were presented. Simulation results indicated that use of a high-back booster gave the best protection for both the Q6 and the Q10 dummies when rated against the Euro NCAP protocol criteria where an airbag was approximated. A higher injury risk in side impacts in small cars was not found in the data-analysis. Results suggest that a CRS with backrest for Q6 and Q10 dummy is used to contain the dummy and, in particular, the head.	Geometrical interference between the CRS and the car, such as the reduction of CRS height adjustability caused by contact between the CRS and the car body. Resultant outcome was calculated injury risk for children using booster seats in a passenger car in any kind of accident No comparison made to non-side-airbag scenario. Airbag was approximated by padding, not an actual airbag
(Kelly *et al.*, 1995b)	Laboratory testing - crash sled	III-2	Australia	Three sled testing programs and a review of six real-world crashes. FFCRs in upright position were tested, using an instrumented 6 month dummy and a high-speed camera.	Lateral head movement and crash energy management was assessed using head injury criteria.	Results show scope for reduction of lateral movement in side impact crashes for restraint anchorage systems available at that time. There was considerable difference in performance of boosters with side wings. Backless boosters offered no protection in terms of lateral head movement and connection with the car door. Some indications that a rigid CANFIX attachment can offer greater safety performance.	Further research into proper containment of the child's head in sideways impact was needed (at the time).
(Klinich *et al.,* 1994)	Anthropometric study	III-3	USA	Comparative study of child anthropometry and belt fit for 155 children aged 7-12 years. Anthropometric analysis of sample of children (volunteers) in 4 different types of booster seats and no booster seat.	Height, weight, sitting height and belt fit using booster seats – contact points with various body parts (face, neck shoulder etc).	Key finding: Booster seats improve belt fit and posture. The minimum size child for using lap-sash belts alone is a sitting height of 74 cm, standing height of 148 cm, and a weight of 37 kg. Comparing the anthropometric data with earlier studies, authors noted that children for a given height were heavier than 20 years earlier (1970s).	Study is now dated as was based in the US – so some limitations to generalisability to current Australian children and booster seats. Participants were volunteers.
(Reed *et al.*, 2009)	Laboratory testing of belt positions	III-3	USA	31 booster seats were tested in 41 modes - backless, high back and ones which can be either. Hybrid III - 6 year old dummy. Manufacturer's instructions were followed.	Scores for belt fit/ position by 2 trained investigators. No simulation of crash conditions - just assessment of how well positioned the seat belt is following manufacturer's instructions.	Results suggest a large proportion of children 4-8 years of age would experience poor shoulder belt fit. Backless booster seat belt fit is more dependent upon the cars' seat belt configuration. Certain booster designs are better for ensuring a good shoulder belt fit.	
(Stockman *et al.*, 2013a)	Driving study on a test track	III-3	Sweden	Four anthropometric test dummies (ATDs), Hybrid III, Q6 and Q10 were positioned in the rear	Kinematics - Lateral motion of the	The focus of the findings was on the representativeness of the ATDs to children of the corresponding age.	Better belt fit and less movement of child during car manoeuvring associated

	with ATDs corresponding to ages 6 and 10 year olds.			seat and subject to 16 sideways manoeuvers. The two 6YO dummies were tested with a booster cushion and high-back booster seat. The 10 year old dummy was tested with a booster cushion and then just a 3-point seat belt. The measurements were compared to a previous study using child volunteers of corresponding age/size. Video and vehicle data were analysed.	forehead and upper sternum, and shoulder belt movement on shoulder and torso tilting angle.	However, some findings indicated better belt retention (and resultant 34% less movement of the dummy during manoeuvring of the vehicle) with high back boosters, and 31% less in the low-back boosters compared to no booster (and 3-point seat belt alone).	with booster seats, notably high back booster seats.

6.1.4 Adult seat belts

For children who have outgrown booster seats, an adult seat belt is the most appropriate form of restraint. This includes most children aged 12 years and older.

Consensus Based Recommendation 1.12	The "5 step test" should be used to determine whether a child is big enough to obtain optimal protection from an adult seat belt in a particular vehicle.

This consensus-based recommendation is based on expert opinion, taking into account the following considerations. The "5 step test" encapsulates the geometric conditions described above in section 1 for ascertaining if a child is tall enough to obtain good seat belt fit without use of a booster seat, by assessing (1) whether a child can sit with their back against the seat back, (2) with their knees bent comfortable over the front edge of the seat cushion, (3) with the shoulder belt across the mid-shoulder, (4) the lap belt low across the top of the thighs, and (5) can stay in this position for the duration of a trip. The "5 step test" has not been formally evaluated, but is widely used in practice worldwide to assess whether a child is tall enough to achieve and maintain good adult seat belt fit. The complexity of remembering the 5 steps and implementing them, may act as a barrier to the correct use of this method. While this has not yet been examined, suitable communication strategies will be considered during the development of the guideline consumer documents. This fit will likely vary from vehicle to vehicle so that a child who fits well in an adult belt in one vehicle may still require a booster seat in another vehicle due to differences in vehicle design. Where available, adjustable upper anchorages (D-rings) may be used to assist with achieving good sash belt fit. As noted in Section 6.1.3 above, a minimum standing height (typically in the range of 145-150cm, although 135cm is used in some locations in Europe) is sometimes recommended as a transition point to adult seat belts, rather than the more comprehensive "5 step test" recommended here, and the suitability of standing height as a transition marker for adult seat belt fit was a topic of debate, particularly among input from the project steering committee, largely due to the relative simplicity of communicating a specific standing height as a transition compared to the "5 step test". However, the evidence base for a specific standing height as the safe transition point is limited. There is considerable variation in rear seat and seat belt geometry in passenger vehicles (Bilston and Sagar, 2007) and in the proportions of leg and torso size in children of similar standing height (Bilston and Sagar, 2007), and thus standing height is not considered to be a good metric for assessing suitability of seat belt fit for a specific child in a particular vehicle. Moreover, the use of a specific standing height as a minimum requirement for adult seat belt use can create confusion for parents and carers, because there remains a gap in restraint availability for children who have outgrown currently available booster seats (Type E, Type F in As/NZS 1754) but still cannot achieve good seat belt fit in some or all vehicles. Specifically, Type E and Type F booster seats are not required to (and do not) accommodate all children up to the commonly quoted standing height of 145-150cm for transition to adult seat belt use, making this an unsuitable metric for transition. Finally, there is some evidence that parents and carers often do not accurately know their child's height and/or weight, but do know their age (Bilston *et al.*, 2008), so a statement of expectation that good seat belt fit is unlikely to be achieved before the age range of 10-12 years (Bilston and Sagar, 2007) is included to set reasonable expectations for the minimum age that a child can achieve good adult seat belt fit, and a time at which the "5 step test" can reasonably be used to test for good seat belt fit. Further research is required on how best to communicate good seat belt fit requirements for the transition to adult seat belts, including the "5 step test", and formal evaluation of the "5 step test" is required.

Recommendation 1.13	**Children in seat belts should use lap-sash seat belts rather than lap-only seat belts whenever possible.**
Overall Evidence Grade	**A**

Table 13: Evidence statements supporting recommendation 1.13

Evidence statement	***Lap-only belts allow excessive torso flexion, and are associated with 'seat belt syndrome' injuries, including abdominal and lumbar spine injuries***	
Grade	**A**	
Component	**Rating**	**Notes**
Evidence base	Good	A total of nine studies including field studies supported by laboratory studies identify the added risk of head injuries, abdominal injuries and fractures of the lumbar spine with the use of lap-only seat belts.
Consistency	Excellent	All studies show similar findings.
Public Health Impact	Excellent	Only two studies had large enough sample sizes to quantify the public health impact – but these reported a doubling of the serious injury risk associated with lap-only seat belts compared to lap-sash seat belts.
Generalisability	Good	Study samples have been reasonably representative of the whole population, and specific sub-populations not represented in existing data are not known to have features that would affect their risk of injury in these circumstances, so the findings available are generalisable.
Applicability	Excellent	Lap and lap-sash seat belt designs are similar in vehicles internationally, so the available studies (Australian and international) are applicable to current vehicles and children in Australia. Lap-only seat belts are becoming less common in centre rear positions in vehicles as their reduced protection is well established.
Other factors		
References		(Anderson *et al.*, 1991; Henderson, 1994; Lane, 1994; Henderson *et al.*, 1997; Gotschall *et al.*, 1998b; Lapner *et al.*, 2001; Levitt, 2005; Ghati *et al.*, 2009; Kirley *et al.*, 2009)

Lap-only seat belts are not recommended for use by children of any age, unless there is no available seating position with a lap-sash seat belt. Lap-only seat belts provide inferior protection to lap-sash seat belts, and are associated with an increased risk of abdominal, lumbar spine and head injuries. There is strong evidence that lap-only seat belts in children are associated with increased risk of SBS injuries, which are the result of excessive loads on the abdomen, and excessive head excursion resulting in head injury. The evidence from seven field studies (including two from Australia) with further support from two laboratory studies provide excellent evidence to support the recommendation that lap-sash seat belts should always be used in preference to lap-only seat belts.

Table 14: Summary of articles providing evidence for recommendation 1.13

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
(Anderson *et al.*, 1991)	Data review – trauma centre	III-2	USA	Retrospective analysis of 303 motor vehicle occupants (adults + children) at one regional trauma centre in USA over 5 years. Only 7 children in series.	Spine and abdominal injuries resulting in admission to trauma centre.	Found that Chance fractures of the lumbar spine and hollow viscus injuries were associated with lap belt restraint use. Two-thirds of patients with Chance fractures were using lap belts which were found to increase the risk of small bowel injuries by 10 fold. Children were found to be particularly susceptible because of their size and body proportions and due to higher frequency sitting in rear seats with lap only belts.	Small number of children in the study. Comparisons not made (possibly due to sample size restrictions) with those restrained in lap-sash belts or child restraints.
(Ghati *et al.*, 2009)	Laboratory testing - sled test	III-2	USA	Side impact collisions, 48 sled tests on rear facing and forward facing child seats with dummies representative of 1 and 3 year olds - tested using latch and lap/shoulder belts to attach the seat. 3 different speeds. High speed video cameras and data from test dummies used.	Acceleration measures on the dummy's head chest and pelvis, forces and moments from the upper and lower neck and lumbar spine.	Findings indicate that there were some differences in performance levels for different type of restraints - and that all experienced some lateral movement regardless of the attachment type. In one of the rear facing restraints the attachment gave way and the seat disengaged from its base - even at the lowest speed level. A range of specific findings are presented for each configuration.	Test dummies were not designed for side-impact and some aspects of the test dummies but there was adequate data to make conclusions about the side impact on the far side of the vehicle to inform further refinement of the design of child safety seats for infants and young children.
(Gotschall *et al.*, 1998b)	Detailed case series review	III-2	USA	From Dec 1991-97, all children 0-15 years, wearing a seat belt (only) and admitted to a specific hospital following a MVC were included (n=98). Medical records, interview with parents and attending pre-hospital providers, review of police reports, crash scene investigation and reconstruction of events provided detailed data.	Injury severity: AIS, ISS, revised Trauma Score and the TRISS probability of survival. Medical treatment and outcome.	There were no belt related fractures to the ribs or sternum, and no belt related injuries to the heart or great vessels. One fracture of the clavicle and 4 to the thoracic cavity were noted to be belt related (3 of 4 in a 3-point belt). Of the 9 abdominal injuries that were belt related, all were in a 2-point belt. There were no injury severity differences by belt type. Incorrect belt use was common. Broadly data suggested more injuries with 3-point belt.	Sample did not include uninjured children - so limits conclusions. No evidence that they controlled for various factors as part of the analysis. Three-point belts are more common in the front seat but not sure that they factored this into the injury severity.
(Henderson *et al.*, 1997)	Laboratory sled test	III-2	Australia	Three anthropometric child dummies in rear seat positions: simulating 18 months, 3 year old and 6 year old. Two sled runs were conducted for belt type (lap-only and lap-sash) with each dummy. Use of a harness was tested with the 3 and 6 year old dummies. Sensors placed on head, neck, chest and pelvis. High speed camera used.	Head, chest and pelvis acceleration measurements; upper neck forces and moments. Lumbar forces and moments for 18 months old.	Head and chest acceleration and lap belt loads were consistently higher for lap belt only compared to lap and shoulder belts. Only the 18 month old dummy was not held correctly in place by either kind of restraint during the entire crash sequence. Results are consistent with field studies indicating lap and shoulder belts, compared to lap-only, serve to minimise head excursion potentially reducing head injury risk and reduce abdominal loads and therefore potentially reduce injury risk to abdominal area. Results from harness testing suggested great loads may lead to greater neck forces than one sided shoulder belts.	Some differences in the reading between the different tests on each configuration.
(Henderson, 1994)	Data review of injuries resulting in hospital attendance or fatality.	III-2	Australia	Cases were 247 children aged <15 years attending hospital following a MVC. Interviews with a parent, inspection of the vehicle and reconstruction of the crash event using the EDCRASH program to obtain estimates of speed, change in velocity and deceleration that is likely to be more accurate that reported during interview or from records. Restraint type	Injury severity (AIS >2) and fatal injuries.	Side impact was the crash type most likely to result in a significant injury (34% of case children sustained an injury of AIS 2 or greater). Few infants were in capsules (n=6, 2.6%). Injuries by restraint type were summarised by possible mechanism. Lap-sash belts appeared to offer good protection but were only available in outboard seats. A higher proportion of unrestrained children had a serious injury or fatality (26.3% fatally injured, 42.1% suffered an injury of AIS	Study population not necessarily representative of all crashes in which children are injured and not those in which an injury was prevented. Strength of study was in understanding the crash event, not just the proportion of children injured and injury severity by each restraint type. Small numbers in some restraint types, e.g. capsules and FFCRs.

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
				was recorded. Vehicles were manufactured from 1966-93.		2 or greater), as compared with restrained children (p<0.01). A high proportion of the cases were in four-wheel drive cars and multi-passenger vehicles. Importance of seating position was highlighted. Concludes that restraints specifically designed for children are most protective and adult seat belts do not offer protection from side-impacts. Some indications that many children were moved out of a CRS too early.	
(Kirley *et al.*, 2009)	Data review from 2 sources: national surveillance system - police attended crashes as well as insurance company database	III-2	USA	Crashes occurring 1997-2006 for children aged 3-7 years not in front seats (with 614 cases drawn randomly for detailed vehicle inspection and interview). Three restraints types classified as lap-only, booster seat and lap and booster with lap-sash belt. Incorrect use, where known, or no restraint were excluded. Restraint use and injuries determined from telephone surveys by a cluster randomised sample and on the police report.	Injury location and severity - maximum abbreviated injury score (MAIS >2).	Results from both datasets suggest that booster seats with lap-sash belts showed the lowest injury rates. None of the differences between restraint types and injury was significant on one dataset (police attended) but the difference between booster and lap-belt only was significant for the insurance claims database. Overall conclusion that booster with both shoulder and lap belt is the safest choice, with the use of lap-only belts (with or without a booster) being the least safe.	Booster seats included shield booster seats. A high error rate in reporting of restraint type. Self-reported data for restraint use and injury type and severity - not possible to determine correct use over the telephone. Low number of children in booster seats with lap belt only.
(Lane, 1994)	Case series – review of mass data on casualty related crashes and follow-up interviews	III-2	Australia	Case series of 48 children aged 0-14 with abdominal or lumbar spine injuries from TAC database, with some analysis of incidence and relative rates of SBS in various seating positions. Exposure in different seating positions was estimated by use of survey data.	Lumbar spine or abdominal injuries associated with SBS.	Changing design rules and legislation has meant calculating an annual rate of SBS injuries was not possible. Substantially elevated risk of SBS injuries in lap-only belts was found. The increase is by a factor of two compared to a rear-seat 3-point belt.	Several assumptions made to calculate the relative risk of lap-belt related injuries including the generalisability of the survey findings – which might be expected to result in an underestimation of the effectiveness of 3-point seat belts in reducing injuries.
(Lapner *et al.*, 2001)	Retrospective case review and a prospective phase	III-2	Canada	Cases were children (aged 3-19) with spinal injuries attending hospital following a MVC, all occupants of the case vehicle were contacted and interviewed - covering pre-crash seating positions, posture of occupants, and the manner in which restraints were used. Engineering team assessment of crashes based on information provided.	The nature and extent of the injuries sustained, and the vehicle dynamics and associated occupant kinematics.	Retrospective case review (n=45) suggested no difference in location of cervical spine injuries for 2-point versus 3-point seat belt (i.e. shoulder strap). However the prospective review of 26 cases (which included all types of injuries) found a 24 increase in the risk of cervical spine injury for children using a 2-point versus 3-point seat belt. Loose fitting lap belts were found to be particularly dangerous. Also concluded that children under 12 should not be in the front seat until airbag sensitivity has improved.	Sample selection bias - no injuries that were not serious were included. Small number of cases in the prospective review.
(Levitt, 2005)	Retrospective review of data from fatal crash database	III-2	USA	Data reviewed for period 1975-2003 - for type of restraint used (none, lap-only, lap and shoulder, child restraint); Vehicle models 1969+. Sample was children aged 2-6 years - over 37,000 observations. Crash characteristics were documented.	Fatal and non-fatal injuries to occupants in which there was a fatality.	Restraint use found to cut fatalities by 44-67%. No evidence to suggest that restraints perform better in terms of safety than adult lap-sash belts. Some mixed evidence that these 2 restraint type perform better than lap-only - in terms of fatalities - but do perform better in terms of reduced injury severity for non-fatal injuries.	Only included crashes involving a fatality - so did not capture crashes where all occupants survived the crash- thus potentially understating the effectiveness of child restraints. Not able to distinguish between correct and incorrect use of restraints.

Consensus Based Recommendation 1.14	**Retrofitting of a lap-sash seat belt in a lap-only seat belt position is recommended, if this meets local engineering requirements.**

This consensus-based recommendation is based on expert opinion, taking into account the following considerations. No data is available on the effectiveness of retrofitted lap-sash seat belts. However, a properly engineered and fitted lap-sash seat belt should perform similarly to a manufacturer-installed lap-sash seat belt. Expert opinion is that the broader evidence of lap-sash vs. lap-only seat belts, and also data that compares lap-sash seat belts to child safety harnesses, are applicable to retrofitted lap-sash seat belts. It has been shown that lap-sash seat belts are safer than a lap-belt used with a child safety harness (see recommendation 3.2 below). The retrofitting of lap-sash seat belts can be expensive and not suitable for all vehicles. The local state road traffic authority can provide details of procedures and requirements for retrofitting of lap-sash seat belts.

6.2 Appropriate restraint use in non-typical situations

6.2.1 Taxis, private hire cars, ride share, and rental cars

Consensus Based Recommendation 2.1	**For optimal safety, children should use their recommended restraint in taxis, private hire cars and ride share services.** ✋

While regulations around Australia vary as to whether child restraints are mandatory up to age 7 in taxis, the safety issues in taxis are the same as for other vehicles. Similarly, regulations around Australia vary as to the legal status of ride share and private hire car or driver services such as Uber, the safety issues are the same as for travel in all passenger vehicles. See Section **Error! Reference source not found.** above.

Consensus Based Recommendation 2.2	**For optimal safety, children should use their recommended restraint in rental cars.** ✋

In rental cars, the usual child restraint legislative requirements apply. Safety issues in rental cars are the same as for other vehicles. See Section **Error! Reference source not found.** above.

These consensus-based recommendations are based on expert opinion, taking into account the following considerations. There are no specific studies of injuries to child passengers in taxis, private hire cars, ride share vehicles, and rental cars. Expert opinion considers these vehicles to be identical in terms of restraints, crash protection and design to private vehicles (since most are the same vehicles as private vehicles), and that therefore all recommendations for best practice restraint use should be followed when children are travelling in taxis, private hire services, ride share, and rental cars.

6.2.2 'Troop carriers' and other 'non-passenger' vehicles

Consensus Based Recommendation 2.3	**Child restraints are not recommended to be used in side-facing seats in 'troop carriers' and similar vehicles.**

Consensus Based Recommendation 2.4	**Children should not travel in vans or other vehicles that do not have appropriate forward facing vehicle seats upon which the appropriate child restraint can be properly installed.** ✋

Consensus Based Recommendation 2.5	**Children should never travel unrestrained in vans, non-passenger parts of a vehicle, such as luggage compartments of cars and station wagons or the trays of utility vehicles and trucks.** ✋

These consensus-based recommendations are based on expert opinion, taking into account the following considerations. There are no specific studies of injuries to child passengers in 'troop carriers' with side-facing seats. Restraint instruction manuals recommend against the use of child restraints in side-facing seating positions. Child restraints should be used in forward facing seating positions.

There is no research that compares the safety of a child in a child restraint in a side facing seating position compared to a child in a seat belt in a side facing seating position that would guide the choice between these two options where no forward facing seat is available for installation of a child restraint. It is likely that the relative risk will depend on the child's age/size. The availability of anchorage points for a child restraint, the child's age/size, other options for safely restraining the child during travel, and the need for the child to travel in a side facing position should be considered carefully. In addition, local regulations may consider installation of a restraint in a side facing seat not to be a *properly fitted* Australian Standard approved child restraint, and thus illegal. Further research is required on this issue.

There are no studies that met our inclusion criteria that include children travelling in child restraints installed in seating positions that are inappropriate for child restraint installation. This is illegal in all states of Australia, as all states require children up to age 7 to be restrained in a *properly fitted* Australian Standard approved child restraint. Expert opinion is that this is the same situation as travelling with an incorrectly installed restraint, and is thus not recommended.

There are no studies that met our inclusion criteria that include children travelling unrestrained in vehicles without appropriate seating positions. This is illegal in all states and territories of Australia. Expert opinion is that this is the same situation as travelling unrestrained in a traditional passenger vehicle, and thus is inadvisable.

6.2.3 Additional ('Dickie') seats

Consensus Based Recommendation 2.6	**Additional seats ('Dickie seats') should only be used when a second row or manufacturer installed seat is not available.**

Consensus Based Recommendation 2.7	**The manufacturer's recommendations for weight or seated height should be followed to avoid overloading the additional seat or increasing the risk of head contact with the vehicle interior for a taller child.**

Consensus Based Recommendation 2.8	**The manufacturer's recommendations on suitability for use of child restraints on an additional seat should be followed, and child restraints should only be used on a suitable additional seat if a manufacturer installed seat is not available.**

Consensus Based Recommendation 2.9	**The "5 step test" should be used to determine whether a child is tall enough to sit in an additional seating position without a booster seat.**

Consensus Based Recommendation 2.10	**If a child between 4 and 7 years of age is seated in an additional seat which has only a lap seat belt available, and the child can meet the "5 step test" in the additional seat, they should use a child safety harness with the lap-only seat belt.** ✋

These consensus-based recommendations are based on expert opinion, taking into account the following considerations. There were no studies of additional seats meeting our inclusion criteria. Additional seats (also known as "Dickie" seats) can be installed as after-market options in non-passenger areas of the vehicle, such as in the cargo area of a station wagon. These additional seats vary considerably in size and design, and are often designed to be used only by children of specific weights and heights. They may or may not have appropriate anchorages for child restraint installation. Some states (e.g. Victoria) discourage the use of child restraints or booster seats in additional seats. Note that the legal requirement to use a child safety harness for a lap-only seat belt applies only to additional seats. Further research is required on this issue.

6.2.4 Integrated child restraint systems

Recommendation 2.11	**For children aged 4-8 years, add-on high back boosters are preferred over integrated booster seats.** **For children older than 8 years, integrated boosters are suitable for use in seating positions adjacent to a curtain airbag.**
Overall Evidence Grade	**D**

Table 15: Evidence statements supporting recommendation 2.11

Evidence statement	*Integrated booster seats without side structures do not offer postural support for children. In vehicles with side curtain airbags, they offer adequate head protection, but offer less protection in the absence of a side curtain airbag.*	
Grade	**D**	
Component	**Rating**	**Notes**
Evidence base	Satisfactory	There is a single level III peer reviewed paper, which reports a range of different sub-studies related to high back and integrated booster performance.
Consistency	N/A	There is only one study.
Public Health Impact	Satisfactory	Although magnitude of differences between add on and integrated boosters differs in each arm of this study, for 4-8 year old children there was a substantially greater child induced error rate in the integrated booster seat (mean 5.4 errors vs 1.2 errors), but a reduction in installation errors compared to the add on booster (zero errors vs mean 0.73 errors).
Generalisability	Satisfactory	The single study evaluated a single integrated booster seat design from one vehicle, and compared it to a range of add-on booster seats n crash testing but only a single add on booster seat in the laboratory trials. The results may not be generalisable to all integrated boosters and add on booster seats.
Applicability	Good	The available research is done on an Australian vehicle and Australian booster seats, and is thus directly applicable to the Australian context. Injury data for integrated booster seats, however, is scarce, and based on overseas studies.
Other factors		There are very few reported injury cases of children restrained in integrated booster seats, and those have all been overseas.
References		(Brown *et al.*, 2017a)

Some vehicles have ‘integrated’ or inbuilt booster seats in the rear seats. They are considered ‘booster seats’ for the purposes of the mandatory child restraint laws, and therefore the evidence statement for 1.11 applies here. They are not currently required to meet the requirements of AS/NZS 1754, which specifies safety standards for add-on child restraints, but instead are subject to vehicle regulations (Australian Design Rules), which require integrated restraints to meet the relevant European Standard. Current Australian regulations consider integrated booster seats as ‘approved’ child restraints, so children aged 4-7 years using these are considered to be appropriately restrained legally.

One Australian laboratory study has demonstrated that there is reduced potential for installation errors, but no apparent benefit for errors related to child behaviour in integrated boosters compared to add-on boosters. That same study conducted comparative frontal sled testing and full-scale side impact crash testing, comparing the crash protection provided by the two types of booster. This demonstrated no substantial difference in crash protection in frontal impact and for near-side seated child occupants in side impact crashes. However, the integrated system did not perform as well as the add-on booster in the far-side or non-struck side occupants. Furthermore, the adequate side impact protection observed for the struck-side occupant was heavily dependent on the presence of a side curtain airbag (Brown *et al.*, 2017a). As this is the only relevant available work, and this work was limited to evaluation of only one type of integrated booster, laboratory evaluations, and a review of limited international injury data in integrated restraints, further research is required on this issue.

Based on the above, and in the absence of further studies, it is preferable for children aged 4-8 to use add-on boosters, as these provide postural support, may reduce movement of children into out-of-position postures, and offer more proven protection for children who fit within them, but children older than 8 years who cannot achieve adequate seat belt fit without a booster seat may benefit from the use of an integrated booster rather an adult seat belt only.

Table 16: Summary of articles providing evidence for recommendation 2.11

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
(Brown *et al.*, 2017a)	1. Retrospective review of crash data 2. Crash testing 3. Laboratory ease-of-use testing	1. USA, Sweden 2,3. Australia	III-2	1. Retrospective review of US database NASS-CDS and data from Children's Hospital of Philadelphia, and from Volvo data in Sweden was reviewed and synthesised 2. Four sled tests using the frontal AS/NZS 1754 and CREP protocols and two full scale side impact crash tests comparing a two-stage integrated booster to previous tests data for add-on booster seats. 3. Ease-of-use was assessed using laboratory trials of installation and fitment in the lab, and used an online survey to obtain information about problems with installation	1. Injury type and severity 2. Head and knee excursion, HIC and seat belt position 3. Errors in use, qualitative feedback on installation problems, questionnaire on perception of ease of use.	1. No differences between integrated boosters and add-on boosters in CHOP data. No integrated booster users in NASS-CDS data. Volvo data was reported to show no differences in injury between integrated and add-on boosters 2. Similar head and knee excursions were observed for the integrated booster and add-on boosters in frontal impacts. In the presence of a side curtain airbag, side impact head injury values for the integrated booster were acceptable but overall restraint was poor due to lack of lateral restraint in integrated booster. 3. The integrated booster achieved a 4 star rating in CREP ease of use, compared to add-on booster three stars. It was rated easier to install and adjust than the add-on booster in the parent rating, and no errors in use were observed in the lab study for the integrated booster but the add-on booster was commonly misused. The survey identified several practical issues with installation of restraints	1. Limited numbers of children in integrated boosters in data analysed, and small numbers of injuries. 2. Only one type of integrated booster tested, small number of tests, no replicates 3. Biofidelity of dummies, particularly the TNO dummies is an issue. The order of exposure to the different restraint types in the lab trial was not randomised however consistency of large increases in errors and poor posture sin the integrated restraint suggests the effect of non-randomisation may be relatively small if present at all this would make to occupant kinematics but they are not commonly used, so data is sparse.

6.2.5 Public transport

Consensus Based Recommendation 2.12	**On urban public buses, children should be seated in their own seating position when possible and use seat belts where available.**

This consensus-based recommendation is based on expert opinion, taking into account the following considerations. There were no studies identified describing injuries to children travelling in urban public buses other than case reports (Lapner *et al.*, 2003) which did not meet formal inclusion criteria. Like adults, children can legally travel in urban public buses without restraints. Most metropolitan buses have no provision for use of seat belts or child restraints. However, since the seat in front can provide some restraint, and to minimise the risk of being sandwiched between a seat and another occupant, it is recommended that children be seated, rather than standing, and in their own seating position and use the seat belt where available, rather than on an adult's lap, when this is possible.

Consensus Based Recommendation 2.13	**On long distance coaches, children should use a size-appropriate restraint. If the size appropriate restraint is a rearward or forward facing child restraint, it should be correctly installed in one of the supplied seating positions equipped with top tether strap anchorages. If these seats or anchorages are not available, children over 1 year of age should use a lap-sash seat belt and children under 1 year of age should be seated in their own seating position if possible.**

This consensus-based recommendation is based on expert opinion, taking into account the following considerations. There were no studies that met inclusion criteria identified describing injuries to children travelling in long distance coaches. There is one NSW State Government report (Henderson and Paine, 1994) that suggests that injuries to children on public buses are rare, and mostly minor, and are likely to be prevented by use of lap-sash seat belts and/or child restraints. There have been a very small number of serious coach crashes in which children were killed when long distance coaches rolled over; the Australian Design Rule (ADR 68) requires all coaches made after 1994 have at least 6 seats equipped with seat belts and child restraint anchorages suitable for fitting child restraints; children in passenger vehicles are best protected in a correctly installed size-appropriate child restraint until they can achieve good belt fit, as assessed by the 5 step test (approximately 10-12 years of age); any restraint is better than no restraint. Infants under 12 months may not be able to be safely restrained in a seat belt. .

Consensus Based Recommendation 2.14	**Children using community transport buses should use an age-appropriate child restraint wherever possible.** ✋

This consensus-based recommendation is based on expert opinion, taking into account the following considerations. There were no studies that met inclusion criteria identified describing injuries to children travelling in community transport buses. '✋' Community transport buses with up to 12 seats must have child restraint anchorages installed in at least 3 seating positions that can be used to install a child restraint and these should be used; not all community transport is exempt from the mandatory child restraint laws outlined in section 6.1.5; children in passenger vehicles are best protected in a correctly installed size-appropriate child restraint until they can achieve good belt fit, as assessed by the 5 step test (approximately 10-12 years of age).

6.2.6 Old restraints

Consensus Based Recommendation 2.15	**Restraints older than 10 years should not be used.**

This consensus-based recommendation is based on expert opinion, taking into account the following considerations. There were no studies identified describing injuries to children travelling in old restraints. While restraints certified to newer standards are tested more rigorously to ultimately improve protection afforded to the child and restraint usability compared to those that are legally allowed to be sold under the Competition and Consumer Act 2010 (i.e. those certified to AS/NZS 1754 (2000) or newer), there is little evidence regarding their relative performance. However, restraint manufacturers typically recommend restraints not be used when they are older than 10 years, as internal structural degradation may not be visible externally; and old restraints that have plastic components not containing UV stabilizers can degrade after extended periods exposed to sunlight (Turbell, 1983). This requirement was introduced in AS/NZS 1754 (1995). Further research is required on this issue.

Consensus Based Recommendation 2.16	**Restraints that have been previously used should be inspected for missing components, wear and degradation before use. Damaged restraints should not be used, and should be disposed of in a way that ensures they cannot be re-used.**

This consensus-based recommendation is based on expert opinion, taking into account the following considerations. There were no studies identified describing injuries to children travelling in old restraints, abrasion of webbing (in harnesses and tether straps) in normal use results in wear and tear that can reduce the strength of the components that consist of webbing. Webbing and some other components can be replaced. Damage to the restraint shell indicates a restraint should not be used. It is also important to ensure all components of the restraint are present, and child restraint fitting stations can inspect restraints to determine this. Disposal by destroying the restraint so that it cannot be re-used is advised. Further research is required on this issue.

Consensus Based Recommendation 2.17	**Restraints that have been in moderate to severe crashes should not be re-used (even if damage to the restraint is not visible), and should be disposed of in a way that ensures they cannot be re-used.**

Moderate to severe crashes where the main body structure of the vehicle has been distorted may include those where any of the following occurred: there were serious injuries to any vehicle occupant, any airbag deployed, there is any damage to the child restraint (however damage is not always visible), the vehicle was unable to be driven away from the crash, or there was any damage to the door nearest the child restraint.

This consensus-based recommendation is based on expert opinion, taking into account the following considerations. While there are two non peer reviewed North American studies reporting that child restraints in minor collisions are able to be re-used without degradation in performance (Gane, 1999; IIHS, 2000) these may not apply directly to Australian restraints, and it is not always possible to see flaws in child restraint structures after a crash, international authorities and Australian child restraint manufacturers recommend replacement after a moderate to severe crash. Disposal by destroying the restraint so that it cannot be re-used is advised. Further research is required on this issue.

6.3 Other restraint options and child restraint accessories

Consensus Based Recommendation 3.1	**Child restraint accessories that are not supplied or recommended by the manufacturer or are not certified for use with a specific restraint under AS/NZS 8005 are not recommended.**

This consensus-based recommendation is based on expert opinion, taking into account the following considerations. There is little field or laboratory testing data covering the safety of child restraint accessories (with the exception of child safety harnesses as outlined in Recommendation 3.2 below). Many accessories have the potential to interfere with the compliance of a restraint with mandatory safety standards, or to create other non-obvious hazards. A new voluntary Australian Standard, AS/NZS 8005 has been developed to assess such accessories, but there is currently no experience with the application of this standard, and further research is needed to determine whether this will be sufficient to ensure good safety performance of child restraint accessories. Accessories supplied with a restraint are tested during the Standards certification process and are safe to use as directed. Use of any accessories not supplied with the restraint may be considered to constitute a modification of the restraint in some jurisdictions, and thus may require a medical or other special exemption from the restraint laws.

Recommendation 3.2	**Child safety harnesses (H-harnesses) are not recommended. They should only be considered for use in a seating position with a lap-only seat belt, in conjunction with a booster seat proven to prevent the child from sliding under the lap belt in a crash when used in conjunction with a child safety harness, or when required by law on an additional seat.**
Overall Evidence Grade	**D**

Table 17: Evidence statement supporting recommendation 3.2

Evidence statement	***Child safety harnesses provide no safety advantage over lap-sash seat belts and may increase the risk of injury***

Grade	D	
Component	**Rating**	**Notes**
Evidence base	Poor	The evidence is indirect, and limited to two reports of laboratory tests showing an increased risk of serious injury in child safety harnesses unless used with an anti-submarining feature on a booster seat. Incorrect adjustment of these was shown to substantially increase potential for 'submarining' and associated injuries. There is also separate evidence from observational studies showing that harnesses are widely misused in the field, which is linked to poor performance in the laboratory tests.
Consistency	Excellent	All studies are consistent in their finding that child safety harnesses provide little clear benefit over lap-sash seat belts and have potentially serious risks.
Public Health Impact	Unknown	No injuries have been reported in the peer reviewed literature.
Generalisability	Satisfactory	While the field misuse was collected on a population similar to the Australian child occupant population, the laboratory tests were conducted only at a limited number of crash severities and crash directions, which do not encompass the full range of crash types that occur in the field.
Applicability	Satisfactory	Misuse was studied in Australian children in a sample representing a large Australian state. Laboratory studies used Australian restraints.
Other factors		
References		(Suratno *et al.*, 2009a; Brown *et al.*, 2010a; Brown *et al.*, 2010b; Brown *et al.*, 2010c)

There is an absence of published field evidence linking child safety harnesses to injury in child occupants. However, the available laboratory evidence shows that child safety harnesses provide worse protection than a lap-sash seat belt (with or without a booster seat) even when correctly used (Charlton *et al.*, 2005; Suratno *et al.*, 2009a; Brown *et al.*, 2010c). Moreover, child safety harnesses are widely misused in the field (Brown et al 2010c,d), which has been shown in laboratory testing to substantially increase the risk of 'submarining' (Charlton *et al.*, 2005; Suratno *et al.*, 2009a; Brown *et al.*, 2010c) and thus likely increase the risk of related abdominal and lumbar spine injuries. There is no published field evidence, but unpublished case reports (which did not meet inclusion criteria) demonstrate that fatal abdominal injuries can occur to children using child safety harnesses in boosters without design features to prevent anti-submarining. There is considerable concern among the drafting group that failure to always use such a design feature could place children at risk of serious injury, and thus this practice is an option of last resort and careful counselling of consumers is required (see below). The technical drafting group also noted that child safety harnesses have been banned in Canada due to concerns about their injury potential. Moreover, child safety harnesses (when not used with a booster seat) are labelled for use from approximately 7 years up to approximately 10 years of age, and the vast majority of children in this age range should be using a booster seat, not a seat belt, as they are not large enough to obtain good fit in an adult seat belt. There is therefore little basis for their use with a seat belt alone under any circumstances (except as required by law on additional seats), nor should a harness be used with a lap-sash belt (with or without a booster seat) as a booster plus lap-sash belt is safer. As noted above (recommendation 1.13), a booster seat user should always use a lap-sash belt (without a child safety harness) if at all possible.

In the case where: (i) there is no alternative to a lap-only seat belt, and (ii) all other options for restraining a child aged 4 to 10 years with a lap-sash belt and booster have been exhausted, the following risks need to be weighed up:

- the high risk of injury when using a lap-only belt while in a crash, which is well established (see section 6.1.4), and

- the increased injury risk due to misuse (which is widespread) of a child safety harness that has been designed to be used with a booster seat to prevent submarining injuries.

There are currently no data indicating *which* booster plus harness combinations can prevent submarining apart from the models (which incorporate one specific design feature for anti-submarining) that were tested in the laboratory studies (Charlton *et al.*, 2005; Suratno *et al.*, 2009a; Brown *et al.*, 2010c). However, this has been included as a requirement for child safety harnesses when used with booster seats in AS/NZS 1754 (2013) and once such harness/booster combinations become available they could be considered for a lap-only seating position when all other options have been exhausted. Other options that should be considered first include (i) relocating the child to another seating position with a lap-sash belt (see section 6.4), (ii) advising the parent/carer to change their vehicle to one where lap-sash belts are available in all seating positions, and (iii) advising the parent/carer to consider retrofitting a lap-sash seat belt to the lap-only belt position. In addition, parents and carers need to be strongly advised of the dangers of child safety harnesses, and carefully counselled how to fit the harness without over-tightening the straps, and that any design feature required to prevent submarining in a booster seat *must be used at all times*, and be checked before every trip. They should also be clearly advised that this is an option of last resort.

Further research is required on this issue to ascertain the relative risks of lap-only belt use compared to a booster/child safety harness combination that has been proven to prevent submarining, and to identify specific booster/harness combinations that would meet such criteria.

Table 18: Summary of articles providing evidence for recommendation 3.2

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
(Brown *et al.*, 2010a)	Laboratory testing - simulated front-impact, instrumented dummies and high-speed cameras	III-2	Australia	Laboratory simulated frontal crash using a 6 y-o dummy and 3 different restraint systems: correct and incorrect harness use and a lap-sash belt - using two different kinds of booster seats.	Dummy motion, belt loads, neck forces and moments, head and knee moments. Submarining was determined visually.	Results suggested that correctly used harness did not perform any better than the -sash belt - either on its own or with two common types of booster seats. Incorrect use of the harness - causing the lap belt to be high and positioned over the abdomen, allowed for submarining to occur. Submarining did not occur when the booster was used and the lap belt kept low on either restraint tested.	Some limitations in the use of dummy head and neck responses to simulate real crash scenarios - biofidelity of the dummies is unknown. Only one model of harness was tested, and two booster seat types - other combinations may results in some different outcomes. Real postures of children are difficult to simulate in dummies. Submarining was determined visually which may be open to a level of subjectivity.
(Brown *et al.*, 2010b)	Field observational study	III-2	Australia	Cluster randomised observational field study of child restraint use, including detailed assessments of misuse.	Observed rates of restraint appropriateness and misuse. Detailed misuse use types identified	A weighted percentage of incorrect use by restraint type found that 100% of children using child safety harnesses showed a serious form of incorrect use. All children observed using child safety harnesses displayed between 2-3 errors in their use. Weighted estimates were calculated indicating that 15.7% (CI 95% 0.0-61.5) of harnesses were very loose. Furthermore, estimates of error prevalence in child safety harness users indicated that a gated buckle/locking clip error occurs in 84.3% (CI 95% 38.4-100.0) of cases, and a seat belt error is present in 15.7% (CI 95% 0.0-61.5).	Misuse of child safety harnesses was universal, but numbers of harnesses in sample are limited.

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
(Brown *et al.*, 2010c)	Laboratory testing - simulated front-impact, instrumented dummies and high-speed cameras	III-2	Australia	Laboratory simulated frontal crash using a 6 y-o dummy and 3 different restraint systems: correct and incorrect harness use and a lap-shoulder belt - using two different kinds of booster seats.	Dummy motion, belt loads, neck forces and moments, head and knee moments. Submarining as determined visually.	Results suggested that a correctly used harness did not perform any better than the lap and shoulder belt - either on its own or with two common types of booster seats. Incorrect use of the harness - causing the lap belt to be high and positioned over the abdomen, allowed for submarining to occur. Submarining did not occur when the booster was used and the lap belt kept low on either restraint tested.	Some limitations in the use of dummy head and neck responses to simulate real crash scenarios - biofidelity of the dummies is unknown. Only one model of harness was tested, and two booster seat types - other combinations may results in some different outcomes. Real postures of children are difficult to simulate in dummies. Submarining was determined visually which may be open to a level of subjectivity.
(Suratno *et al.*, 2009a)	Laboratory testing - simulated front-impact, instrumented dummies and high-speed cameras	III-2	Australia	Twelve front impact crashes were simulated using a 6 year old dummy - three different restraint types (seat belt, booster seats and safety harness) and the use and incorrect use and non-use of a harness.	Sensors to detect head, chest and pelvis acceleration, upper neck forces and moments, and chest deflection. Dummy motion was captured with high-speed camera.	Results indicated that in frontal impact at least, child safety harness systems provide no better protection than lap-sash seat belt systems, either with a booster seat or alone. The main danger is "submarining". Misuse of harnesses is common and associated with serious degradation of the protective effect.	Testing was limited to frontal impacts and did not test for the risk of submarining with different speeds at impact. No evidence to support their use particularly in conjunction with lap-sashes and that if too tight - they can result in excessive head excursion.

Consensus Based Recommendation 3.3	Seat belt positioners, particularly those that link the lap and sash belts to alter sash belt fit, are not recommended. If children cannot fit well into adult seat belts, they should use booster seats with a lap-sash seat belt.

This consensus-based recommendation is based on expert opinion, since there have been no studies of seat belt positioners. The following issues were considered. Devices that attach the lap belt to the shoulder belt tend to pull the lap belt up, away from the anterior iliac spines of the pelvis, and into the soft abdomen. They can therefore act similarly to child safety harnesses to encourage 'submarining', where the child slips under the lap belt, and are likely to pose an elevated risk of abdominal and/or lumbar spine injury. In addition, these may be perceived as being a valid alternative to proven safer options, such as the use of a booster seat. Note: This consensus-based recommendation does not address 'gated buckles' and other restraint installation aids (see consensus-based recommendation 3.6).

Consensus Based Recommendation 3.4	Buckle covers and other devices to stop a child from escaping from a restraint are not recommended. Behavioural solutions are preferred.

This consensus-based recommendation is based on expert opinion, taking into account the following considerations. There are no formal studies of buckle covers and other devices. These are designed to make it more difficult for a young child to release themselves from a restraint, either inadvertently, or intentionally when the vehicle is moving, thus leaving the child unrestrained (or partially unrestrained). The potential risks associated with the increased difficulty of removing a child from a restraint in an emergency when one of these devices is used, together with potential for a child to quickly learn to operate such a device, negating its benefits is the rationale behind this consensus-based recommendation. Future designs of after-market accessories for this purpose that have been certified to AS/NZS 8005 may be considered for use if behavioural approaches fail.

Consensus Based Recommendation 3.5	**Padding, pillows, cushions, and blankets or wraps that surround the head or neck, are positioned behind the head, or within the harness of a restraint that are not supplied by the manufacturer with the restraint are not recommended.**

This consensus-based recommendation is based on expert opinion, taking into account the following considerations. Apart from manufacturer supplied pads and accessories, which are tested with the restraint when it is tested for mandatory safety performance under AS/NZS 1754, there have been few studies of padding, pillows and cushions. Padding or cushions behind the head that displace the head forward could potentially expose the head outside the side structure of the restraint in a side impact; pillows that surround the child's neck could pose a suffocation hazard; soft padding, including blankets or wraps (including infant swaddling), inside the harness is likely to introduce slack into the harness, increasing the risk of injury.

Consensus Based Recommendation 3.6	**Seat belt tensioners and other fitting accessories that actively tighten the seat belt are not recommended. Other fitting accessories are rarely required for normal installations and should only be used if required by the child restraint manufacturer or recommended by a child restraint fitter.**

This consensus-based recommendation is based on expert opinion, taking into account the following considerations. Devices that tighten the seat belt excessively to ensure tight restraint fit (i.e. those that actively tighten the seat belt) have not been formally studied. Some devices use high force ratchets, which could potentially deform the restraint structure, compromising its strength and performance in a crash; child restraints are designed to perform well in the absence of seat belt tightening devices, and are thus considered not to be necessary under normal circumstances. There can be specific circumstances where fitting devices (e.g. gated buckles, padding to position the restraint in a contoured seat etc.) may be required to firmly install a restraint, and child restraint fitters are able to provide advice in such circumstances. Accredited restraint fitters (who have completed one of two nationally accredited short courses) are preferred where available.

Consensus Based Recommendation 3.7	**Seat belt extenders are not recommended. If their use is unavoidable, the buckle should not be located over the child. Great care should be taken not to introduce seat belt slack when used, and that both extender and main seat belt buckle are latched.**

This consensus-based recommendation is based on expert opinion, taking into account the following considerations. Seat belt extenders, which lengthen the seat belt to allow for fitting in some restraints for which existing seat belts are not long enough to correctly fit the restraint or go around a booster seat, have not been formally studied. Seat belt buckles placed over the abdomen of a child have the potential to interact with the soft abdomen of the child or the child's head in a crash; depending on the location of the seat belt extender. This can introduce slack into the seat belt, which reduces the effectiveness of the seat belt. It is necessary that both the extender buckle and the main seat belt buckle be correctly buckled for an 'extended' seat belt to function.

Consensus Based Recommendation 3.8	**Toys and entertainment accessories: Only soft toys that contain no rigid parts that could make contact with a child during a crash should be used for entertainment of children in child restraints.**

This consensus-based recommendation is based on expert opinion, taking into account the following considerations. Toys and entertainment accessories have not been formally studied. Loose rigid objects in a vehicle can become projectiles in a crash, causing injury to vehicle occupants; rigid fixed objects could be struck by the child or another vehicle occupant in the event of a crash, potentially creating an injury hazard.

Consensus Based Recommendation 3.9	**Add-on chest clips designed to prevent the child from removing his/her arms from the harness, other than those supplied with the restraint or certified under AS/NZS 8005, are not recommended. Behavioural solutions are preferred.**

This consensus-based recommendation is based on expert opinion, taking into account the following considerations. Add-on chest clips (aftermarket devices not supplied with the restraint) have not been well studied and there is no real world injury data. The potential risks associated with the increased difficulty of removing a child from a restraint in an emergency when one of these devices is used, together with potential for a child to quickly learn to operate such a device, negating its benefits; the potential for injurious throat contact if the device is positioned improperly. Chest clips that have been provided with the restraint by the manufacturer, or certified under AS/NZS 8005 may be safe to use. Future designs of after-market accessories for this purpose that have been certified to AS/NZS 8005 may be considered for use if behavioural approaches fail.

Consensus Based Recommendation 3.10	**Sun shades, insect nets, blankets or other cloths which cover the child and restraint are not recommended.**

This consensus-based recommendation is based on expert opinion, taking into account the following considerations. Sun shades and insect nets have not been formally studied. Sun shades, insect nets, or other cloths such as muslins over the top of a restraint could reduce airflow to a child, reduce visibility of the child, and make it more difficult to remove the child rapidly in the event of an emergency. Window-mounted sun-shades are available as an alternative.

6.4 Seating position

Recommendation 4.1	**Children up to and including 12 years of age should sit in a rear seating position.** ✋
Overall Evidence Grade	**A**

Table 19: Evidence statement supporting recommendation 4.1

Evidence statement	***Injury risk to children is lower in the rear seat, irrespective of restraint type***	
Grade	**A**	
Component	**Rating**	**Notes**
Evidence base	Good	Thirteen studies (10 based on large population representative samples, 2 cases control studies and 1 laboratory study) of III-2 level of evidence have examined the relative protective level of rear versus front seating for children.
Consistency	Excellent	All studies have findings in the same direction, that after controlling for other factors, rear seating offers greater protection than front seating to children in the event of a crash. The only exception is the study by Glass, et al (Glass *et al.*, 2000), which while supporting these findings for younger children, reported that for 9-12 year olds in vehicles with an airbag, the front seating position offered more protection than the rear seat.
Public Health Impact	Excellent	The protective effect of the rear seat, after controlling for other factors, was reported to be a 33- 40% reduction of injury risk, with some studies indicating as much as 80% if the child is unrestrained. One study found a 21% reduction in the risk of fatal injury if seated in the rear seat compared to the front seat for restrained children.
Generalisability	Good	The number of studies employing large surveillance databases in the USA (10), in Australia (1) plus one study based on hospital admission in Greece, together with the findings from an Australian laboratory study suggest that available findings are generalisable to a wide range of children.
Applicability	Good	While airbag differences between the USA and Australia until the late 1990s indicate that the earlier American studies are not directly applicable to the Australian context, there are 5 USA studies post 2005 and 3 other studies which all provide evidence directly applicable to the Australian context.
Other factors		
References		(Partyka, 1988; Johnston *et al.*, 1994; Braver *et al.*, 1998; Giguere *et al.*, 1998; Petridou *et al.*, 1998; Berg *et al.*, 2000; Glass *et al.*, 2000; Cummings *et al.*, 2002; Durbin *et al.*, 2005; Brown *et al.*, 2006c; Smith and Cummings, 2006; Lennon *et al.*, 2008; Arbogast *et al.*, 2009c; Sahraei *et al.*, 2009; Bilston *et al.*, 2010; Ma *et al.*, 2012; Durbin *et al.*, 2015)

There are 13 studies, including two well-designed matched cohort studies in large population-representative samples which provide strong evidence that children at least up to the age of nine, and likely twelve, are better protected in the event of a crash if seated in the rear seat rather than the front seat when other factors (such as restraint use, collision type etc.) are controlled for. Glass et al (Glass *et al.*, 2000) reported that 9-12 year olds with passenger airbags are safer in the front seat, but in non-airbag cars children are safer in the rear. Bilston et al (2010) showed that 9-16 year olds in newer vehicles with passenger airbags were safer in the rear seat, although the benefit was less in newer vehicles than in older vehicles (Rear to front risk ratio (RFR) = 0.40 95%CI = 0.37–0.43, for older vehicles (model year 1990–1996); RFR 0.69, 95% CI = 0.64–0.75 for newer vehicles (model year 1997-2007) (Bilston *et al.*, 2010)). While restraint type was not factored in, a surveillance study with large sample size indicated being seated in the rear seat for children 0-8 years reduced the risk of fatal injury by over 70% compared to sitting in a front seat (Durbin *et al.*, 2015)) the same study also reported the risk ratio of fatal injury for 9-12 year olds was higher in the rear than the front (1.83, CI 1.18-2.84) primarily due to small fatal risk in front row (.1%) rather than elevated risk in rear. There is one study that suggested that front seated infants <1 year of age in child restraints were at lower risk of non-fatal injury compared to optimal restraint use (Ma *et al.*, 2012) based on weighting of a small number of cases in a dataset not designed to examine non-fatal injury, so the results should be viewed with caution. The precise age of the child or size cut-off for rear seating is not well defined.

Table 20: Summary of articles providing evidence for recommendation 4.1

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
(Arbogast *et al.*, 2009c)	Data review from insurance claims database, onsite crash scene inspection and telephone survey.	III-2	USA	State Farm insurance claims (Dec 1998 - Nov 2007) in 15 states plus DC. Stratified cluster sample, by vehicle towed or not towed and level of medical treatment received by the child (0-16 years). Passenger vehicles 1998 or newer. Paired information (crash investigation and survey) for 518 children (90% agreement on child restraint use). Interview data on 16, 920 children in 10,670 crashes.	Injury severity: AIS <2 or 2+.	Limiting the sample to newer vehicles enabled consideration of the impact of airbags on the risk of injury by seating position. Findings suggested that children seated in the rear seat row(s) were half to two-thirds less likely to sustain a severe injury than those in the front seat. Children seated in the rear row of the newer vehicle (2003+) had the lowest risk, although it was noted that there were insufficient numbers of children seated in the front row of these newer vehicles to compare the risk.	Discussion notes that other findings, presented by Braver (1998), Berg (2000) and Durbin (2005) have found a safety benefit from rear row seating. While high degree of agreement on seating position between survey and site investigation - most data were self-reported. Sample limited to State Farm customers - cannot be generalised to uninsured vehicles or older vehicles. Data not able to shed light on injury mechanisms.
(Berg *et al.*, 2000)	Data review for crash surveillance system	III-2	USA	5751 children aged <15 years were identified from state crash database (Utah) 1992-1996. Hospital data linkage to obtain data on diagnosis, length of stay, hospital charges.	Injury severity (length of stay), cost.	After controlling for age and restraint use, findings indicated that serious injury or fatality risk to a child was1.7 higher if sitting in the front seat versus the rear seat during a crash. Front row seating was associated with only 37% the chance of such injuries compared with not optimally restrained regardless of seating position.	Restraint use was based on self-report which may result in over-reporting. Database did not include cases not reported to the police or those on private property and surveillance system may include some data entry errors.
(Bilston *et al.*, 2010)	Matched cohort study based on cases from large surveillance system	III-2	USA	This is analysis of the NASS database in front (passenger and driver) and rear seat occupants, large sample, representative of US population - matched cohort study comparing vehicles of model year 1990–1996 to newer vehicles (with other confounders controlled for including occupant age, belt type and intrusion).	Serious injury (AIS3+).	Children aged 9-15 have a lower risk of serious injury in the rear seat in both older and newer vehicles, although the gap has narrowed in newer vehicles. For occupants aged 9–15, while there is still benefit in being rear seated in newer model year vehicles (1997–2007) rear to front risk = 0.40 (CI = 0.37–0.43), this relative benefit is smaller than in older vehicles (1990–1996); RFR 0.69 (CI = 0.64–0.75) for newer vehicles. While children appear to be better protected in the rear seat compared to the front seat, this was not the case with adults in newer vehicles.	As the study used a matched cohort design, vehicles were only included when there were both front and rear occupants present, hence absolute injury risks were not able to be calculated. Cases were excluded where the occupant was unrestrained or had missing values. Strength of the study design was in matched cohort, so factors relating to the crash were largely controlled for.
(Braver *et al.*, 1998)	Data review from fatality surveillance system.	III-2	USA	Data were reviewed for 1988-95 from the US FARS database (police reported crashes in which at least one person died) for children 0-12 in. Over 26000 child cases were included - using vehicles from 1981-96 (airbags were known for 1991-96). Variables examined included front versus rear seats, restraint use and vehicle size. RR examined while controlling for other factors.	Mortality rates.	A 36% reduction in the risk of fatal injury was observed for children in the rear seat compared to the front seat. Children aged 1-4 years appeared to have the greatest benefit from rear seating (41% reduction). The risk of fatal injury was 41% lower for children in the rear seat in vehicles with a front passenger seat airbag, and a 31% reduction among those without a passenger seat airbag (but with a driver airbag). Looking at only children aged 5-12 in adult seat belts, those in the rear seats using lap belt only were less likely to be fatally injured than those in the front seat with shoulder and lap belts.	The study could not control for the severity of crashes, nor did it examine non-fatal crashes.

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
(Brown *et al.*, 2006c)	In depth crash study	III-2	USA	The Crash Injury Research Engineering Network (CIREN) linked crash reconstructions to medical data. Injuries were limited to Abbreviated Injury Scale (AIS) scores of 3 or higher. Crash reconstructions were conducted as soon as possible following participant approval. Statistical analyses used Fisher's Exact test and multiple logistic regressions.	Injury pattern and severity (AIS>=3).	Data from 417 children were collected. Children in front-seat positions were more likely than those in the rear seat to sustain severe injury (AIS>= 3) to thoracic (27% vs. 17%; OR 1.7 CI 95% 1.1-2.8), abdominal (27% vs. 17%; OR 1.7 CI 95% 1.0-2.9), pelvic (11% vs. 1%; OR 10.8 CI 95% 2.5-46.3), and orthopaedic injuries (28%vs 13%; OR 3.3 CI 95% 1.9-5.8).	The sample size was limited due to the expensive nature of in-depth investigations
(Cummings *et al.*, 2002)	Case control study	III-2	USA	Cases (N = 20,987) were front seat passengers who died, and controls (N = 69,277) were a sample of survivors – from FARS database. Factors examined were children vs. adults, restrained or unrestrained in the front seat, presence of airbag.	Fatal injury versus not fatal.	Airbags appeared to offer no reduced risk of death for unrestrained passengers in the front seat and a 12% reduction among those who were restrained. Study found that airbags may be a hazard to unrestrained children and of little benefit to unrestrained adults. Protective effects of air bags were limited to restrained teenagers and adults. Concluded that children younger than 13 years who sit in front of an air bag are at increased risk of dying in a frontal crash (RR = 1.22. 1.03 – 1.45) Adjusted RR 1.16 was not significant.	Study covered older models of cars and airbags and fewer restrained children than is current practice. Improvement to airbag deployment has since reduced some of the hazards of these earlier models.
(Durbin *et al.*, 2005)	Cross-sectional study using a child specific crash surveillance system	III-2	USA	Children 0-16 in 15 states who were involved in a MVC over a four year period (Dec 1998-Nov 2002) - in cars 1990 or newer. Over sampling of children presenting for medical treatment. Data from telephone interview with driver or proxy were included. Seating row and restraint use (correct and incorrect - with CRS or booster seat use for children <9 years was classified as "correct"). Approx. 18,000 children were included in the sample. Weighted logistic regression was used.	Injury status and by severity (AIS<2 and 2+).	As age increased the severity of injury to front row passengers also increased (without controlling for restraint type). Children 4-8 years had the highest proportion of inappropriate restraint use. The highest risk of injury was to unrestrained children in the front seat, followed by unrestrained in the back seat. Children in the front seat had a 40% greater risk of injury, compared with children in the rear seat (OR: 1.4; 95% CI: 1.2–1.7). The effect of seating row was less than restraint status. No restraint use was 4.3 times greater for children in the front seat.	Age appropriate restraint use and second (or third) row seating work synergistically to achieve greater safety. Restraint use and seating position relied on driver reporting of this information. Study did not cover vehicles older than 1990 nor uninsured vehicles.
(Durbin *et al.*, 2015)	Retrospective longitudinal study using a crash surveillance system	III-3	USA	Analysis of FARS crash database 2007-2012 for all vehicles model year 2000 or newer involved in reported crash and National Automotive Sampling System Crashworthiness Data System (NASS-CDS) for injury severity AIS 3+. Analysis included (RR) of death for restrained occupants in the rear vs. front passenger seat by occupant age, impact direction, and vehicle model year.	Serious injury (AIS 3+) as well as fatal versus not fatal.	Compared with passengers in the front passenger seat, the relative risk of death was lower for restrained children up to age 8 in the rear (RR = 0.27, 95% CI 0.12–0.58 for 0–3 years, RR = 0.55, 95% CI 0.30–0.98 for 4–8 years) but was higher for restrained 9–12-year-old children (RR = 1.83, 95% CI 1.18–2.84). There was a clear fatality risk reduction for restrained children ages 0–8 years in the rear seat compared with the front seat.	The type of restraints system being used, or even the non-use of a restraint, was not identified. This is a limitation as it might be expected that children are restrained differently if sitting in the rear seat than in the front seat. All rear seating positions were treated the same, so if some positions are safer than others this was not identified in the analysis.
(Giguere *et al.*, 1998)	Small case series of properly restrained children in the front passenger seat	IV	Can	Three cases with physical examination and autopsy results following motor vehicle accidents while the child was seated in the front passenger seat.	Injury type.	Case 1 – following a low speed crash, the child had superficial burns and abrasion to the right zygomatic region, corneal abrasions, and right eye hyphema; injuries were due to contact with hot gas released from the airbag. Case 2 – The child was restrained by only the lap portion of the belt in a low speed crash. X-rays showed a large prevertebral hematoma, and type III atlanto-occipital dislocation. Patient later died. Case 3 – A 3 year old in a booster seat was in a 60km/h crash. Brain scans showed a subarachnoid haemorrhage with a hematoma anterior to the pons and spinal cord. In summary: in case 2 a minor accident resulted in a fatal injury primarily due to the airbag.	Uncontrolled small case series only. Potential selection bias, but demonstrates this injury mechanism.
(Glass *et al.*, 2000)	Data review from fatality surveillance	III-2	USA	Data were reviewed for 1989-98 (vehicles 1990-99) from the US FARS database for fatality outcome for children 0-12. Variables examined	Fatal injury to child.	Airbags were found to add to the risk of fatality in age groups less than 10 year (by 31% in restrained children and unrestrained children by 84%), with it being	Data limitations inherent with the FARS database including the possibility of misclassification of restraint use and lack of

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
	system – matched pairs study.			included age group of child, driver use of restraint, crash severity, front passenger airbag, front versus rear seats, restraint use and vehicle size. Logistic regression was used to examine the RR while controlling for other factors examined. Matched pairs in which both driver and child were restrained and those in which both were not restrained were also examined (n=1329).		protective for 10-12 year olds (with a 39% reduction in risk). Rear seat position offered greater protection than front seat in both restrained and unrestrained children (21% and 29% reduction in risk of fatality respectively). For 9-12 year olds, the data suggested that front seat positioning with an airbag was more protective than rear seat positioning.	data on airbag design and factors associated with deployment.
(Johnston *et al.*, 1994)	Cross-sectional case series - data review	III-2	USA	Probability sample of police reported crashes in 26 states - over a 2 year period. Selected crashes in which there was one or more child under 15 as a passenger (n=16,685) reviewed police data on type of restraint and whether child was injured. 10,098 children with known restraint use.	Injury outcomes to children as passengers in MV crashes by restraint use. No attempt was made to classify injury severity.	Compared to children in the back seat, children in the front seat have 1.5 times the risk of injury. The use of a car seat reduced injuries by 60% for 0-14 year olds, while a lap-sash harness was only 38% effective in reducing injuries for 5-14 year olds.	For children aged 0- 4 (preschool), optimal use was defined as police reported use of a child safety seat. For the 5- to 14-year-old children, shoulder belt combination, as that is the current recommendation. Any other restraint usage inducing lap belt or shoulder belt alone was considered sub-optimal.
(Lennon *et al.*, 2008)	Data review of traffic crashes in which an injury occurred.	III-2	Australia	Data from Victorian traffic crash files for 1993-98 and 1999-2004 were reviewed for analysis of seating position (front vs. rear), restraint use (child restraint, seat belt, none), age of child (0-3, 4-7 and 8-12). Fatalities were cross-matched with the National Coroner's Information System for 2000-2004.	Injury severity: serious (fatal or hospitalised), minor or none.	Data on 30,631 children indicated that being in the front seat more than doubles the risk of serious injury among 0-12 year olds compared to being in the back seat. For children under 4 years, the risk of serious injury was 60% higher for those in the front seat than those in the back and for those 12 months of under the risk was 3.3 times higher in the front than the back seat (not controlling for restraint type). For older children the relative risk was close to unity (1.1 of 4-7 year olds and 0.93 for 8-12 year olds). The fatality rate was 15.1/1,000 among unrestrained children and 2.4/1,000 among restrained children.	Introduction outlines the difference between US and Australian restraint use. Most vehicles would not have been equipped with front passenger seat airbags. By only classifying restraints as child restraint or seat belts, no conclusions could be made about appropriate use and no differentiation is made between belt positioning booster seats and seat belts alone. There appears to be no controlling for restraint type when comparing the relative risk of front and rear seat positions.
(Ma *et al.*, 2012)	Cross-sectional study to examine association between use and non-use of restraints and injury outcome	III-3	USA	Retrospective cross-sectional study from police reported MVCs involving children from 0-12 years in the US from 1996 to 2005. Children were grouped into 4 age groups: 0- <1 year, 1-3 years, 4-7 years and 8-12 years. Logistic regression on these grouping with appropriate restraint use, inappropriate use and non-use (which included whether in he correct restraint and seating position for age). Potential confounders considered included characteristics of the child passenger, driver, vehicle and crash.	Non-fatal and fatal injuries.	A total of 7633 cases were included. Children with no restraint use experienced a significantly higher prevalence of fatal injury than children who were appropriately restrained in all age groups: <1 year olds had an estimated 23 times the risk odds of fatal injury were significantly greater among unrestrained children among all age groups (children aged <1 year old OR=23.79, 95%CI=1.20-472.72; 1-3 years OR=21.11, 95%CI=4.39-101.57; 4-7 years OR=16.24, 95%=2/76-95.54; and 8-12 years 9.81, 95% CI 2.05-46.90). Children aged 1 to 3 years who were inappropriately restrained had 6.28 times the odds of being fatally injured compared with those who were appropriately restrained after adjustment for potentially confounding factors. Children in this age group who were restrained and in the rear seat but inappropriately restrained had approximately 12 times the odds of dying compared with children with appropriate restraint use. The odds of a non-fatal injury for front seated infants appropriately restrained were reduced by 74% compared with rear-seated appropriately-restrained infants.	Vehicles and restraints in this study are now 13-20 years old so current models of both may have quite different injury risks associated with them. Due to data limitations, the authors were not able to determine if the restraints were correctly installed.
(Partyka, 1988)	Retrospective review of crashes using a matched pairs technique	III-2	USA	FARS surveillance system - covering the period 1982-87 in which there were 7060 vehicles included on the reporting system. Looking at children under 5 years of age, matched pairs - based on restraint usage by driver and child occupant and fatality ratios were calculated.	Fatal vs. non-fatal injuries.	Based on the fatality ratios it was estimated that children were 50% less likely to be killed if they were in a child restraint. When fatality ratios were applied to front versus rear seating of the child who is restrained, it was found a 33% reduction in chance of a fatal injury of the child is in the back seat. The effectiveness of a CRS was	Old study - many changes to recommended restraints since 1980's. Assumptions are made about correct restraint use, and that driver fatality was indicative of the risk of fatality for the child occupant.

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
						52% in avoiding a fatal injury after controlling for seating position. Effectiveness of restraints: for infants in CRSs were 69%, toddlers (1-4 years) in CRSs were 47% and toddlers in adult belts were 36%.	
(Petridou *et al.*, 1998)	Case control study.	III-2	GREECE	A random sample of child (0-11 years) in MVC cases presenting to 2 major children's hospitals in Greece in 1996 (n=129). Review of hospital records and survey with parents. Controls were from an observational survey of restraint use at 20 sites in and around Athens. N= 191 child occupants (0-11 years old). Interviews with parent/guardian. A 40 day observational survey of restraint use via inspections.	Injury Severity Score. Comparison between cases and controls on restraint use, seating position, and age of child (<5 or 5+).	Child restraint system used by less than one third of children under five. This group was at 3.3 times the risk of injury if not in a restraint. Front seating increased the risk of injury five-fold.	Sample size limitations reduced the opportunity to examine interaction effects of restraints and seating positions by age group. Population controls are not able to examine effectiveness of restraints in a crash situation - just the proportion that are likely to be using them. Little information available on the type of restraints being used.
(Sahraei *et al.*, 2009)	Data review from two surveillance systems: on fatal crashes (FARS) and tow-away crashes based on police reports (NASS CDC).	III-2	USA	Frontal crashes with no roll-over were included where restraints were used properly or not used at all (improper use were excluded). Age groups were 0-8, 9-15 and two adult age groups. For fatal crashes (1991-2007) a double paired comparison approach was employed: each was with restrained driver and either a front passenger or a back seat passenger. Tow-away crashes (1993-2007) were examined and logistic regression conducted.	Fatal injuries and those with a severity score of MAIS= 2+.	Findings indicated that rear seat positioning is most advantageous for children under 8 year's old, providing 63% reduction in risk of a fatal injury for unrestrained children and a 47% reduction for restrained children.	While model year was examined (front seat versus back seat) this was not done by age group so the impact on children cannot be seen. The non-fatal injuries in the NASS database were not reported by age group - so the front seat versus rear seat difference is not reported for children.
(Smith and Cummings, 2006)	Data review from surveillance system (FARS)	III-2	USA	All fatal crashes from 1990-2001. Seating positions examined were front right (passenger) or back right and left and consideration of airbag presence - by year and model of car - if not reported. Restraint use was classified as restrained or not. Age categories for children 0-4, 5-12, 13-18 plus adults.	Fatal injury (within 30 days of the crash).	The risk of death was found to be 21% lower for passengers in the rear seat, particularly for child passengers (approx. half the risk RR=0.47). Seated in the front seat with restraint and airbag is no different risk than in the rear seat with just a restraint. No indication of increased risk for children in the front seat if restrained.	Did not report on 0-4 year olds separately - only less than 13 years as a whole. Others to consider seating position for children were Braver (1998), Berg (2000) and Durbin (2005) - consistent finding of lower injury risk in the rear seat.

Consensus Based Recommendation 4.2	**When deciding on the position of a child using a child restraint or booster in the rear seat, the most appropriate choice of seating position will have as many of the following attributes as practicable:** **1. The anchorage points needed for the child restraint (top tether anchorage and ISOFIX lower anchorage points if relevant) are available for the restraint.** **2. There are no potential interactions with other child restraints installed, such as a top tether strap from a child seated in front, or space required for other restraints.** **3. For children in seat belts or booster seats, the seat belt buckle is readily accessible.** **4. If limited lap-sash seat belts are available, that position should be prioritised for children in booster seats or seat belts alone before those in a rearward or forward facing child restraint.** **5. The top tether strap is not able to fall off the side of the seat back or into a gap between seat back sections such as if there is a split-folding seat.** **6. The seating positions and restraint types do NOT compromise the safety needs of other occupants in the rear seat.** **7. Easy and safe access to the child restraint, for the parent to correctly secure the child in the restraint.** **8. Easy and safe entry and exit of the child from the vehicle on the kerb side of the vehicle.**

This consensus-based recommendation is based on expert opinion, taking into account the following considerations. Comparative studies of centre rear versus outboard seating positions for child restraint system (CRS) users show lower risk in the centre rear position (Kallan *et al.*, 2008; Arbogast *et al.*, 2010), but the first of these studies did not control for the category of child restraint. The latter study examined side impact crashes, and showed that the centre rear seat was safer. However, the restraint types used in these studies largely do not use top tethers and are not subject the side impact protection requirements that are in place in Australia, so the applicability of these studies to the Australian context is likely to be very limited. A recent study examining severe injuries in the rear seat among children up to age 17, showed a substantially higher risk of serious head injury in the centre rear position, providing conflicting evidence about centre rear seat safety (Stewart *et al.*, 2013). While the kerb side position has been suggested to have lower potential for injury to either parent or child while entering or exiting the vehicles from the roadway, there is no formal data on injuries under this condition. On the other-hand there is one US study that found children seated behind the driver have a slightly (8.1%) lower fatality risk than those seated behind the front passenger (Viano and Parenteau, 2008), but that study did not control for the type of restraint used by the child. Sled tests of side-impacts and Q6 ATD with FFCR found highest injury values when the booster seat was behind the driver seat (Tylko *et al.*, 2015). This evidence base is insufficient for making recommendations for specific seating position. In addition, practical constraints around fitting multiple children in the vehicle, whether the specific design of the rear seat is suitable for a child restraint and tether installation (if the seat can fold) and ease of correctly securing the child in the restraint need to be considered in each case. That is, at a population level, being seated in the centre position may be safer for child restraint users, but the evidence base is weak. However, when fitting a child restraint, all relevant safety issues should be considered and individual circumstances may outweigh general considerations.

While no studies identified address this directly, there is concern among experts that if a vehicle has a split-fold rear seat, a top tether strap could fall into the gap between seatback sections, and thus fail to adequately restrain the child in a crash. A warning regarding this is required in instruction books for all child restraints using a top tether under AS/NZS 1754 One recent sled testing study indicated that there may be elevated risk of head injury for RFCRs in 3rd row seats, due to the narrow clearance and increased risk of head impacts with the seat in front (Tylko, 2011) but there is no published real-world data on this issue.

For families with more than one child, the location of each restraint is likely to be influenced by how well the restraints fit in different seating positions, and how the restraints fit relative to each other, and also how easily seat belt buckles (for seat belt or booster seat users) can be accessed for correct use of the restraints. In addition, child restraints (including many booster seats) that have tether straps must be installed in seating positions with top tether anchorage positions. In Australian vehicles with more than one row of seats, these are only available in the rear seat. When carrying multiple children in a vehicle, the needs of all children and correct installation of the restraints used by those children need to be considered together.

No studies of the safety of entering and exiting from the vehicle were identified. The following factors were considered: children entering or exiting the vehicle in the roadway may be at risk of being struck by passing traffic, parents fastening children in child restraints positioned in roadway side outboard seating positions may be at risk of being struck by passing traffic.

Consensus Based Recommendation 4.3	**When deciding on the position of a child using adult seat belts in the rear seat, these issues should be considered:** **1. Whether there is a lap-sash seat belt in the target seating position.** **2. Quality of the seat belt fit in different seating positions due to the seat shape and seat belt anchorage locations.** **3. Ease of access to the seat belt buckle if other children using child restraints are in the rear seat.** **4. Ease and safety of the child's entry and exit from the vehicle.**

This consensus-based recommendation is based on expert opinion, taking into account the following considerations. There is no clear evidence regarding the overall safest seating position in the rear seat. One study using a US fatality database shows that for all children aged up to 7 years, the centre rear position had the lowest risk of death (Viano and Parenteau, 2008), however, this study does not control for type of restraint used, and is not directly applicable to older children using seat belts that are the subject of this recommendation. A recent study examining severe injuries in the rear seat among children up to age 17, showed a substantially higher risk of serious head injury in the centre rear position (Stewart *et al.*, 2013) suggesting the centre rear seating position is less safe, in contrast to previous assumptions. However, the absolute number of injured seat belt users was small. Children in the centre rear seat using a lap-sash seat belt are further away from intruding structures in a side impact, and this is expected to reduce their risk of serious injury, if the centre rear position has only a lap-only seat belt, the lap-sash seat belt in the kerb outboard position is likely to provide better upper torso restraint and thus reduce the risk of lumbar spine, abdominal and head injuries due to excessive forward flexion in frontal crashes (Anderson *et al.*, 1991; Henderson, 1994; Lane, 1994; Henderson *et al.*, 1997; Gotschall *et al.*, 1998b; Lapner *et al.*, 2001; Levitt, 2005; Ghati *et al.*, 2009; Kirley *et al.*, 2009) which is expected to outweigh the potential benefits of the centre rear seating position during side crashes, since frontal crashes are more common. Children entering or exiting the vehicle in the roadway may be at risk of being struck by passing traffic. If a family has multiple children, some using child restraints and some using seat belts, then practical considerations of restraint fit may influence the choice of seating position of each child within the rear seat. The seat belt geometry and vehicle seat contours may also influence the seat belt fit in the outboard seating positions compared to the centre rear seat.

Consensus Based Recommendation 4.4	**If seating a child up to and including 12 years of age in the front seat is unavoidable, the child should be correctly restrained in the appropriate restraint, and the front seat should be adjusted as far back as possible.**

This consensus-based recommendation is based on expert opinion, taking into account the following considerations. While evidence strongly supports the rear seating position of children up to and including 12 years of age, there may be circumstances in which front seating of a child is unavoidable, due to the rear seats being occupied by younger children. If (and only if) their age appropriate restraint can be correctly installed in the front seat, then pushing the front seat back may help to minimise any risks associated with interaction with the front passenger airbag (Giguere *et al.*, 1998). The potential encroachment on a rear seat passenger behind should also be considered, ensuring the front passenger seat is not making contact with the child restraint or seated passenger behind it. There is no evidence to indicate what a safe clearance in the rear seat is in this circumstance.

6.5 Use of child restraints in airbag-equipped seating positions and other active safety devices

Airbags are pyrotechnic devices designed to inflate rapidly in crashes, and be interposed between an occupant and rigid structures of the vehicle and/or intruding structures to minimise injury. They control the occupant's decelerations and have been shown to reduce serious head injuries in adult occupants. Front seat airbags have been designed to protect adult occupants, and since the mid 1990s, it has been advised that children not be seated near active airbags. More recently side airbags, including torso airbags and curtain airbags have become more common in later model vehicles to provide additional protection in side impacts. Curtain airbags often cover the rear seat occupants as well as the driver and front passenger. Here, we consider each type of airbag separately. Seat belt pretensioners are active safety devices that operate when a crash is sensed to remove slack in a seat belt in the early stages of a crash. They often include a component that limits the maximum force that the seat belt applied to the chest (a load limiter). They are increasingly common in the front and rear seat of vehicles. Here, we consider each type of airbag and seat belt pretensioners separately. Vehicle manufacturers provide guidance on airbag safety in the user manuals.

Recommendation 5.1	**Rearward facing child restraints are not recommended to be used where an active front passenger airbag is installed.**
Overall Evidence Grade	**C**

Table 21: Evidence statement supporting recommendation 5.1

Evidence statement	***Older airbags led to small number of cases of fatal injury in RFCRs***
Grade	**C**

Component	**Rating**	**Notes**
Evidence base	Poor	There are three studies reporting case series reporting that infants in RFCRs were injured or killed as a result of front passenger air bag deployments in the USA. These studies do not use control groups of children not exposed to airbags, and there is thus potential for bias due to case selection.
Consistency	Good	All field studies are consistent in finding that children in rearward facing infant restraints can be at high risk of serious or fatal injury if directly exposed to front passenger airbag deployment. One laboratory study suggested that the risk from a single modern airbag design was no greater than with no airbag, but absolute injury risk was high for both, and recommended rear seat positioning.
Public Health Impact	Satisfactory	Front seat positioning of RFCRs in Australian vehicles is rare, but potential consequences are serious.
Generalisability	Satisfactory	Cases are drawn from a wide range of crashes in the USA, in older vehicles with 1st generation passenger airbags that were not typically installed in Australian vehicles.
Applicability	Satisfactory	All studies are from the USA, and most injuries were in older vehicles with different airbag designs to those used in Australian vehicles. No similar injuries have been reported in Australia, but front seating of infant restraints is rare due to the requirement for top tether anchorages, which are installed in the rear seat.
Other factors		There have been government investigations in the USA, leading to mandatory warnings in vehicles.
References		(CDC, 1995; National Transportation Safety Board, 1996) plus case reports: (Giguere *et al.*, 1998; Cummings *et al.*, 2002; Durbin *et al.*, 2002)

There have been approximately 50 infant fatalities in the USA where RFCRs were installed in the front passenger position and the child's head or the restraint was directly impacted by a deploying passenger airbag (Giguere *et al.*, 1998; Marshall *et al.*, 1998) , largely in the 1990s. Since this time, it has been recommended by road safety stakeholders that children in RFCRs not be seated in front seating positions, and all vehicles with front passenger airbags carry mandatory warnings to this effect. There have been changes to airbag designs to reduce the force of inflation and the direction of airbag deployment in the last 15 years since these injuries occurred, and there is evidence that this has reduced injury risk for restrained children (Olson *et al.*, 2006), but that study sample is dominated by forward facing restraints (FFCRs, boosters, and seat belt). No similar injuries have been reported in Australia. In Australian vehicles with 2 rows of seats, there are no top tether anchorages in front seating positions for vehicles, which makes the practice of placing RFCR in front seats uncommon. There are, however, utility vehicles on the market with only one row of seats, and these can have child restraint anchorages in the front passenger seats. In these vehicles it is possible to install a RFCR. One laboratory study in Australia (Suratno *et al.*, 2009b) showed that a passenger airbag did not exacerbate the existing head injury risk for a single design of RFCR installed in the front seat, but that the absolute head injury risk for either airbag or non-airbag case was high, and thus installation of a RFCR in the front seat is not recommended.

In light of the known risks (albeit in US vehicles with different airbag designs), and in the absence of data to show that this risk has been mitigated by changes to airbag designs, consensus was reached by the technical drafting group that RFCRs should not be installed in front seating positions where a passenger airbag is installed.

Table 22: Summary of articles providing evidence for recommendation 5.1

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
(CDC, 1995)	Small case series of child passengers in fatal crashes involving air-bag deployment	IV	USA	Three cases describing the occurrence of fatal injuries as a result of airbag deployment following a motor vehicle crash.	Injury – fatal	Case 1 – an unrestrained 5-year-old seated in the front passenger seat sustained a fatal skull fracture following contact with the airbag, and subsequently, the roof of the vehicle following . Case 2 – an infant seating in a rear RFCR in the front seat sustained multiple skull fractures and skull injuries following low speed (23 miles per hour) airbag deployment. Case 3 – an unrestrained 6-year-old seated in the front passenger seat died from a brain injury caused by blunt force trauma following airbag deployment.	Uncontrolled small case series only. Older models of cars and airbags and fewer restrained children than is current.
(Cummings *et al.*, 2002)	Case control study	III-2	USA	Cases (N = 20,987) were front seat passengers who died, and controls (N = 69,277) were a sample of survivors – from FARS database. Factors examined were children vs. adults, restrained or unrestrained in the front seat, presence of airbag.	Fatal injury versus not fatal.	Airbags appeared to offer no reduced risk of death for unrestrained passengers in the front seat and a 12% reduction among those who were restrained. Air bags in cars from model years 1989 through 1997 were associated with a net increase in the risk of death for young children in all crashes. Study found that they may be a hazard to unrestrained children and of little benefit to unrestrained adults. Protective effects of air bags were limited to restrained teenagers and adults. Concluded that children younger than 13 years who sit in front of an air bag are at increased risk of dying in a frontal crash (RR = 1.22. 95% CI = 1.03 – 1.45) Adjusted RR 1.16 was not significant.	Older models of cars and airbags and fewer restrained children than is current. Improvement to airbag deployment has since reduced some of the hazards of these earlier models.
(Durbin *et al.*, 2005)	Retrospective case review	III-3	USA	Cases collected by the Partners for Child Passenger Safety study between January 1998 and November 2001 using a stratified cluster sampling methodology. All cases involve at least one child under the age of 16. Following identification of a crash, a telephone interview and a crash investigation were conducted.	Injury risk.	The population of children at risk of exposure to a passenger air bag included 12.3% of all children involved in a motor vehicle crash. Among children exposed to a passenger airbag, 14% suffered serious injuries vs. 7.5% of those in the comparison group (OR 2.0, 95% CI 1.1-3.7; Adjusted OR 1.9, 95% CI =1.1-3.4). A trend was identified towards higher risk of head injury with airbag exposure (OR 1.7, 95% CI =0.9-3.4).	No fatalities were found in the PAB (passenger air bag) group. Limitations are that while crash database was collected prospectively, airbag exposed cases were extracted retrospectively.
(Giguere *et al.*, 1998)	Small case series of properly restrained children in the front passenger seat	IV	Canada	Three cases with physical examination and autopsy results following motor vehicle accidents while the child was seated in the front passenger seat.	Injury type.	Case 1 – following a low speed crash, the child had superficial burns and abrasion to the right zygomatic region, corneal abrasions, and right eye hyphema; injuries were due to contact with hot gas released from the airbag. Case 2 – The child was restrained by only the lap portion of the belt in a low speed crash. X-rays showed a large prevertebral hematoma, and type III atlanto-occipital dislocation. Patient later died. Case 3 – A 3 year old in a booster seat was in a 60km/h crash. Brain scans showed a subarachnoid haemorrhage with a hematoma anterior to the pons and spinal cord. In summary: in case 2 a minor accident resulted in a fatal injury primarily due to the airbag.	Uncontrolled small case series only. Potential selection bias, but demonstrates this injury mechanism.

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
(National Transportation Safety Board, 1996)	Detailed crash investigation – employing sequential sampling	IV	USA	US in-depth analysis of 120 accidents involving at least one vehicle in which there was a child passenger younger than age 11 and in which at least one occupant was transported to the hospital. Age quota-based sample designed to be representative of population, 207 children. Examined collision type, restraint use. Also examined incorrect use and combinations, but numbers are small so statistical analysis was not done.	Injury – severity defined or fatal.	207 children in these 120 crashes, 43 unrestrained. 13 children exposed to passenger airbags, 2 uninjured and 4 injured, 7 were killed; mentions another 17 child fatalities caused by passenger airbag from separate data source. Four were in RFCR, all had skull fractures. In chld restraints, "the children in low to moderate severity crashes who were in appropriate restraints sustained less serious injuries than the children who were in inappropriate restraints". Also examined incorrect use and combinations, but numbers are small so statistical analysis was not done, but injuries more common in suboptimal restraint use, and injury severity lower in optimally restrained children.	Frequencies and analysis of crash information – no calculation of RR. Low numbers of air bag involved cases. Mostly an exploratory study and now quite dated, considering vehicle and airbag design modifications since then.

Consensus Based Recommendation 5.2 — **Forward facing child restraints and booster seats are not recommended to be used in front seating positions where an active front passenger airbag is installed.**

This consensus-based recommendation is based on expert opinion, taking into account the following factors and information. There is no Australian injury data on the safety of FFCRs in front seats, as in Australian vehicles with two rows of seats, there are no top tether anchorages in front seating positions that are required for child restraint installation, which makes this practice unusual compared to other countries where top tether straps are not always required. There are a small number of studies which include cases of children in FFCRs and booster seats in front seating positions who sustained airbag-related injuries (Giguere *et al.*, 1998; Lueder, 2000; Durbin *et al.*, 2002; Durbin *et al.*, 2003). A single laboratory study has indicated that a modern airbag in a single modern vehicle from a single manufacturer may pose minimal injury risk to FFCR occupants (Suratno *et al.*, 2009b). The applicability of these studies to Australia is limited as they were largely restrained in untethered forward facing restraints which are not used here. Further research is required on this issue.

Consensus Based Recommendation 5.3 — **If it is unavoidable to seat a child in a forward facing restraint or booster seat in a seating position where an active front passenger airbag is installed, the front seat should be pushed as far back as possible.**

There are utility vehicles on the market in Australia with only one row of seats, and these can have child restraint anchorages in the front passenger seats, in which is it possible to install a FFCR or tethered booster seat. When front seating of a child in a restraint is unavoidable (e.g. in a car with only one row of seats or when all rear seats are occupied by younger children), it was concluded that the vehicle seat should be placed as far back in its travel as possible to maximise distance between the child and the airbag. One US study (Giguere *et al.*, 1998) recommends pushing seat back as far as possible to minimise child-airbag interaction if seating in this position is unavoidable, and this would be applicable to untethered booster seats in Australia. In a vehicle with more than one row of seats, consideration should also be given to encroachment on the rear passenger(s) space. There is very limited data on children in booster seats in front seating positions, and international data is of limited applicability to the Australian context because all booster seats over 2kg in Australia require the use of a top tether, unlike overseas restraints. Further research is required on this issue.

Recommendation 5.4	**It is not recommended that children up to and including 12 years of age be seated in the front seat of vehicles where active airbags are installed.**
Overall Evidence Grade	**C**

Table 23: Evidence statement supporting recommendation 5.4

Evidence statement	***1. Children under 13 in the front seat are:*** ***a. at greater risk of injury than adults due to air-bag deployment*** ***b. at lower risk of serious injury and death in the rear seat than in the front seat with a passenger airbag*** ***2. However, there have been no reported deaths in seat belt wearing children due to frontal airbag deployment*** *(see corresponding references)*	
Grade	**C**	
Component	**Rating**	**Notes**
Evidence base	Satisfactory	Bilston et al (2010)(Bilston *et al.*, 2010) showed that children in airbag-equipped cars are safer in the rear seat, while adults are safer in the front seat. Glass, however, found that children 9-12 years of age in the front seat with an airbag were at the same risk of death as those in the rear seat, i.e. the airbag was not detrimental for this group of children (Glass *et al.*, 2000).
Consistency	Good	Studies tend to have consistent findings or findings that show no increased risk, for younger age groups, but less clear for older children.
Public Health Impact	Satisfactory	While different studies assessed slightly different things (age or size) – increased risk of serious injury to children under 13 years due to airbag deployment was around 16% (Cummings *et al.*, 2002).
Generalisability	Good	Studies are large, and include a broad range of children and ages, and are thus generalisable to the whole child passenger population.
Applicability	Satisfactory	US studies are only partially applicable because of different airbag design for earlier model cars, but the studies in newer vehicles, and the large Australian study, albeit limited to Victoria (Lennon *et al.*, 2008) is applicable.
Other factors		
References		1 a. (Cummings *et al.*, 2002; Arbogast *et al.*, 2005; Newgard and Lewis, 2005) b. (Durbin *et al.*, 2002; Olson *et al.*, 2006; Smith and Cummings, 2006; Bilston *et al.*, 2010) 2. (Lennon *et al.*, 2008)

Several studies have shown that for younger children aged up to approximately 12-14 years (study age groups differ), front passenger airbags increase the risk of serious injury for front-seated child occupants. Airbag-associated risk of injury is age-dependent, with studies showing older children may benefit from the presence of a front passenger airbag, although most studies still find the risk of injury to be lower in the rear seat than in the front seat with a passenger airbag up to approximately 16 years of age e.g. (Bilston *et al.*, 2010). There is one exception, which showed that fatality risk for 9-12 year olds is similar in the front seat in the presence of an airbag to the rear seat (Glass *et al.*, 2000). Taken together, these studies provide a consistent evidence base for recommending rear seating in children up to and including 12 years old, when a passenger airbag is present. The evidence for children aged 13-16 is less clear, with one study grouping them with 9-12 year olds and showing a benefit of rear seating in the presence of passenger airbags (Bilston *et al.*, 2010) but other studies do not provide definitive evidence on this question.

Table 24: Summary of articles providing evidence for recommendation 5.4

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
(Arbogast *et al.*, 2005)	Cohort study – surveillance system plus interview	III-2	USA	A probability sample of 1781 children (3-15 years) wearing a seat belt in the front seat passenger position of car when an airbag deployed during a frontal crash. 4 years surveillance (Dec 1998-Nov 2002). A validated telephone interview was conducted with the driver. The study sample was weighted according to each subject's probability of selection, with analyses conducted on the weighted sample. OR was adjusted for child's age, crash severity and vehicle type.	Risk of serious injury (AIS $\geq$2 and facial injuries/ lacerations).	The risk of serious injury for restrained children in the front passenger seat was reduced by 41% with the newer (second-generation) airbags (Adjusted OR=0.59, 95%CI= 0.36-0.97). In raw terms, 14.9% of children with older style airbags incurred this level and type of injury compared with 9.9% of those with the newer, more gently deploying style. While not reaching statistical significance, there were fewer injuries to all body regions except the abdomen in the second-generation group. There were no fatalities in either group.	Only children in a seat belt were included – so impact of airbag type on children in CRS was not identified. Cases with no airbag were not included so the benefit of an airbag in these instances was also not identified. Some potential for reporting bias on restraint use.
(Bilston *et al.*, 2010)	Matched cohort study based on cases from large surveillance system	III-2	USA	This is analysis of the NASS database in front (passenger and driver) and rear seat occupants, large sample, representative of US population - matched cohort study comparing vehicles of model year 1990–1996 to newer vehicles (with other confounders controlled for including occupant age, belt type and intrusion).	Serious injury (AIS3+).	Children aged 9-15 have a lower risk of serious injury in the rear seat in both older and newer vehicles, although the gap has narrowed in newer vehicles. For occupants aged 9–15, while there is still benefit in being rear seated in newer model year vehicles (1997–2007) rear to front risk (RFR) = 0.40 (CI = 0.37–0.43), this relative benefit is smaller than in older vehicles (1990–1996); RFR 0.69 (CI = 0.64–0.75) for newer vehicles. While children appear to still be better protected in the rear seat compared to the front seat, this was not the case with adults.	As the study used a matched cohort design, vehicles were only included when there were both front and rear occupants present, hence absolute injury risks were not able to be calculated. Excluded were cases where the occupant was unrestrained or there were missing values for the variables of interest. Strength of the study design was in matched cohort so factors relating to the crash were largely controlled for.
(Cummings *et al.*, 2002)	Case control study	III-2	USA	Cases (N = 20,987) were front seat passengers who died, and controls (N = 69,277) were a sample of survivors – from FARS database. Factors examined were children vs. adults, restrained or unrestrained in the front seat, presence of airbag.	Fatal injury versus not fatal.	Airbags appeared to offer no reduced risk of death for unrestrained passengers in the front seat and a 12% reduction among those who were restrained. Air bags in cars from model years 1989 through 1997 were associated with a net increase in the risk of death for young children in all crashes. Study found that they may be a hazard to unrestrained children and of little benefit to unrestrained adults. Protective effects of air bags were limited to restrained teenagers and adults. Concluded that children younger than 13 years who sit in front of an air bag are at increased risk of dying in a frontal crash (RR = 1.22, CI = 1.03 – 1.45) Adjusted RR 1.16, was not significant.	Older models of cars and airbags and fewer restrained children than is current. Improvement to airbag deployment has since reduced some of the hazards of these earlier models.
(Durbin *et al.*, 2002)	Cohort study – surveillance system plus interview	III-2	USA	Data were collected from 1 December 1998 to 30 November 2001 from a large-scale, child-specific crash surveillance system based on insurance claims, a telephone survey, and on-	Minor injuries, including facial and chest abrasions, and more serious injuries.	Among PAB-exposed children, 175 (14%) suffered serious injuries versus 41 (7.5%) of those in the comparison group (OR 2.0; 95% CI, 1.1-3.7). The overall risk of any injury (both minor and serious) was 86%	Limited to insured vehicles from one insurance company, injury data via telephone interview (but technique has been

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
				site crash investigations. Vehicles qualifying for inclusion were State Farm-insured, model year 1990 or newer, and involved in a crash with at least one child occupant <=15 years of age. Qualifying crashes were limited to those that occurred in 15 states and DC. A stratified cluster sample was designed to select vehicles (the unit of sampling) for the conduction of a telephone survey with the driver. For cases in which child occupants were seriously injured or killed, in-depth crash investigations were performed.		among children exposed to PABs, compared to 55% among the comparison group (OR 5.3; 95% CI, 2.1-13.4). Exposure to PABs increased the risk of both minor injuries, including facial and chest abrasions, and more serious injuries, particularly upper extremity fractures.	validated to distinguish between minor and moderate to severe injuries).
(Lennon *et al.*, 2008)	Data review of traffic crashes in which an injury occurred.	III-2	Australia	Data from Victorian traffic crash files for 1993-98 and 1999-2004 were reviewed for analysis of seating position (front vs. rear), restraint use (child restraint, seat belt, none), age of child (0-3, 4-7 and 8-12). Fatalities were cross-matched with the National Coroner's Information System for 2000-2004.	Injury severity: serious (fatal or hospitalised), minor or none.	Data on 30,631 children indicated that being in the front seat more than doubles the risk of serious injury among 0-12 year olds compared to being in the back seat. For children under 4 years, the risk of serious injury was 60% higher for those in the front seat than those in the back and for those 12 months of under the risk was 3.3 times higher in the front than the back seat (not controlling for restraint type). For older children the relative risk was close to unity (1.1 of 4-7 year olds and 0.93 for 8-12 year olds). The fatality rate was 15.1/1,000 among unrestrained children and 2.4/1,000 among restrained children.	Introduction outlines the difference between US and Australian restraint use. Most vehicles would not have been equipped with front passenger seat airbags. By only classifying restraints as child restraint or seat belts, no conclusions could be made about appropriate use and no differentiation is made between belt positioning booster seats and seat belts alone. There appears to be no controlling for restraint type when comparing the relative risk of front and rear seat positions.
(Newgard and Lewis, 2005)	Cohort study using a crash surveillance system	III-2	USA	Cases (aged 0-18) were drawn from the National Automotive Sampling System (NASS) Crashworthiness Data System (CDS) from 1995-2002. All cases were seated in the front passenger seat. Exposure data included whether an airbag was present. Factors relating to the age and size of the child were considered, use of restraint and type of collision. A total of 3790 cases were included, 2535 involved a primary or secondary frontal collision and 60 children (1.6%) had a serious injury.	Serious injury defined as AIS >3 for any body region.	Children under 14 years of age had the greatest odds of serious injury when seated in the front passenger seat when an airbag was present (OR=2.66, CI= 0.23-30.9) and deployed (OR=6.13, 95%CI=0.30-126). Note these findings are not statistically significant. Among those aged 15-18 the airbag was seen to have a protective effect (as intended). For children aged 15-18 years there was a protective effect of airbag deployment (OR: 0.19; 95% 0.09–0.99). These findings persisted in analyses involving all collision types. The study did not identify any effect modification associated with child height or weight. The study also did not identify any effect modification based on restraint use.	Limitations included a relatively small number of children (n=60 or 1.6% of the total sample) who were seriously injured, minimising the potential to examine possible interactions including height and weight cut-offs and model years of vehicles (as proxy for airbag types).
(Olson *et al.*, 2006)	Matched cohort analysis of data from the National Highway Traffic Safety Administration Fatality Analysis Reporting System	III-2	USA	Analysis of crashes occurring between 1990-2002. Cars had to have between two and four occupants, with at least one of whom had died.	Death within 30 days of the crash.	Airbags were found to increase the risk of death for children aged 0 – 5, however 2nd generation airbags posed less of a risk (RR=1.10, 95% CI: 0.63 to 1.93) than 1st generation airbags (RR=1.66: 1.20 to 2.30). For children aged 6-12, similar results were obtained, however airbags were seen to reduce overall risk of death as compared with no airbags for this age group.	Restraint type is poorly defined in the FARS database.
(Smith and Cummings, 2006)	Data review from surveillance system (FARS)	III-2	USA	All fatal crashes from 1990-2001. Seating positions examined were front right (passenger) or back right and left and consideration of airbag presence - by year and model of car - if not reported. Restraint use was classified as restrained or not. Age categories for children 0-4, 5-12, 13-18 plus adults.	Fatal injury (within 30 days of the crash).	The risk of death was found to be 21% lower for passengers in the rear seat, particularly for child passengers (approx. half the risk RR=0.47). Seated in the front seat with restraint and airbag is no different risk than in the rear seat with just a restraint. No indication of increased risk for children in the front seat if restrained.	Did not report on 0-4 year olds separately - only less than 13 years as a whole. Others to consider seating position for children were Braver, Berg and Durbin - consistent finding of lower injury risk in the rear seat.

Consensus Based Recommendation 5.5	**Curtain airbags that come out of the roof rail above the side window of a vehicle have not been shown to pose any risk to a properly restrained child, and may have safety benefits, but children should not rest any part of their body (particularly the head) on the window or sill, in the path of a deploying curtain airbag, and should maintain an upright posture.**

This consensus-based recommendation is based on expert opinion, taking into account the following factors and information. One laboratory study suggests side airbags have the potential to cause injury to out-of-position children who have their head (or other body part) directly in the line of a deploying airbag (Tylko and Dalmotas, 2000). One field study (Arbogast and Kallan, 2007) provides data which suggests that side airbags (including curtain airbags) pose no additional injury risk over similar vehicles without a side airbag, but total case numbers are small (n=19) and there are limitations in the choice of matching cases for comparison. There are no reports of real-world injuries to child passengers from deploying side curtain airbags that were deemed unlikely to have occurred in the absence of the side airbag, despite many children being exposed to them in crashes, and the laboratory study was conducted under artificial (static) conditions, limiting applicability. In addition, several studies utilising side airbags under a range of impact conditions have not noted any injury risks due to an airbag both in simulation studies (Andersson *et al.*, 2013; Holtz *et al.*, 2016) and in full-scale tests (Brown *et al.*, 2017a). Therefore it was considered that children are not likely to be at significant additional risk from deploying side curtain airbags, however to maximise the benefit of a side curtain airbag children should be encouraged to sit in an upright position (See also Recommendation 6.7).

Consensus Based Recommendation 5.6	**Torso airbags, that typically deploy from the side of the seat, or the door panel in side crashes, have not been shown to pose a risk to properly restrained child occupants, but children should not rest any part of their body (particularly the head) on the door, in the path of a deploying torso airbag, and should maintain an upright posture.**

This consensus-based recommendation is based on expert opinion, taking into account the following factors and information. Torso airbags are currently uncommon in rear seating positions, but becoming more common in front seating positions. One field study (Arbogast and Kallan, 2007) provides data which suggests that side airbags (including curtain airbags) pose no additional injury risk, but total case numbers are small, and torso airbags made up less than 20% of the airbag deployments studied and there are limitations in the choice of matching cases for comparison. There are no reports of real-world injuries to child passengers from deploying side curtain airbags that were deemed unlikely to have occurred in the absence of the side airbag. Therefore, it was considered that children who are large enough to sit in the front seat where torso airbags are installed (up to and including 12 years of age) are not likely to be at additional risk from deploying torso airbags, but precautionary advice given by manufacturers to all occupants to maintain good seating posture relative to the airbag should be followed.

Recommendation 5.7	**It is safe for children correctly using size appropriate child restraints and booster seats to sit in seating positions equipped with seat belt pretensioners**
Overall Evidence Grade	**B**

Table 25: Evidence statement supporting recommendation 5.7

Evidence statement	***Based on crash testing and driving simulations, seat belt pretensioners do not appear to increase injury risk to children using lap-sash belts either alone or with a booster seat, and may provide benefit by reducing motion of the child in a crash.***	
Grade	**B**	
Component	**Rating**	**Notes**
Evidence base	Satisfactory	There are seven level three studies of the effect of seat belt pretensioners, with or without load limiters on child occupants in child restraints and booster seats. These studies used sled tests and computational modelling, and showed no deleterious effects in most conditions. Some studies indicated a beneficial effect in some cases.
Consistency	Good	All studies are consistent in their conclusions that in most circumstances, seat belt pretensioners, including those with load limiters are unlikely to cause an increase in injury risk for child restraint and booster seat users. There were some cases in some studies where chest injury risk may have been elevated slightly by the seat belt pretensioner, but this was not found in all studies.
Public Health Impact	Satisfactory	In several studies, pretensioners improved injury risk values in testing. There were a small number of test cases in some studies where chest deflection in child dummies increased with the pretensioner, but the load limiter mitigated this effect. Most vehicles have combined pretensioner and load limiter systems.
Generalisability	Good	There is no real-world crash data on pretensioner effects on child restraint users, and results are based on sled testing and computational modelling only. The types of pretensioner system tested are reasonably representative of those used in the wider vehicle fleet.
Applicability	Satisfactory	The seat belt pretensioner systems tested are largely similar to those in Australian vehicles, although some are of novel systems under development.
Other factors		
References		(Forman *et al.*, 2008; Johansson *et al.*, 2009; Bohman and Fredriksson, 2014; Rola and Rzymkowski 2015; Tylko *et al.*, 2015; Rola, 2016; Sun *et al.*, 2016; Stockman *et al.*, 2017)

Seat belt pretensioners are active safety devices that operate when a crash is sensed to remove slack in a seat belt in the early stages of a crash. They most commonly include a load-limiting component that controls the maximum seat belt force. They are increasingly common in the front and rear seat of vehicles. Four crash testing studies, one simulated off road driving study (non-crash), and two modelling studies (Johansson *et al.*, 2009; Rola and Rzymkowski 2015; Rola, 2016) have examined the influence of seat belt pretensioners on motion of, and loads developed in, child crash test dummies seated in booster seats, child restraints, or on the rear seat using the lap-sash belt. All studies showed that the pretensioners (including pretensioner designs that incorporate load limiters) reduce dummy excursion, four in simulated crashes ((Forman *et al.*, 2008; Bohman and Fredriksson, 2014; Tylko *et al.*, 2015; Sun *et al.*, 2016) and one in pre-crash off-road maneuvers (Stockman *et al.*, 2017)), and three in computational modelling (Johansson *et al.*, 2009; Rola and Rzymkowski 2015; Rola, 2016). One crash testing study showed that chest forces for a three year old dummy were higher than the acceptable level for one model of pretensioner that allowed a higher peak force (Bohman and Fredriksson, 2014) but not in another model with lower maximum force (achieved via load limiting). These elevated chest forces were not seen in larger child or adult dummies in frontal (Bohman and Fredriksson, 2014; Sun *et al.*, 2016) or side impacts where the child is sitting on the other side of the vehicle to the impact (Tylko *et al.*, 2015). Since average sized three year olds are not recommended to use booster seats, and older children appear to derive benefit, taken together, these studies suggest that it is safe to use booster seats in seating positions equipped with seat belt pretensioners. Children three years old and younger are likely to be safer in child restraints than booster seats in these positions, and one computational study (Rola and Rzymkowski 2015) showed that pretensioners reduced predicted injury metrics in a single model restraint. There is little research about RFCR occupant in seating positions equipped with seat belt pretensioners, but design principles predict that pretensioners would operate similarly as for forward facing restraints.

Table 26: Summary of articles providing evidence for recommendation 5.7

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
(Bohman and Fredriksson, 2014)	Sled tests to assess injury risk associated with frontal collisions and use of pretensioners	III-3	Sweden	Hybrid III 3 year old, 6 year old, 5th and 50th percentile ATDs sled tested for neck, chest and abdominal loads, with and without pretensioner, and two different retractor pretensioners were tested. The dummies were seated on booster seats with and without a back positioned in a rear outboard seat.	Loading to the neck, chest and abdomen were compared to injury reference values (IARVs)	Head excursion and neck loading were reduced for both pretensioner types for all ATDs compared to no pretensioner. The pretensioner reduced chest deflection in the adult ATDs but not in child ATDs when seated on a high back booster, which exceeded the IARV. A lower force limiter reduced this loading below IARV. On a low back booster, chest loads were below injury reference values with the pretensioner.	The belt sometimes got stuck in the non-biofidelic gap between arm and torso; the ATD is difficult to position in the out-of-position postures; no repeated tests were performed
(Forman *et al.*, 2008)	Sled tests with and without pretensioners and force limiters in seat belts.	III-2	USA	48 frontal impact sled tests at two speeds (48 km/h and 29 km/h ΔV) with a mid-size sedan seat buck. 4 different dummies (Hybrid III 6yo, 5th% female, 50th % male and THOR) were tested with either a la-sash belt only, belt plus retractor pretensioner and belt, retractor plus progressive force-limiter. Head, chest and pelvis accelerations and chest deflection were measured.	ATD head, chest and pelvis accelerations and chest deflections	The combined seat belt pretensioner and progressive force limiter reduced peak chest deflection in all Hybrid dummies, including by 29% of the 6yo ATD. This combination also reduced head acceleration and HIC15 for all dummies.	The combined seat belt pretensioner and progressive force limiter reduced dummy injury values without allowing significant additional forward excursion in frontal crashes. Only frontal crashes and a single belt geometry was tested
(Johansson *et al.*, 2009)	Computational simulation of 3 year old to examine restraint design parameters	III-2	USA	MADYMO model of Q3 ATD on a child seat with lap sash seat belt. Effects of seat belt pretensioner and load limiter, belt geometry and seat shape were simulated.	Q3 ATD head, chest, and pelvis accelerations and head displacement	Lap belt angle had the largest effect on head excursion. Good belt geometry, pretensioners with load limiters are beneficial in improving injury risk.	Mathematical modelling only, validated against sled tests.
(Rola and Rzymkowski 2015)	Sled test with and without seat belt pretensioner and smart airbag system	III-2	Poland	Modelling using MADYMO software was done, based on sled test results with a 3 year old dummy in a FF-CRS 5-point harness. A combination of different factors were modelled, including factors relating to the child restraint and to the child safety belt.	Head resultant accelerations and chest resultant accelerations and estimated injury to the head, chest and neck for a 3 year old.	The occurrence of slack in belts was seen to increase the chest resultant acceleration. The addition of a safety device (a seat belt retractor pretensioner, a load limiter and a special airbag) was seen to reduce this acceleration. The airbag was observed to distribute the forces over a wider area of the body and limiting the relative motion between the head and the thorax in a controlled way. High neck loads occurred.	Many factors associated with real-world crashes could not be examined, including: interior vehicle structures, different vehicle types, different installation modes, and various seat back angles - and the crash scenario was limited to front crash (not oblique or side-impact).

Reference	**Study type**	**Level of Evidence**	**Country**	**Methods**	**Outcomes**	**Findings**	**Comments**
(Stockman *et al.*, 2017)	A rig test and an in-vehicle test using 6 and 10 year olds ATDs.	III-3	USA	A rig test with a robot simulating a run-off event and an in-vehicle test both using ATDs corresponding to ages 6 and 10 year olds seated on an integrated booster cushion and 5th% adult female on the rear seat.	Kinematics and the shoulder belt position	When the pre-tensioner was activated, compared to when it was inactivated, the displacement for each ATD was reduced. Shoulder belt slip-off occurred for the Q6 and Q10 in tests where the pre-tensioner was inactivated. The maximum inboard head displacement was reduced in tests where the pre-pretensioner was activated compared to tests in which it was inactivated.	Only one rear seat environment was tested. The contribution of other structures including booster type, seat structure and belt geometries was not considered.
(Sun *et al.*, 2016)	Sled test of child dummies in frontal crashes	III-3	Unknown	Sled test with pulse similar to 40% offset frontal impact in a small passenger vehicle (within 10% in peak acceleration). Q6 and Q10 ATDs to represent 6 and 10 year olds, were used with three popular child restraints with ISOFIX, with and without seat belt retractor pretensioner, and a belt positioner, and three different shoulder height belt positions. A total of 10 tests were run to examine the optimal set of variables in terms of potential to reduce injury outcomes.	Head and chest accelerations and neck force recorded in Q3 and Q10 ATDs	The main findings were that the child restraint model and seat belt pretensioner variables made a significant contribution to dummy injury values, while shoulder-belt position and locking device did not have a significant effect on the injury values. Seat belt pretensioners reduced head and chest accelerations and neck forces in both dummies.	Findings are from a single crash pulse and orientation, and used a limited number of child restraints.
(Tylko *et al.*, 2015)	Sled test and analysis of existing side impact tests using child dummies	III-3	Canada	Sled tests on a car buck were conducted and analysis of existing side impact full scale crash tests of passenger vehicles using a Q6 (2 tests) or Q6s (42 tests) dummy representative of a six year old child. Various crash configurations were analysed. In the sled tests, a Hybrid III 10yo dummy in a high back booster was added, and tests with and without a pretensioner were compared. Two high back and one low back booster were compared.	Head and chest acceleration, head motion	Near-side positioning of the FF-CRS was associated with significantly more frequent head contacts than other seating positions. Next most frequently contacted were RF-CRS in the near-side seat. Chest acceleration responses were notably greater for the Q6 compared to the Q6s. The seat belt pretensioner reduced lateral head velocity and displacement and chest acceleration in the sled tests.	Tests were conducted over several years (2009-2014) and authors noted that vehicle designs changed over this time. The side impact tests were conducted with intrusion.

Consensus Based Recommendation 5.8	**Child restraints should not only be used in seating positions equipped with inflatable belts if <u>both:</u>** **(i) The vehicle manufacturer advises child restraints can be used in this seating position, AND** **(ii) The child restraint manufacturer advises that the specific child restraint model is suitable for use with inflatable seat belts.**

This consensus-based recommendation is based on expert opinion, taking into account the following factors and information. There has been limited research on the effect of inflatable seat belts on child restraint performance. The work done to date has used only one model of inflatable seat belt, and there has been no work with Australian child restraints. Inflatable seatbelts have airbags fitted into the sash section and are relatively uncommon in Australia but are available in some seating positions in some vehicles. Potential fitment issues with some child restraints are that a gated buckle/locking clip cannot be fitted to the sash belt (see recommendation 3.6); and the additional thickness of the sash belt means that the lock-offs fitted to some child restraints cannot be used. Child restraint manufacturers can advise whether their child restraints and booster seats are suitable for use with inflatable seatbelts, and currently this advice varies between manufacturers and restraint models, so it is necessary to check with the restraint manufacturer for each make and model of restraint regarding suitability of that specific restraint model for use in a vehicle with inflatable seat belts.

All current available research has been conducted by or in partnership with one vehicle manufacturer (Ford) who introduced the first rear seat inflatable seatbelts. Inflatable seatbelts are also starting to be introduced by other vehicle manufacturers. Studies available focus on the development of suitable test methods to determine compatibility between child restraint systems (CRS) and inflatable seatbelts and evaluation of the interaction between children/small occupants and inflatable seatbelts (Rouhana *et al.*, 2013; Pline *et al.*, 2017a; Pline *et al.*, 2017b). Research is limited to laboratory testing of international restraints only, and only a limited selection of restraints with one study focusing solely on the interaction between rear facing restraints and inflatable seatbelts (Pline *et al.*, 2017b). Overall the results concluded that the injury risk to children and small occupants from deployment of inflatable seatbelt systems is low. The proposed test method for determining compatibility of CRS and inflatable seatbelts concludes that it is an important step in evaluating compatibility but that it may not be applicable to inflatable seat belt systems from different vehicle manufacturers. For rearward facing restraints installed with a base (as used in infant carrier style rearward facing restraints in Australia), the inflation of the inflatable seatbelt system did not affect system integrity of the attachment of the carrier to the base or the integrity of the base itself. While there was increased lateral rotation when installed using the inflatable seatbelt, in all cases, acceptable installation of the CRS could be achieved with the inflatable seatbelt system, though installation procedures may differ from those of the standard seatbelt system. Note that these restraints differ from Australian rearward facing restraints as they do not use a top tether, and it is not known how this might alter performance.

There are no reports of real world injuries to child passengers from deploying inflatable seatbelts, but this has not been formally studied. Therefore, it was considered that children who are large enough to sit in the adult seatbelt alone or in conjunction with a compatible child restraint or booster seat are not likely to be at additional risk from a deploying inflatable seatbelt.

6.6 *Correct use of restraints*

Using a restraint in any way other than as it was designed to be used is called incorrect restraint use. Incorrect restraint use is common, and substantially reduces the protection that a restraint provides in a crash. Using a restraint correctly on every trip is equally important to choosing the right type of restraint for optimal protection of child passengers. Incorrect use encompasses both how a restraint is installed in the vehicle, and how a child is secured within the restraint. Both major errors and an accumulation of minor errors can substantially compromise the performance of a restraint. Correct use should be checked every time a restraint is used. Vehicle and child restraint manufacturers provide specific advice on the installation of child restraints in a vehicle, and these should be read and adhered to.

The physics underpinning optimal restraint performance are well understood, and restraints are designed to provide optimal protection when used in specific ways. Key concepts include having a restraint fit the occupants well, so that crash forces can be directed to the strongest parts of the body (such as the skeleton), and removing all slack from seat belts, harnesses and tether straps. Slack in a restraint increases the forces that the occupant experiences, and thus increases the risk of injury (Huang *et al.*, 1995). Poorly fitting or poorly positioned restraint components can apply crash forces to vulnerable regions of the body, such as the soft abdominal organs and the neck, increasing the risk of serious injury (Eppinger, 1993).

6.6.1 Restraint installation

Recommendation 6.1	**All child restraints and booster seats must be installed correctly, according to the manufacturer's instructions:** **1. Always use a top tether strap for all rearward facing child restraints, forward facing child restraints and booster seats that are equipped with tethers.** **2. Always use the correct seat belt path for the restraint (following the colour coding available on newer restraints).** **3. Ensure there is no slack or looseness in any part of the system – the top tether, the seat belt anchoring the restraint to the vehicle, nor the seat belt used by a child in a booster seat.** **4. The seat belt buckle should be examined prior to each trip to ensure it has not been inadvertently unbuckled.**
Overall Evidence Grade	**B**

Table 27: Evidence statement supporting recommendation 6.1

Evidence statement	***Incorrect installation of child restraints allows greater motion of the child in the event of a crash and increases the risk of serious injury***	
Grade	**B**	
Component	**Rating**	**Notes**
Evidence base	Good	There are two field studies (Brown and Bilston, 2007) and three laboratory studies (Manary *et al.*, 2006; Sherwood *et al.*, 2006; Lucas *et al.*, 2008), that indicate that greater forces and related injury risks are associated with errors in installation, two focusing on the added injury risk associated with slack in the top tether strap.
Consistency	Excellent	All of the laboratory studies found that head excursion was greater when slack was introduced to top tethers or seat belts used to anchor the restraint to the vehicle, resulting in high injury indicators on the test dummies. The two studies analysing field data reported a significant risk of actual injuries with incorrect restraint use.
Public Health Impact	Excellent	One study found incorrect use increased the risk of life-threatening injuries by six-fold and another found that the risk of a hollow injury was than a solid visceral injury was increased four-fold. Laboratory studies report significant findings in the same direction however, actual relative risk of injury cannot be determined from these types of studies.
Generalisability	Good	While available laboratory studies cover common misuse modes, their data is limited to a small number of combinations of errors, vehicles, crash types and severity and child sizes. The field studies present data from one Australian paediatric hospital and a large US insurance crash data base using from over 10 years ago.
Applicability	Good	Studies available have been conducted on Australian child restraints and the most common misuse modes.
Other factors		
References		(Lalande *et al.*, 2003; Lutz *et al.*, 2003; Manary *et al.*, 2006; Sherwood *et al.*, 2006; Brown and Bilston, 2007; Lucas *et al.*, 2008; Tai *et al.*, 2011)

There are many potential forms of incorrect installation of restraints. These include failure to use a top tether anchorage when required (i.e. for all rearward facing and forward facing restraints and booster seats over 2kg); incorrectly routing the seat belt through the restraint; and slack in the seat belt or top tether. Particular care should be taken to ensure that the correct seat belt path is used for convertible restraints, where the two different restraint modes (e.g. rearward and forward facing) may have different seat belt installation paths. In newer restraints, these belt paths are colour coded. There are numerous field injury studies and laboratory crash testing studies that show that the risk of serious injury is substantially increased in restraints that are not correctly used. Field (injury) studies (Lutz *et al.*, 2003; Brown and Bilston, 2007) often combine installation errors with securing errors (see below) when estimating relative risks, and some studies combine incorrect use with the use of inappropriate restraints for a child size, so the effect size for public health impact is not precisely defined. However, all studies found that incorrect use substantially increased the likelihood of injury and the field studies reported the impact as being 4 to 6 times greater with incorrect installation.

Crash investigation studies are well known to be limited in their ability to retrospectively identify many forms of incorrect restraint use (e.g. incorrect positioning of a seat belt), thus the data on specific forms of misuse drawn from laboratory studies using anthropomorphic test dummies under controlled conditions is most valuable. The latter studies, while providing direct comparisons that are not usually available in real-world injury data, do not simulate the full range of child sizes and crash types that occur in the real-world, but larger studies simulate the more commonly observed forms of incorrect use in the field. One analysis suggested that incorrect restraint use (including incorrect installation) has a greater deleterious effect on injury risk than the use of inappropriate types of restraints for a child's size (Du *et al.*, 2008). Failure to buckle the seat belt in a booster seat leaves the child effectively unrestrained, with the associated very high risk of injury discussed in recommendation 1.1 above. (Kahane, 1986; Partyka, 1988; Agran *et al.*, 1992; Henderson, 1994; Johnston *et al.*, 1994; Cuny *et al.*, 1997; Isaksson-Hellman *et al.*, 1997; Tyroch *et al.*, 2000; Valent *et al.*, 2002; Durbin *et al.*, 2005; Elliott *et al.*, 2006; Du *et al.*, 2008).

Some studies classify incorrect use into minor and serious forms, based on their potential for increased injury risk, but one laboratory study (Tai *et al.*, 2011) (has suggested than the combination of multiple minor errors can accumulate to be equivalent to a single "major" error. Observational studies have shown that incorrect restraint use is very common in the Australian population and overseas (Ebel *et al.*, 2003; Koppel and Charlton, 2009; Brown *et al.*, 2010b; Bilston *et al.*, 2011).

Table 28: Summary of articles providing evidence for recommendation 6.1

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
(Brown and Bilston, 2007)	Retrospective case review, portion with in-depth investigation including laboratory simulation of main use errors.	III-2	Australia	Review of 152 children aged 2-8 years and restraints involved in crashes and presenting to a paediatric emergency department. Assessment of restraint use, quality of restraint, data on heights and weights from interview or medical records - or age-based estimates. Comparisons made between appropriate and inappropriate use and fit for size. Also 6 sled crash tests were done to simulate outcomes in optimal and sub-optimal restraint use.	Correct/incorrect use of restraint (appropriateness of restraint for child and correct use). Laboratory testing of head accelerations, neck loads and moments, dummy motions and head displacement.	Of the 142 cases for which quality of restraint use was known, 82% were sub-optimally restrained with 78% using inappropriate restraint for size. An injury AIS 2+ (serious) was incurred by 0% of those who were appropriately restrained and 28% of those inappropriately restrained (not significant after controlling for crash severity); and moderate injuries were incurred by 22% and 57% (p<0.05) respectively. Incorrect use was associated with 6 times the risk of life-threatening injury after controlling for crash severity. Laboratory testing confirmed that excessive torso and head movement occurs with incorrect belt use. Results suggest that incorrect use of a restraint is potentially more serious in terms of risk of injury than using the incorrect restraint for size.	Quality assessments not made blind to the injury outcome. Convenience sample of children presenting to hospital - excludes minor injuries and deaths. Limited data available as used case review only - not collected systematically.
(Hauschild *et al.*, 2015)	Sled test on 3 yo ATD	III-3	USA	Q3s dummy (3 year old) in FFCRS, with and without large side-wings, positioned in the rear seat of 2 vehicle types - was used during oblique side impact tests. G22:J22	ATD head excursions, head accelerations, LATCH belt loads, and neck loads.	Results indicated there was little difference in the head excursion with and without side-wings (median lateral head excursion was 435mm and 443mm, respectively). The factor more strongly associated with head excursion was the vehicle seat head restraint design. In the bench seat, where the head restraint is integrated, the top tether goes over the head restraint and tended to slip off during the crash, resulting in greater head excursion, but lower HIC and lower neck loads.	The findings are limited to one CRS design, with one crash angle and one crash pulse. There are other head rest designs not included in this test. Flexible LATCH lower anchors were used so results do not necessarily apply to those anchored with rigid LATCH anchors or with seat belts.
(Hauschild *et al.*, 2016)	Sled test on 3 yo ATD	III-3	USA	Q3s dummy (3 year old) in FF-CRS during oblique side impact tests. A structure was used as a test of intruding object. Tests were conducted with and without tether strap and at 34kph.	Head kinematic data, as well as neck tension and moment, and chest, shoulder and pelvic acceleration and deceleration.	The ATD head made contact with the simulated door in all tests without a tether, as well as and 2 tests with a tether in which the impact was at the less oblique angle (80° cf 60°). Lateral head excursion was reduced in the tests without a tether compared to those with a tether (median 400mm vs. 442 mm). In all, tether appeared to reduce head excursion for centre- or far-side-seated child occupants in oblique side impact crashes and limiting the head injury potential with an intruded door.	While the CRS used in the crash test was a popular style it only represents one model, and only tested with one vehicle seat fixture - others may have different results. Similarly, a flexible LATCH webbing system was used to attach the CRS. Seat belt attachment, use of a rigid LATCH or ISOFIX may produce different results.
(Kapoor *et al.*, 2011b)	Sled tests to assess injury risk associated with CRS misuse	III-3	USA	Numerical simulations were conducted using data from full frontal and near-side impact sled test crashes with Hybrid III three year old dummies. Test conditions included absence and presence of CRS misuse: absence of top tether and presence of slack in the seat belt	Head, chest and neck accelerations and associated injury values	Findings indicated that the presence of slack in the system and absence of the top tether strap both served to increase the probability acceleration induced head injuries. Upper neck forces were increased by approximately 15% in a near-side impact when there was slack in the seat belt webbing. The	Data were derived from laboratory testing using one car model and a three year old dummy. Variables introduced by real-world conditions such as child posture other crash angels and speed etc. could not be determined from this study

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
				webbing under two configurations- using flexible LATCH and rigid ISOFIX		use of cross-shaped rigid ISOFIX system reduce head accelerations by approximately 20% and 40-60% in the frontal impact condition. Use of the cross-shaped rigid ISOFIX system was found to reduce upper neck forces by 20–25% and the resultant lower neck moments by approximately 20% for both the child dummies, in the absence and presence of the CRS misuse.	
(Lalande *et al.*, 2003)	Laboratory sled test	III-2	Canada	44 dynamic sled tests with frontal impact using an anthropometric 3 year old dummy in forward facing CRs in some common misuse modes. Three restraints types were used: 5-point harness, T-shield, and an overhead shield configuration. Each type was measured in correct mode, as a baseline, and misuse modes. Repeat tests were done for each mode.	Neck forces, head excursion and head and chest acceleration, shoulder loading.	Pulling the dummy's arms through the shoulder harness had the most significant negative effect on safety in all 3 restraint types. The next most detrimental misuse mode was adding 3 inches of slack to the shoulder harness, the tether and the seat belt. All three restraint types had poorer results with increased shoulder harness slack (80-100% increased lower neck forces and 50% increased shoulder forces). Introducing harness slack had an important impact on neck loading while tether slack was associated with greater head and chest acceleration. Performance worsened with the number of twists of the shoulder harness. The effect of chest clip use was important especially with regard to neck injury values and head injury risk was most affected by incorrect routing of the seat belt.	The testing bench employed could not account for the large number of vehicle seat and set belt configurations. Some features of the test bench are not similar to modern vehicles.
(Lucas *et al.*, 2008)	Laboratory sled test	III-2	Australia	15 common misuse modes of forward facing CRs were tested.	Head accelerations, and head excursion v values which were used to estimate head injury criteria (HIC).	The majority of misuse modes were associated with a higher HIC compared to correct use. The highest HIC values were when the tether was not used (82% higher) or was slack (70% higher). The worst configuration in terms of head excursion was when both arms were not within the harness and the slack left in the harness was 75mm. Most modes of misuse had greater head injury potential than installation errors.	While head injuries are generally associated with contact with the vehicle - this was not directly tested - so impact forces were not measured.
(Lutz *et al.*, 2003)	Data review from insurance claims database, onsite crash scene inspection and telephone survey.	III-2	USA	State Farm insurance claims (Dec 1998 - Aug 2001) in 16 states plus DC. Passenger vehicles 1990 or newer. Interview data on injuries sustained and restraint use for 13,558 children in 10,594 crashes. Paired information on 164 children to compare parental reporting and vehicle inspection regarding restraint type.	Body region by injury severity (AIS <2 and 2+) focus on abdominal injuries.	Of sample 56% were optimally restrained and 44% sub-optimally restrained. Compared to those who were optimally restrained, those who were sub-optimally restrained were 4 times more likely to sustain a hollow than a solid visceral injury.	Limitation with surveillance system - only those vehicles insured and only vehicles 1990 or newer. Nearly all information was obtained from parents reporting.
(Majstorovic *et al.*, 2018)	Sled tests using side impact collisions to examine effect of top tether	III-2	USA	Sled tests using a 10o and 30o from lateral direction side impact collisions to examine kinematics of a dummy 3 year old (Q3s ATD) in two types of forward facing restraint attached via a flexible anchor each with and without top tether.	Q3s responses and CRS kinematics and calculated injury values	The sled test results suggest that the top tether has a stronger influence on head acceleration and calculated head injury values during near-side impacts in the oblique (30o) direction than in the lateral (10o) direction. The top tether increased the head injury criterion (HIC) by 3.3 - 4.4% for the two FF-CRS. For 3 of the 4 scenarios, when the top tether increased either the resultant head acceleration or resultant head angular velocity, the other decreased. For CRS A (no side wings), top tether usage resulted in less than a 5% difference for the resultant head angular velocity. For CRS B (with side wings), the percentage	There are some limitations in the representativeness of the sled test and real vehicles and crash scenarios. The authors noted some field of view limitations. They also suggest that further research is needed on the effect of different top tether locations.

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
						differences ranged from approximately 11 to 13%. However, the injury values were below current injury assessment reference values (IARVs). Additionally, the top tether proved beneficial in preventing forward and lateral CRS rotations.	
(Manary *et al.*, 2006)	Laboratory testing - dynamic sled test	III-2	Australia	16 sled tests using a dummy simulating a 12 month infant with head, upper neck, and chest instrumentation. Frontal and rear impact.	Highest ATD accelerations, forces, and moments were observed during the primary impact.	ATD and CRS motions were best controlled in frontal impact by the rearward tethering geometry while the motions in rear impact were best controlled by tethering to the floor. The data shows a potential benefit in both frontal and rear impacts of tethering rear-facing CRS to a point above vehicle seatback.	Similar limitations to all laboratory studies – limited number of specific crashes simulated, dummy sizes and ages limited. Potential biofidelity limitations of the dummies.
(Sauber-Schatz *et al.*, 2014)	Surveillance system linking police reports with hospital data - retrospective review	III-3	USA	Surveillance system linking police and hospital records (probabilistic linkage) for motor vehicle crashes in 11 states, from 2005-2008. The database includes 50 crash related variables and 18 health outcomes. Sample was children aged 1-12 who were involved in a motor vehicle crash. Child ages were grouped 1-3, 4-7, 8-12. Restraint use was classified as optimal, sub-optimal or unrestrained. Optimal and sub-optimal were only crudely defined as in a child restraint or booster seat if aged 1-7 as optimal and in an adult seat belt as sub-optimal, and 8 -12 years was just in an adult seat belt or not (booster seats were not coded for this age group).	Injuries by body region and whether hospitalised	Across all age groups unrestrained children had the highest percentage of injuries for each body region. Children optimally and sub optimally restrained had minor differences in body region injured, by age group. Children who were unrestrained had approximately 7 times the risk of traumatic brain injuries than those who were restrained – either optimally or sub-optimally. Children in each age group who were optimally restrained were significantly less likely to have a neck, back or abdominal injuries or to be hospitalised than those who were unrestrained. Sitting in the back seat was found to be protective for children 8-12 years old. By age group: the odds of children aged 1–3 year having neck, back or abdominal injuries who were optimally restrained was 63% less than children who were not restrained, with the true effect being between 68% and 59% (odd ratio [OR] = 0.37; 95% CI = 0.32–0.41); similar results shown for TBI (OR = 0.13; 95% CI = 0.10–0.17) or for being hospitalised (OR = 0.41; 95% CI = 0.38–0.45). Children aged 4-7 years optimally restrained versus not restrained had significantly lower odds of TBI (OR = 0.10; 95% CI = 0.08–0.12)	Data were limited by not being able to distinguish if children were correctly restrained or the restraint was correctly installed, and booster use for children over 8 could not be determined. Data for children aged <1 year unable to be used due to coding issue (missing ages also coded as 0 years)
(Sherwood *et al.*, 2006)	Geometric testing	IV	USA	15 vehicles all 2005 models (4 main types: passenger, minivans, SUVs, pick-up trucks) were assessed for their clearance spaces from front seat intrusion into child restraint area. 7 different child restraints were used and a 12 month old dummy. Both lower LATCH and upper tethers were used - though the latter was varied to test its effect.	The geometry of the back of front seat to the front of the child restraint ("RFCR clearance distance"), as well as to the front of the back seat -in various positions/seat ("FFCR excursion distance").	On average the SUV had the smallest available excursion distance while minivans had the largest. For FFCR analysis suggests that use of top tether anchorage is crucial to the reduction of risk of the child's head making contact with the front seat or the dashboard in the case of trucks and CRs only being in the front seat.	US vehicles, limited sample of fleet.
(Skjerven-Martinsen *et al.*, 2014)	Prospective study of children in motor vehicles crashes in which one person was taken to hospital. Each case was	II	Sweden	Prospective study of 158 children aged <16 years in motor vehicle crash in which one person was taken to hospital. Each case was closely investigated and followed-up including examination of the vehicle and interviewing witnesses. Injuries occurred from November 2009 through January 2013. Multidisciplinary team review of each case as well as reports from police and hospitals. Evaluation of any safety errors in restraint use including wrong	Injuries with AIS of >=2	Multivariate modelling indicated that the child's age, restraint misuse and lighting conditions at the time of the crash were all independently related to injury severity outcome. Restraint misuse was documented in 14 of the 15 children with AIS >=3 and was associated with over 4 times the risk of severe injury (AIS.2). Unsecured cargo also posed a contributor to several of the injuries.	The small sample size (n=158) posed a limitation to the analysis of factors contributing to the risk of injury to different body regions or organs, and crash variables.

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
	closely investigated for crash factors and those relating to the child and driver.			size, twisting or slack in straps etc. Crash forces and directions were also estimated.			
(Tai *et al.*, 2011)	Laboratory study - sled testing	III-2	Australia	Minor restraint misuses were tested (single and double twisting or slack of the internal harness strap, and slack of the lower anchorage) in concert with serious incorrect uses (such as the harness being below the shoulder level, an incorrectly routed seat belt, considerable slack in the top tether, and in the anchorage system, non-use of lower or upper anchorage and non-buckling of the belt used as the lower anchorage). Data was taken from 40 frontal crash sled tests (32km/hr) using an instrumented 6 month dummy. High speed cameras were used to capture head and neck movement.	Head excursion.	Multiple or combined minor errors in the use of a forward facing restraint was found to increase the amount of forward excursion to the level seen with serious errors. The excursion of the head increased substantially when three minor errors were in place. Unexpectedly one of the errors actually reduced the head excursion (i.e. showed greater safety performance) - when the seat belt was incorrectly routed through the intended rear-facing slots while the seat was being used in a forward facing mode (however this is specific to this model of restraint).	Limitations were acknowledged to be; the dummy's rigid torso which may not reflect the real response of a child in these scenarios; the relatively low velocities (30-35 km/hr) of the crashes may not be directly extrapolated to higher velocities; the results presented may be an underestimation of the worst cases. Only one type of child restraint (albeit one of the most common), was used so the results may not be representative of all other restraints.

6.6.2 Securing the child in the restraint

Recommendation 6.2	**For rearward facing child restraints and forward facing child restraints, the internal harness should be done up firmly and any slack or looseness should be removed. Twists in webbing straps should be avoided.**
Overall Evidence Grade	**B**

Table 29: Evidence statement supporting recommendation 6.2

Evidence statement	***Harness slack can allow a child to escape from the harness during a crash, and/or allow excessive head excursion and increase forces on the child, increasing the risk of head and spinal injuries.***	
Overall Grade	**B**	
Component	**Rating**	**Notes**
Evidence base	Good	Three field studies, 2 of which included laboratory simulations of key misuse scenarios, and 2 other laboratory studies all of level III-2 evidence, indicate that harness slack increases the risk of injury, or motion of the child (or dummy) in the event of a crash to likely lead to injury.
Consistency	Excellent	All studies have findings in the same direction.

Public Health Impact	Good	Only one study (Lutz *et al.*, 2003) provided odds ratios of injuries in association with harness slack and this study indicated the risk was four times. Other studies reported head injury indicators were significantly higher when there was harness slack.
Generalisability	Excellent	A range of study contexts indicates and acceptable generalisability of the findings.
Applicability	Excellent	Three Australian studies, including field and laboratory studies, suggest the findings are applicable to the Australian context.
Other factors		
References	(Lalande *et al.*, 2003; Lutz *et al.*, 2003; Brown and Bilston, 2006a; Bilston *et al.*, 2007; Brown and Bilston, 2007; Lucas *et al.*, 2008; Kapoor *et al.*, 2011a; Tai *et al.*, 2011)	

Field studies in this area face the difficulty of identifying harness slack after a crash, and the reliance on self-reported assessments by parents/drivers of the vehicle or in-depth crash investigation, which is expensive. Laboratory studies, which can carefully control for the amount of harness slack, are therefore most valuable in the findings they provide about injury risk indicators. In all, findings available from both types of studies support each other in indicating that spinal injuries occur when the child does not fit firmly within the internal harness and excessive head excursion results. As noted by some researchers (Arbogast *et al.*, 2002), when the CRS harness is loose around the child, the thoracic spine is allowed to flex and there is relative movement between the torso of the child and the back of the child seat. Significant problems can also occur when the harness is loose enough that the child's arms are not both within the harness which is linked with significantly higher head injury values.

Adequate harness firmness is achieved when no more than two fingers can fit inside the harness when tightened. Loose harnesses can allow the child to be ejected from the restraint during a crash. While studies of twists in harness and tether webbing suggest that 1-2 twists do not significantly degrade performance (Lucas *et al.*, 2008; Tai *et al.*, 2011) multiple twists that induce slack, or twists in combination with other errors in installation can significantly degrade performance (Tai *et al.*, 2011) so they should be minimised where possible.

Table 30: Summary of articles providing evidence for recommendation 6.2

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
(Bilston *et al.*, 2007)	Observational study - crash laboratory simulation of real crashes	III-2	AUS	Reconstruction of crashes in which 4 children aged 2-8 were injured and another 4 with minor injuries - assessing child kinematics. Comparison with crashes in which children would not have been injured and with crashes in which the same restraints were correctly worn.	Measurement on dummies of tri-axial head acceleration and upper neck forces and moments - some had tri-axial pelvis accelerations measured instead.	Detailed case by case analysis of real scenario, and when varying factors to do with restraint use in the lab. Results indicate that inappropriate use and misuse of restraint by child occupants can result in unfavourable kinematics - exposing child to high risk of injury.	Dummy sensors were not useful in predicting injury (as evidenced by the injuries sustained in the real situations). Differences in crash factors (not being able to replicate it exactly) may have contributed.
(Brown and Bilston, 2006a)	Laboratory testing - based on real-world crashes	III-2	AUS	152 Children aged 2-8 presenting to a paediatric hospital between July 2003 and January 2005. Cases where good restraint information could be determined were kept, leaving 142. Restraint use was labelled as either appropriate or inappropriate, and correct or incorrect. Laboratory testing of misuse modes was performed	Injuries - by MAIS and ISS codes – in three levels; minor injury (ISS>4), moderate injury (ISS>9), and severe injury (ISS>15).	Incorrectly restrained children were 7 times more likely to sustain life-threatening injuries. There was a higher proportion of abdominal injury among those incorrectly restrained (unadjusted OR for abdominal injury in incorrectly restrained 2.1, CI 95% 0.39-10.7, adjusted 1.8, CI 95% 0.34-9.5). Inappropriate restraint use, including premature graduation to an adult seat belt, was seen as the most common form of sub-optimal restraint use.	The field sample may be more biased towards more serious crashes as children were collected following admittance to the emergency department.

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
(Brown and Bilston, 2007)	Retrospective case review, portion with in-depth investigation including laboratory simulation of main use errors.	III-2	AUS	Review of 152 children aged 2-8 years and restraints involved in crashes and presenting to a paediatric emergency department. Assessment of restraint use, quality of restraint, data on heights and weights from interview or medical records - or age-based estimates. Comparisons made between appropriate and inappropriate use and fit for size. Also 6 sled crash tests were done to simulate outcomes in optimal and sub-optimal restraint use.	Correct/incorrect use of restraint (appropriateness of restraint for child and correct use). Laboratory testing of head accelerations, neck loads and moments, dummy motions and head displacement.	Of the 142 cases for which quality of restraint use was known, 82% were sub-optimally restrained - with 78% using inappropriate restraint for size. An injury AIS 2+ (serious was incurred by 0% of those who were appropriately restrained and 28% of those inappropriately restrained (not significant after controlling for crash severity); and moderate injuries were incurred by 22% and 57% ($p<0.05$) respectively. Incorrect use was associated with 6 times the risk of life-threatening injury after controlling for crash severity. Laboratory testing confirmed that excessive torso and head movement occurs with incorrect belt use. Results suggest that incorrect use of a restraint is potentially more serious in terms of risk of injury than using the incorrect restraint for size.	Quality assessments not made blind to the injury outcome. Convenience sample of children presenting to hospital - excludes minor injuries and deaths. Limited data available as used case review only - not collected systematically.
(Kapoor *et al.*, 2011)	Laboratory crash simulations	III-2	USA	A Q3 and Hybrid III 3 year old dummy were used in full frontal and near side impact testing conditions under a number of conditions. Experimental sled testing was conducted to investigate of two types of misuse; top tether absence and seat belt slack.	Head and chest accelerations, neck loads and moments.	A slight increase in the forward displacement of the dummy's head was observed due to the presence of slack in the seat belt webbing. Peak head accelerations were 20% greater when seat belt slack was present. Lower neck forces were increased by 75-85% in the Q3 dummy when the seat belt was not sufficiently tight. During side impacts, head acceleration was 15% greater when the seat belt was slackened. Additionally, upper neck forces were increased by 15% in the Hybrid III dummy.	Similar limitations to all laboratory studies.
(Lalande *et al.*, 2003)	Laboratory sled test	III-2	CAN	44 dynamic sled tests with frontal impact using an anthropometric 3 year old dummy in forward facing CRs in some common misuse modes. Three restraints types were used: 5-point harness, T-shield, and an overhead shield configuration. Each type was measured in correct mode, as a baseline, and misuse modes. Repeat tests were done for each mode.	Neck forces, head excursion and head and chest acceleration, shoulder loading.	Pulling the dummy's arms through the shoulder harness had the most significant negative effect on safety in all 3 restraint types. The next most detrimental misuse mode was adding 3 inches of slack to the shoulder harness, the tether and the seat belt. All three restraint types had poorer results with increased shoulder harness slack (80-100% increased lower neck forces and 50% increased shoulder forces). Introducing harness slack had an important impact on neck loading while tether slack was associated with greater head and chest acceleration. Performance worsened with the number of twists of the shoulder harness. The effect of chest clip use was important especially with regard to neck injury values and head injury risk was most affected by incorrect routing of the seat belt.	The testing bench employed could not account for the large number of vehicle seat and set belt configurations. Some features of the test bench are not similar to modern vehicles.
(Lucas *et al.*, 2008)	Laboratory sled test	III-2	AUS	15 common misuse modes of forward facing CRs were tested via 32 simulated oblique impact crashes and compared with correct use of FFCR. Of the 15 misuse modes, 8 represented usage errors and 7 installation errors.	Head accelerations, and head excursion v values which were used to estimate a head injury criteria (HIC).	The majority of misuse modes were associated with a higher HIC compared to correct use. The highest HIC values were when the tether was not used (82% higher) or was loosely attached (70% higher). The worst configuration in terms of head excursion was when both arms were not within the harness and the slack left in the harness was 75mm. Most modes of misuse had greater head injury potential than installation errors.	While head injuries are generally associated with contact with the vehicle - this was not directly tested - so impact forces were not measured.
(Lutz *et al.*, 2003)	Data review from insurance claims database, onsite crash scene	III-2	USA	State Farm insurance claims (Dec 1998 - Aug 2001) in 16 states plus DC. Passenger vehicles 1990 or newer. Interview data on injuries sustained and restraint use for 13,558 children in 10,594 crashes. Paired information on 164 children to compare parental reporting and vehicle inspection regarding restraint type.	Body region by injury severity (AIS <2 and 2+) focus on abdominal injuries.	Of sample 56% were optimally restrained and 44% sub-optimally restrained. Compared to those who were optimally restrained, those who were sub-optimally restrained were 4 times more likely to sustain a hollow than a solid visceral injury.	Limitation with surveillance system - only those vehicles insured and only vehicles 1990 or newer. Nearly all information was obtained from parents reporting.

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
	inspection & telephone survey.						
(Rola and Rzymkowski 2015)	Modelling different variables from sled test results	III-2	Poland	Modelling using Madymo v7.5.2 and HyperWorks v13 software was done, based on sled test results with a 3 year old dummy in a FF-CRS 5-point harness. A combination of different factors was modelled, including factors relating to the child restraint and to the child safety belt.	Head resultant accelerations and chest resultant accelerations and estimated injury to the head, chest and neck for a three year old.	The occurrence of slack in belts was seen to increase the chest resultant acceleration. The addition of a safety device (a seat belt retractor pretensioner, a load limiter and a special airbag) was seen to reduce this acceleration. The airbag was observed to distribute the forces over a wider area of the body and limiting the relative motion between the head and the thorax in a controlled way. High neck loads occurred.	Many factors associated with real-world crashes could not be examined, including: interior vehicle structures, different vehicle types, different installation modes, and various seat back angles - and the crash scenario was limited to front crash (not oblique or side-impact).
(Tai et al., 2011)	Laboratory study - sled testing	III-2	Australia	Minor restraint misuses were tested (single and double twisting or slack of the internal harness strap, and slack of the lower anchorage) in concert with serious incorrect uses (such as the harness being below the shoulder level, an incorrectly routed seat belt, considerable slack in the top tether, and in the anchorage system, non-use of lower or upper anchorage and non-buckling of the belt used as the lower anchorage). Data was taken from 40 frontal crash sled tests (32km/hr) using an instrumented 6 month dummy. High speed cameras were used to capture head and neck movement.	Head excursion.	Multiple or combined minor errors in the use of a forward facing restraint was found to increase the amount of forward excursion to the level seen with serious errors. The excursion of the head increased substantially when three minor errors were in place. Unexpectedly one of the errors actually reduced the head excursion (i.e. showed greater safety performance) - when the seat belt was incorrectly routed through the intended rear-facing slots while the seat was being used in a forward facing mode (however this might be limited to this model of restraint).	Limitations were acknowledged to be the dummy's rigid torso which may not reflect the real response of a child in these scenarios, the relatively low velocities (30-35 km/hr) of the crashes may not be directly extrapolated to higher velocities. The results may be an underestimation of the worst cases. Only one type of child restraint (albeit one of the most common), was used so the results may not be representative of all other restraints.

Recommendation 6.3	**For rearward and forward facing child restraints, the appropriate shoulder harness strap slot for the child's size must be used, and these need to be adjusted as the child grows.** • **for rearward facing child restraints, the strap slot nearest to the child's shoulders, but not below the shoulders, should be used.** • **for forward facing child restraints, the strap slot nearest to the child's shoulders, but not more than 2.5cm below the shoulders, should be used.**
Overall Evidence Grade	**C**

Table 31: Evidence statement supporting recommendation 6.3

Evidence statement	***Too low a harness can allow shoulders to escape and potentially allow the child to be ejected in a crash or can apply high compressive forces on a child's spine.***

Overall Grade	**C**	
Component	**Rating**	**Notes**
Evidence base	Satisfactory	Evidence for compressive spinal force increases is limited to one Australian laboratory study and one field study of child restraint misuse which suggests that low shoulder slots height make poor positioning of the harness more likely. The link to real-world injuries is not direct, relying on separate studies that indicate that having the shoulders out of the harness increases injury risk (Lalande *et al.*, 2003; Lucas *et al.*, 2008), limiting the strength of the evidence base.
Consistency	Satisfactory	There is only one study of each aspect, and while they both agree on the need to use the nearest shoulder harness strap slot to the child's shoulders, confirmatory evidence is not available for either.
Public Health Impact	Unknown	The laboratory study showed modest increases in compressive spine forces when the harness is too low. The link to injury risk in real-world crashes is not known. Precise estimates of the increased risk of injury associated with having the shoulder harness off the shoulder as a result of having the slot height adjusted too low are not available, but escape of the torso from the harness is associated with increased serious injury risk (Lalande *et al.*, 2003; Lucas *et al.*, 2008).
Generalisability	Satisfactory	Only two types of restraints and one collision type were tested in the laboratory study in 1996, and these restraints, while Australian, may no longer be available in Australia. The generalisability to all children in all restraint currently used in Australia is limited. The field study of misuse is reasonably representative of the Australian population, based on a population representative sample design, albeit only in one state (NSW).
Applicability	Satisfactory	Both studies are relevant to Australia.
Other factors		
References	(Sampson *et al.*, 1996; Brown and Bilston, 2007; Brown *et al.*, 2010a)	

This recommendation is based on limited field data (individual cases in larger studies) and one laboratory study. Field data are limited, in part because it is typically very difficult to retrospectively identify whether the appropriate shoulder slot was used, as the crash investigator rarely sees the child in situ. Observational studies of child restraints being used in the field show that children using low slots are more likely to have the shoulder straps off the shoulder (Brown *et al.*, 2010a), and field studies and two laboratory studies (Lalande *et al.*, 2003; Lucas *et al.*, 2008) have shown that having the shoulders out of the harness is likely to substantially increase the risk of injury. One additional laboratory study conducted demonstrated that a low slot can increase the compressive forces in a child dummy's spine, but the applicability of these findings to the real-world are not certain, due to potential limitations in the biofidelity of the spine in child dummies. Restraint manufacturers recommend that in rearward facing restraints, the slot nearest to the child's shoulders, but not below them should be used. In forward facing restraints, the slot nearest to the child's shoulders, but not more than 2.5cm below their shoulders should be used, to minimise the potential for compressive forces in the child's spine (Sampson *et al.*, 1996). However, there is a paucity of field data on the impact of shoulder harness strap slot height on injury outcomes. Further research is required on this issue.

Table 32: Summary of articles providing evidence for recommendation 6.3

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
(Brown and Bilston, 2007)	Case review of children 2-8 injured as occupants of crashed vehicles.	III-2	AUS	Assessment of restraint use, quality of restraint, data on heights and weights from interview or medical records - or age-based estimates. Comparisons made between appropriate and inappropriate use and fit for size. Also 6 sled crash tests were done to simulate outcomes in optimal and sub-optimal restraint use.	Correct/incorrect use of restraint (appropriateness of restraint for child and correct use). Laboratory testing of head accelerations, neck loads and moments, dummy motions and head displacement.	Review of 152 children and restraints involved in crashes - 82% were sub-optimally restrained - with 78% using inappropriate restraint for size. Results suggest that incorrect use of a restraint is potentially more serious in terms of risk of injury than using the incorrect restraint for size.	Quality assessments not made blind to the injury outcome. Convenience sample of children presenting to hospital - excludes minor injuries and deaths. Limited data available as used case review only - not collected systematically.
(Brown *et al.*, 2010a)	Laboratory testing - simulated front-impact, instrumented dummies and high-speed cameras	III-2	AUS	Laboratory simulated frontal crash using a 6 y-o dummy and 3 different restraint systems: correct and incorrect harness use and a lap-shoulder belt - using two different kinds of booster seats.	Dummy motion, belt loads, neck forces and moments, head and knee moments. Submarining as determined visually.	Results suggested that correctly used harness did not perform any better than the lap and shoulder belt - either on its own or with two common types of booster seats. Incorrect use of the harness - causing the lap belt to be high and positioned over the abdomen, allowed for submarining to occur. Submarining did not occur when the booster was used and the lap belt kept low on either restraint tested.	Some limitations in the use of dummy head and neck responses to simulate real crash scenarios - biofidelity of the dummies is unknown. Only one model of harness was tested, and two booster seat types - other combinations may results in some different outcomes. Real postures of children are difficult to simulate in dummies. Submarining was determined visually which may be open to a level of subjectivity.
(Sampson *et al.*, 1996)	Laboratory testing - sled tests	III-2	AUS	Sixteen tests were conducted using 2 forward facing restraints with a 6 month-old and 18 month-old dummies in frontal tests to test two different heights for shoulder straps. Accelerators and load cells and high-speed cameras were used to measure outcomes.	Acceleration of head chest and pelvis, forces and moments in the neck and lumbar spine.	Harness mounting locations below shoulder height were associated with greater lumbar compressive force than when positioned at the same height as the shoulder. Harness heights above the shoulder produced slightly lower head and neck loads (compared to those at shoulder height). In all cases, higher positioning of shoulder harness better limited the dummy's head excursion.	Authors concluded that optimal level is at shoulder height, but if it has to be above or below it is better to be above. Testing did not take into account behaviour of children in these age groups while seated in CRSs – as just a static dummy was used.

Consensus Based Recommendation 6.4	Excess webbing from restraint tether straps should be secured and stored where it cannot fall out a car door or be reached by a child.

This consensus-based recommendation is based on expert opinion, taking into account the following factors and information. Frequently child restraint top tether straps have excess webbing when installed in many vehicles. If the excess tether strap is not secured, it could potentially pose a hazard if dangling out of a vehicle door, or if they became looped around a child. While there are no published reports of these causing a problem, there are anecdotal reports of severe injuries caused when an unsecured tether strap has become entangled with the vehicle wheel.

Recommendation 6.5	**For booster seats, all supplied seat belt guides must be used, including any designed to position the sash belt and/or the lap belt. The seat belt path should be followed exactly, care taken that features designed to locate the seat belt low across the hips (e.g. armrests) are used correctly. The seat belt must not be worn under the arm or behind the back.**
Overall Evidence Grade	**B**

Table 33: Evidence statement supporting recommendation 6.5

Evidence statement	***Incorrect use of booster seats reduces their effectiveness in crashes.***	
Overall Grade	**B**	
Component	**Rating**	**Notes**
Evidence base	Good	The three laboratory studies (one based on field observations of restraint use errors linked with injury outcomes) all indicated that the risk of injury increases when restraints are not used correctly.
Consistency	Excellent	The laboratory studies were all consistent in the direction of their findings.
Public Health Impact	Unknown	As data are limited to laboratory studies, the public health impact is not directly measurable.
Generalisability	Satisfactory	As data are limited to laboratory studies, the generalisability is limited but can be assumed to apply to different racial and cultural groups equally.
Applicability	Good	The testing of a range of misuse modes are based on common forms observed in the field, a range of booster types have been simulated, mostly in frontal or oblique crashes, giving the findings reasonable.
Other factors		
References	(Brown *et al.*, 2005; Brown *et al.*, 2006b; Bilston *et al.*, 2007; Brown and Bilston, 2007; Lucas *et al.*, 2008; Tai *et al.*, 2011)	

It is very difficult to identify incorrect seat belt routing, and non-use of positioning features in field studies unless they are reported by parents or carers. Limited field data exists, consisting only of a few cases in larger series of injuries due to seat belt misuse in boosters. A small number of cases where such misuse has been identified have been simulated in the laboratory (e.g.(Bilston *et al.*, 2007)) suggesting that the injuries sustained could have been prevented by correct restraint use. Larger laboratory crash studies of incorrect restraint use have studied the effect of incorrect seat belt routing, non-use of seat belt guides, and demonstrated that these forms of misuse appear likely to reduce the protection afforded by booster seats. A limitation of the field studies is that they do not separate booster seat misuse from other types of child restraint in estimating odds ratios.

Table 34: Summary of articles providing evidence for recommendation 6.5

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
(Bilston *et al.*, 2007)	Observational study - crash laboratory simulation of real crashes	III-2	AUS	Reconstruction of crashes in which 4 children aged 2-8 were injured and another 4 with minor injuries - assessing child kinematics. Comparison with crashes in which children would not have been injured and with crashes in which the same restraints were correctly worn.	Measurement on dummies of tri-axial head acceleration and upper neck forces and moments - some had tri-axial pelvis accelerations measured instead.	Detailed case by case analysis of real scenarios, and when varying factors to do with restraint use in the lab. Results indicate that inappropriate use and misuse of restraint by child occupants can result in unfavourable kinematics - exposing child to high risk of injury.	Dummy sensors were not useful in predicting injury (as evidenced by the injuries sustained in the real situations). Differences in crash factors (not being able to replicate it exactly) may have contributed to findings.
(Brown and Bilston, 2007)	Case review of children 2-8 injured as occupants of crashed vehicles.	III-2	AUS	Assessment of restraint use, quality of restraint, data on heights and weights from interview or medical records - or age-based estimates. Comparisons made between appropriate and inappropriate use and fit for size. Also 6 sled crash test were done to simulate outcomes in optimal and sub-optimal restraint use.	Correct/incorrect use of restraint (appropriateness of restraint for child and correct use). Laboratory testing of neck loads head accelerations, and moments, dummy motions and head displacement.	Review of 152 children and restraints involved in crashes - 82% were sub-optimally restrained - with 78% using inappropriate restraint for size. Considerable detail on the moment and injury outcomes linked with a range of restraint use and misuse. Results suggest that incorrect use of a restraint is potentially more serious in terms of risk of injury than using the incorrect restraint for size.	Quality assessments not made blind to the injury outcome. Convenience sample of children presenting to hospital - excludes minor injuries and deaths. Limited data available as used case review only - not collected systematically.
(Brown *et al.*, 2005)	Review of medical record data crash investigation and interview with the driver.	III-2	AUS	152 Children aged 2-8 presenting to 1 of from 2 paediatric hospitals in Sydney, as a result of a MVC. Interviews were conducted with the driver and an inspection of the vehicle before repair, where possible. Optimal restraints were for 2-4 year olds: forward facing with a 6-point internal harness, for 4-6 year olds - belt positioning booster seat with lap-sash belt, and 6-8 year olds an adult lap-sash belt. Crash impact parameters were calculated, age and height and weight were collected. Data from Henderson's 1994 study was analysed.	Injuries - by AIS code.	93% of the cases were in some restraint, 62% of these were in an adult seat belt. 20% of 2 year olds were in an adult seat belt - and this increased with age to over 90% of 8 year olds. Only 18% of children were optimally restrained. A non-significant difference between the proportion of sub-optimally restrained children who were injured (76%) and those optimally restrained (61%) - but when examining only serious injuries the difference was significant (29% versus 0% respectively). Younger children who are inappropriately restrained are at higher injury risk than older children. Fewer children unrestrained (3%) than 10 years earlier in the Henderson study (11%).	Sample was from paediatric teaching hospitals so biased towards more serious injuries. Cross validation of findings done on several factors. Optimal restraint was adapted from the American Academy of Paediatrics guidelines (2005). Misuse was not able to be included, except where gross misuse was evident as noted on the ambulance form or medical record.
(Brown *et al.*, 2006a)	Retrospective case review, portion with in-depth investigation including laboratory simulation of main use errors.	III-2	AUS	Review of 152 children aged 2-8 years and restraints involved in crashes and presenting to a paediatric emergency department. Assessment of restraint use, quality of restraint, data on heights and weights from interview or medical records - or age-based estimates. Comparisons made between appropriate and inappropriate use and fit for size. Also 6 sled crash tests were done to simulate outcomes in optimal and sub-optimal restraint use	Correct/incorrect use of restraint (appropriateness of restraint for child and correct use). Laboratory testing of head accelerations, neck loads and moments, dummy motions and head displacement.	Of the 142 cases for which quality of restraint use was known, 82% were sub-optimally restrained - with 78% using inappropriate restraint for size. An injury AIS 2+ (serious was incurred by 0% of those who were appropriately restrained and 28% of those inappropriately restrained (not significant after controlling for crash severity); and moderate injuries were incurred by 22% and 57% ($p<0.05$) respectively. Incorrect use was associated with 6 times the risk of life-threatening injury after controlling for crash severity. Laboratory testing confirmed that excessive torso and head movement occurs with incorrect belt use. Results suggest that incorrect use of a restraint is potentially more serious in terms of risk of injury than using the incorrect restraint for size.	Quality assessments not made blind to the injury outcome. Convenience sample of children presenting to hospital - excludes minor injuries and deaths. Limited data available as used case review only - not collected systematically.
(Lucas *et al.*, 2008)	Laboratory sled test	III-2	AUS	15 common misuse modes of forward facing CRs were tested.	Head accelerations, and head excursion v values which were used to estimate a head injury criteria (HIC).	The majority of misuse modes were associated with a higher HIC compared to correct use. The highest HIC values were when the tether was not used (82% higher) or was loosely attached (70% higher). The worst configuration in terms of head excursion was when both arms were not within the harness and the slack left in the harness was 75mm. Most modes of misuse had greater head injury potential than installation errors.	While head injuries are generally associated with contact with the vehicle - this was not directly tested - so impact forces were not measured.

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
(Tai *et al.*, 2011)	Laboratory study - sled testing	III-2	AUS	Minor restraint misuses were tested (single and double twisting or slack of the internal harness strap, and slack of the lower anchorage) in concert with serious incorrect uses (such as the harness being below the shoulder level, an incorrectly routed seat belt, considerable slack in the top tether, and in the anchorage system, non-use of lower or upper anchorage and non-buckling of the belt used as the lower anchorage). Data was taken from 40 frontal crash sled tests (32km/hr) using an instrumented 6 month dummy. High speed cameras were used to capture head and neck movement.	Head excursion.	Multiple or combined minor errors in the use of a forward facing restraint was found to increase the amount of forward excursion to the level seen with serious errors. The excursion of the head increased substantially when three minor errors were in place. Unexpectedly one of the errors actually reduced the head excursion (i.e. showed greater safety performance) - when the seat belt was incorrectly routed through the intended rear-facing slots while the seat was being used in a forward facing mode (however this might be limited to this model of restraint).	Limitations were acknowledged to be the dummy's rigid torso which may not reflect the real response of a child in these scenarios, the relatively low velocities (30-35 km/hr) of the crashes may not be directly extrapolated to higher velocities. The results may be an underestimation of the worst cases. Only one type of child restraint (albeit one of the most common), was used so the results may not be representative of all other restraints.

Recommendation 6.6	**When using lap-sash seat belts, the sash belt should be positioned over the mid-shoulder and not be worn under the arm or behind the back.**
Overall Evidence Grade	**B**

Table 35: Evidence statement supporting recommendation 6.6

Evidence statement	***Incorrect use of the sash belt increases the risk of abdominal, lumbar spine and head injuries in crashes***	
Grade	**B**	
Component	**Rating**	**Notes**
Evidence base	Good	While only five studies have directly examined incorrect use of seat belts in children, there is a solid evidence base for the reduction in safety in lap-only seat belts compared to lap-sash seat belts, and incorrect use of the shoulder belt effectively converts a lap-sash seat belt to a lap-only seat belt.
Consistency	Good	There is good agreement among the studies that incorrect seat belt use reduces the effectiveness of the seat belt.
Public Health Impact	Excellent	The studies of incorrect use of sash belts did not provide estimates of relative risk, but two studies of lap-only seat belts compared to lap-sash seat belts reported a doubling of the serious injury risk associated with lap-only seat belts compared to lap-sash seat belts.
Generalisability	Good	Study samples have been reasonably representative of the whole population, and specific sub-populations not represented in existing data are not known to have features that would affect their risk of injury in these circumstances, so the findings available are generalisable.

Applicability	Good	Lap and lap-sash seat belt designs are similar in vehicles internationally, so the available studies (Australian and international) are applicable to current vehicles and children in Australia. Lap-only seat belts are becoming less common in centre rear positions in vehicles as their reduced protection is well established. The applicability of the lap-only vs. lap-sash seat belt studies to seat belt misuse has not need directly proven.
Other factors		
References		(Johnston *et al.*, 1994; Lane, 1994; Henderson *et al.*, 1997; Gotschall *et al.*, 1998a; Lapner *et al.*, 2001; Arbogast *et al.*, 2007; Bilston *et al.*, 2007)

Incorrect use of the sash belt by placing the belt behind the back effectively converts the lap-sash seat belt into a lap-only seat belt. There are several studies that demonstrate the benefits of lap-sash seat belts compared with lap-only seat belts as noted in the table above, which are applicable to this situation. Placing the sash belt under the arm provides no restraint for the upper torso, similar to a lap-only seat belt, but applies the sash belt forces directly to the upper abdomen and/or lower rib cage, which is a potentially different injury mechanism. Upper abdominal injuries and spinal fractures have been shown to be associated with, or directly attributable to, this type of seat belt misuse (Arbogast *et al.*, 2007; Skjerven-Martinsen *et al.*, 2014).

Table 36: Summary of articles providing evidence for recommendation 6.6

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
(Arbogast *et al.*, 2007)	Retrospective data review - child injury surveillance system	III-2	USA	Abdominal injuries (n=21) compared to those without abdominal injuries (N=16) in children 15 years or less. Detailed case review of those under 12 sustaining an abdominal injury (AIS >2) from a frontal crash. A second group with similar crashes but without severe abdominal injury were reviewed.	Abdominal or chest wall injury (AIS >2) - other injuries.	Belt loading directly over the injured organs was responsible for the majority of the abdominal injuries. The loading was attributed to either poor belt positioning, poor child posture or misuse of the shoulder belt.	Convenience sample from insurance database from 15 states plus DC. Mechanism of injury was inferred from analysis after the crash.
(Bilston *et al.*, 2007)	Observational study - crash laboratory simulation of real crashes	III-2	AUS	Reconstruction of crashes in which 4 children aged 2-8 were injured and another 4 with minor injuries - assessing child kinematics. Comparison with crashes in which children would not have been injured and with crashes in which the same restraints were correctly worn.	Measurement on dummies of tri-axial head acceleration and upper neck forces and moments - some had tri-axial pelvis accelerations measured instead.	Detailed case by case analysis of real scenario, and when varying factors to do with restraint use in the lab. Results indicate that inappropriate use and misuse of restraint by child occupants can result in unfavourable kinematics - exposing child to high risk of injury.	Dummy sensors were not useful in predicting injury (as evidenced by the injuries sustained in the real situations). Differences in crash factors (not being able to replicate it exactly) may have contributed to the findings.
(Gotschall *et al.*, 1998a)	Detailed case series review	III-2	USA	From Dec 1991-97, all children 0-15 years, wearing a seat belt (only) and admitted to a specific hospital following a MVC were included (n=98). Medical records, interview with parents and attending pre-hospital providers, review of police reports, crash scene investigation and reconstruction of events provided detailed data on each case.	Injury severity: AIS, ISS, revised Trauma Score and the TRISS probability of survival. Medical treatment and outcome.	There were no belt related fractures to the ribs or sternum, and no belt related injuries to the heart or great vessels. One fracture of the clavicle and 4 to the thoracic cavity were noted to be belt related (3 of 4 in a 3-point belt). Of the 9 abdominal injuries that were belt related, all were in a 2-point belt. There were no injury severity differences by belt type. Incorrect belt use was common. Broadly data suggested more injuries with 3-point belt.	Sample did not include uninjured children - so limits conclusions. No evidence that they controlled for various factors as part of the analysis. Three-point belts are more common in the front seat but not sure that they factored this into the injury severity.
(Henderson *et al.*, 1997)	Laboratory sled test	III-2	AUS	Three anthropometric child dummies in rear seat positions: simulating 18 months, 3 year old and 6 year old. Two sled runs were conducted for belt type (lap-only and lap/shoulder) with each dummy. Use of a harness was tested with the 3 and 6 year old	Head, chest and pelvis acceleration measurements; upper neck forces and moments. Lumbar forces and moments for 18 months old.	Head and chest acceleration and lap belt loads were consistently higher for lap belt only compared to lap and shoulder belts. Only the 18 month old was not held correctly in place by either kind of restraint during the entire crash sequence. Results are consistent with field studies indicating lap and shoulder belts, compared to lap-only, serve to minimise head excursion potentially	Some differences in the reading between the different tests on each configuration.

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
				dummies. Sensors placed on head, neck, chest and pelvis. High speed camera used.		reducing head injury risk and reduce abdominal loads and therefore potentially reduce injury risk to abdominal area. Results from harness testing suggested great loads may lead to greater neck forces than one sided shoulder belts.	
(Johnston *et al.*, 1994)	Cross-sectional case series - data review	III-2	USA	Probability sample of police reported crashes in 26 states - over a 2 year period. Selected crashes in which there was one or more child under 15 as a passenger (n=16,685) reviewed police data on type of restraint and whether child was injured.	Injury outcomes to children as passengers in MV crashes by restraint use. No attempt was made to classify injury severity.	10,098 children with known restraint use. Compared to children who were "optimally restrained", children who were sub-optimally restrained had a slightly higher risk of injury, but those unrestrained were at 2.7 times the risk. Compared to children in the back seat, children in the front seat have 1.5 times the risk of injury. The use of a car seat reduced injuries by 60% for 0-14 year olds, while a lap-shoulder harness was only 38% effective in reducing injuries for 5-14 year olds.	For children aged 0 - 4 tears (preschool), optimal use was defined as police reported use of a child safety seat. For the 5 to 14year-old children, shoulder belt combination, as that was the current recommendation. Any other restraint usage inducing lap belt or shoulder belt alone was considered sub-optimal.
(Lane, 1994)	Retrospective data review - injury insurance claims	III-2	AUS	Personal injury insurance claims for July 1978 - June 1988, included 3,369 children 0-14 years and approx. 23,500 over 14 years, Survey data used to estimate restraint type use.	Lumbar spine or abdominal/visceral injuries - to define "SBS injuries".	There were 46 cases of SBS over the 10 year period in Victoria. Data indicate that lap belts are protective against injury - when compared to no seat belt. Lap belts were shown to cause 2-3 times the incidence of SBS than 3-point belts. It was estimated that 2/3 of the SBS injuries associated with the centre position in the rear seat could be prevented with 3-point seat belts in that position.	There were changes in the belt wearing law (1981) during that period. Survey was based on arterial roads observations and assumptions made that these are representative of wearing rates on all road types.
(Lapner *et al.*, 2001)	Retrospective case review and a prospective phase	III-2	CAN	Cases were children (aged 3-19) with spinal injuries attending hospital following a MVC, all occupants of the case vehicle were contacted and interviewed - covering pre-crash seating positions, posture of occupants, and the manner in which restraints were used. Engineering team assessment of crashes based on information provided.	The nature and extent of the injuries sustained, and the vehicle dynamics and associated occupant kinematics.	Retrospective case review (n=45) suggested no difference in location of cervical spine injuries for 2-point versus 3-point seat belt (i.e. shoulder strap). However, the prospective review of 26 cases (which included all types of injuries) found a 24-fold increase in the risk of cervical spine injury for children using a 2-point versus 3-point seat belt. Loose fitting lap belts were found to be particularly dangerous. Also concluded that children under 12 should not be in the front seat until airbag sensitivity has improved.	Sample selection bias - no injuries that were not serious were included. Small number of cases in the prospective review.
(Skjerven-Martinsen *et al.*, 2014)	Prospective study of children in motor vehicles crashes in which one person was taken to hospital. Each case was closely investigated for crash factors and those relating to the child and driver.	II	Sweden	Prospective study of 158 children aged <16 years in motor vehicle crash in which one person was taken to hospital. Each case was closely investigated and followed-up including examination of the vehicle and interviewing witnesses. Injuries occurred from November 2009 through January 2013. Multidisciplinary team review of each case as well as reports from police and hospitals. Evaluation of any safety errors in restraint use including wrong size, twisting or slack in straps etc. Crash forces and directions were also estimated.	Injuries with AIS of >=2	Multivariate modelling indicated that the child's age, restraint misuse and lighting conditions at the time of the crash were all independently related to injury severity outcome. Restraint misuse was documented in 14 of the 15 children with AIS >=3 and was associated with over 4 times the risk of severe injury (AIS.2). Unsecured cargo also posed a contributor to several of the injuries.	The small sample size (n=158) posed a limitation to the analysis of factors contributing to the risk of injury to different body regions or organs, and crash variables.

Recommendation 6.7	Children should be encouraged to sit in an upright posture with their head back against the seat when traveling in vehicles, including when sleeping, as poor posture, such as leaning against the car window, can increase the risk of injury.
Overall Evidence Grade	**C**

Table 37: Evidence statement supporting recommendation 6.7

Evidence statement	***Leaning forward or sideways can increase the risk of injury in a crash.***	
Grade	**C**	
Component	**Rating**	**Notes**
Evidence base	Satisfactory	There is one level II prospective study that found two incidents (from 27 serious injuries) of children whose injuries could be associated with sleeping whilst resting on the side window or leaning forward (Skjerven-Martinsen *et al.*, 2014). There are two level III studies, using crash tests and computational modelling, that have determined a slightly increased injury risk associated with leaning forward and/or sideways (Andersson *et al.*, 2013; Bohman *et al.*, 2018).
Consistency	Good	All studies have determined an increased injury risk associated with leaning forward and/or sideways.
Public Health Impact	Satisfactory	The prospective study showed that serious injury can occur from adopting a poor position in the car seat (leaning against a window or leaning forward). The simulation and sled test studies indicated that there was a slight increase in the risk of injury due to either greater head excursion for frontal crashes whilst sitting in a booster seat or increased risk of injury in in side impact crashes whilst sitting with a regular seat belt with side thorax and curtain airbags.
Generalisability	Satisfactory	The crash series is from a highly resourced country with a good record of road safety, it is reasonable to generalise to these results to the Australian population. The dummies used in the simulation and sled test studies are a reasonable representation of Australian children and young adults, but these dummies are not designed to be seated in the non-standard positions used in these studies. However, they are the best available tool for studying impacts like these and their results are likely to reflect the true effect of sitting forward or sideways. The side impact study is most relevant to vehicles with curtain and side impact airbags.
Applicability	Satisfactory	The frontal study of booster seats is relevant to the Australian context because some of the booster seat frontal tests were conducted with a tether installed. The side impact study is relevant to vehicles with both a curtain airbag and side impact airbag in-place.
Other factors		The research on this topic is largely based on sled testing and simulation studies rather than real-world or full-scale crash testing.
References		(Andersson *et al.*, 2013; Skjerven-Martinsen *et al.*, 2014; Bohman *et al.*, 2018)

Children commonly fall asleep and/or change their posture when travelling in cars. There are few studies specifically focused on the effects of poor posture or sleeping on injury. A single prospective study of child injury in motor vehicle accidents has identified specific cases of children being injured where being poorly positioned while sleeping, such as by leaning against the side window or leaning forward when a crash occurred was a contributing factor (Andersson *et al.*, 2013; Skjerven-Martinsen *et al.*, 2014; Bohman *et al.*, 2018). One simulation study of side impact for older children (Andersson *et al.*, 2013) and one frontal impact sled test study of six-year-old dummies in booster seats (Bohman *et al.*, 2018), have both indicated there is an increased risk of injury if the child is seated either leaning forwards or sideways in their seat. The increase in injury risk is due to the reduced effectiveness of the protective devices which are designed for a child sitting upright (seat belts and airbags). While it is not always possible to ensure that children remain in an optimal seated posture when travelling, good posture should be encouraged. Parents/carers should not use supplementary restraint padding or accessories to assist with achieving an upright posture for children travelling in cars, unless this is has been provided under specialist advice for children with additional needs (see 6.7.2.3). It is not recommended that manual repositioning of a sleeping child by another vehicle occupant be done while the vehicle is in motion.

Table 38: Summary of articles providing evidence for recommendation 6.7

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
(Andersson *et al.*, 2013)	Simulated crash testing with modelled vehicle and 5th percentile female dummy representing average 12 year old.	III-2	Sweden	The model of a complete passenger car, including head and thorax–pelvis air bags, was used and which was impacted laterally by a barrier in 2 load cases. Six common sitting positions in the rear outboard seat were selected for the SIDIIs. Inboard is leaning inwards, outboard is leaning outwards.	Simulated injury measurements: HIC 36, linear head acceleration, rotational head acceleration, peak chest deflection, peak chest VC.	Broadly speaking, the study results suggested the outboard and inboard positions resulted in the highest head injury measures, but absolute values are still below injury levels. Authors conclude these positions should be discouraged. As braking and swerving are not avoidable, the key take home message is that children should sit upright and not lean to the side with head on the door.	Study was limited to a single car model: a large sedan. The dummy was designed for upright seating positions, so it could not closely simulate the range of positions children may adopt. Authors indicated that due to the limitation of the dummy (SID-II) it is likely that the chest injury measures underrated the influence of the thorax–pelvis air bag in the runs with direct impact to the rear side of the chest by the deploying air bag.
(Bohman *et al.*, 2018)	Frontal and oblique crash tests of HIII 6-year-old child ATD using real-world, observed child passenger postures	III-2	Sweden, Australia, USA	HIII 6-year-old ATD was positioned in booster seat (tethered and untethered) in standard, forward leaning and forward leaning with lateral (outward) leaning postures. 17 frontal or oblique sled tests at 64km/hr.	HIC-15, head acceleration,, chest acceleration, head excursion, neck axial load and head impact	The belt slipped off in all forward and oblique positions, and in most 'normal' position tests. Neck tension reduced as head excursion increased. Head excursion increased in forward leaning positions	The belt sometimes got stuck in the gap between arm and torso; the ATD is difficult to place in the out-of-position postures; no repeated tests were performed
(Skjerven-Martinsen *et al.*, 2014)	Prospective study of children in motor vehicles crashes in which one person was taken to hospital. Each case was closely investigated for crash factors and those relating to the child and driver.	II	Sweden	Prospective study of 158 children aged <16 years in motor vehicle crash in which one person was taken to hospital. Each case was closely investigated and followed-up including examination of the vehicle and interviewing witnesses. Injuries occurred from November 2009 through January 2013. Multidisciplinary team review of each case as well as reports from police and hospitals. Evaluation of any safety errors in restraint use including wrong size, twisting or slack in straps etc. Crash forces and directions were also estimated.	Injuries with AIS of >=2	Multivariate modelling indicated that the child's age, restraint misuse and lighting conditions at the time of the crash were all independently related to injury severity outcome. Restraint misuse was documented in 14 of the 15 children with AIS >=3 and was associated with over 4 times the risk of sever injury (AIS.2). Unsecured cargo also posed a contributor to several of the injuries.	The small sample size (n=158) posed a limitation to the analysis of factors contributing to the risk of injury to different body regions or organs, and crash variables.

6.6.3 Securing unoccupied restraints

Consensus Based Recommendation 6.8	**Unoccupied child restraints should be secured to the vehicle.**

This consensus-based recommendation is based on expert opinion, taking into account the following factors and information. While restraints that have top tether straps remain secured to the vehicle even when unoccupied, untethered restraints, particularly booster seats that do not have a top tether, may become projectiles in a crash when unoccupied. It is recommended that all booster seats and restraints be secured to the vehicle when not occupied.

6.6.4 Restraint/vehicle compatibility

Consensus Based Recommendation 6.9	**Not all restraints fit well in all vehicles, so when buying or hiring a restraint, parents and carers should test the fit/compatibility of the restraint in their vehicle before purchase.**

This consensus-based recommendation is based on expert opinion, taking into account the following factors and information. The contouring of seats, headroom, and seat belt geometry in some vehicles can interfere with correct installation of a restraint or allow undesirable motion of the restraint. Also, in a small number of vehicles, the rear seat belt may not be long enough for installation of some child restraint models. While this is often noted as an issue in research papers, there were no Australian data on how well restraints fit in different vehicles identified in the literature review, and only one US study (IIHS, 2000) showing significant variation in restraint/vehicle fit, but this does not directly assess Australian restraints as it is focused on dedicated child anchorage systems. Further research is required on this issue.

6.6.5 ISOFIX lower anchorage systems

Australian child restraints are generally installed using a seat belt and top tether. Internationally, there are two systems of child restraint installation that use special anchorages designed for child restraints (“ISOFIX lower anchorages”), typically in the seat bight at the join between the seat back and seat cushion, either together with a top tether “LATCH”, in North America) or with other means of controlling the restraint’s rotation (“ISOFIX”, in Europe and elsewhere). Requirements for Australian child restraints to use these ISOFIX lower anchorages were introduced in AS/NZS 1754 (2013). In these restraints, the ISOFIX lower anchorages are used instead of the seat belt in forward and rearward facing restraints, but existing requirements for the use of top tethers will remain.

Recommendation 6.10	**Approved restraints that can be used with ISOFIX lower anchorages should be used as instructed by the restraint manufacturer only in seating positions specified by the vehicle manufacturer.** **No recommendation can be made on the overall benefits of ISOFIX restraints compared to restraints installed using seat belt.**
Overall Evidence Grade	**D**

Table 39: Evidence statements supporting recommendation 6.10

Evidence statement	***1. Restraints with flexible ISOFIX compatible anchorages provide similar protection to restraints secured with seat belts.*** ***2. Restraints with rigid ISOFIX compatible anchorages may provide better side impact protection than restraints secured with seat belts or flexible ISOFIX.*** ***3. Restraints with ISOFIX compatible anchorages may reduce installation errors, but this varies with restraint and vehicle design.*** *(see corresponding references)*	
Grade	**D**	
Component	**Rating**	**Notes**
Evidence base	Good	For Statement 1 and 2 there are 5 Level 2 studies by different research groups demonstrating same or similar outcomes. For Statement 3, there are 5 Level 2 studies all demonstrating same/similar outcomes
Consistency	Excellent	As above
Public Health Impact	Unknown	Correct use is critical for optimum protection, and reducing injury risk in side impact is high priority therefore public health impact may be high but no studies examining this as yet.
Generalisability	Satisfactory	Studies supports Statement 1 and 2 include rearward and forward facing restraints from Australia and elsewhere so generalisability is high but data on correct use is limited to LATCH in the US
Applicability	Satisfactory	As above. Note that most laboratory work with rigid and semi-rigid systems have not included commercially available systems but instead have been 'mock ups'.
Other factors		
References		1. (Kelly *et al.*, 1995b; Brown *et al.*, 1997; Charlton *et al.*, 2004; Bilston *et al.*, 2005; Kapoor *et al.*, 2011a; Hauschild *et al.*, 2018) 2. (Kelly *et al.*, 1995b; Brown *et al.*, 1997; Charlton *et al.*, 2004; Bilston *et al.*, 2005; Kapoor *et al.*, 2011a; Hauschild *et al.*, 2018). 3. (Decina and Lococo, 2007; Klinich *et al.*, 2013; Roynard *et al.*, 2014; Cicchino and Jermakian, 2015; Raymond *et al.*, 2017)

ISOFIX is a system of dedicated child restraint lower anchorage points, to which special attachments on the child restraint can be fastened. There are two different ISOFIX compatible lower anchorage systems allowed under the requirements of AS/NZS 1754. One involves rigid ISOFIX compatible fixtures on the child restraint, and the other involves flexible webbing ISOFIX compatible fixtures. The rigid system is similar to the lower anchorage fixtures allowed in EUROPE and the flexible system is similar to those employed in the North American LATCH system. ISOFIX systems were designed to improve ease of installation and reduce errors in use. When correctly installed, crash tests indicate that flexible attachment systems (such as LATCH) provide comparable levels of protection to the traditional vehicle seat belt attachment method (Kelly *et al.*, 1995b; Brown *et al.*, 1997; Charlton *et al.*, 2004; Bilston *et al.*, 2005; Kapoor *et al.*, 2011a; Hauschild *et al.*, 2018) although US researchers have identified aspects of LATCH design that are associated with a lower propensity for errors – with a focus on the characteristics of the ISOFIX anchorages provided in vehicles (Decina and Lococo, 2007; Klinich *et al.*, 2013; Cicchino and Jermakian, 2015; Raymond *et al.*, 2017). One European study showed 20% lower overall rates of misuse for rigid ISOFIX-installed restraints, but there is a high risk of bias in this estimate (Roynard *et al.*, 2014). Rigid systems provide superior side impact performance compared to anchorage systems incorporating the seat belt or flexible connectors as the lower anchorage component (Kelly *et al.*, 1995b; Brown *et al.*, 1997; Charlton *et al.*, 2004; Bilston *et al.*, 2005; Kapoor *et al.*, 2011a; Hauschild *et al.*, 2018).

Table 40: Summary of articles providing evidence for recommendation 6.10

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
(Hauschild *et al.*, 2018)	Sled test on 3 year old dummy	III-2	USA	Q3s dummy (3 year old) in FF-CRS centre position during oblique side impact tests set at 35km/h with 3 restraint modes: rigid ISOFIX, and two forms of flexible ISOFIX compatible lower anchorage systems - single loop webbing through belt path and a dual flexible belt path. All were tested with and without top tether attached.	Lateral and head excursion, neck loads and moments, and neck lateral bending.	The rigid ISOFIX and dual webbing attachment of the FF-CRS had significantly lower ATD lateral head excursions than when it was attached with single webbing (331, 356, and 441 mm, p<0.001). There was also evidence of significant reductions in neck tension forces (1.4, 1.6, and 2.2 kN, P<.01), and lateral neck bending (31.8, 38.7, and 38.0Nm, P=.002). These reductions were assessed to reduce the potential for head contact and therefore injury, as well as neck bending and injury. The dual webbing attachment without a tether performed comparable to the single webbing with a tether.	Findings are limited to a specific oblique orientation but oblique orientations are not included in regulatory testing and are an issue in real-world crashes. A European FF-CRS was used on a single model vehicle seat. Vehicles, sled pulse and size of dummy may produce different results. There was no comparison with traditional seat belt lower anchorage. The single loop ISOFIX compatible lower anchorage method is not permitted by Australian Standards.
(Kapoor *et al.*, 2011a)	Computer simulations of sled tests and child dummies to assess injury risk associated with two forms of CRS misuse and comparison of rigid versus flexible lower anchorage systems	III-3	USA	Numerical simulations validated with data from full frontal and near-side impact sled test crashes with Hybrid III three-year old dummies. Test conditions included absence and presence of CRS misuse: absence of top tether and presence of slack in the seat belt webbing under two configurations- using flexible LATCH and rigid ISOFIX.	Head, chest and neck accelerations and associated injury values	Findings indicated that the presence of slack in the system and absence of the top tether strap both served to increase the probability of head injuries. Upper neck forces were increased by approximately 15% in a near-side impact when there was slack in the seat belt webbing. The use of cross-shaped rigid ISOFIX system reduce head accelerations by approximately 20% and 40-60% in the frontal impact condition. Use of the cross-shaped rigid ISOFIX system was found to reduce upper neck forces by 20–25% and the resultant lower neck moments by approximately 20% for both the child dummies, in the absence and presence of the CRS misuse.	Numerical simulations of one CRS type. Variables introduced by real-world conditions such as child posture other crash angels and speed etc. could not be determined from this study. Uncertain whether the cross shaped ISOFIX system represents a current design or a prototype. Likely the flexible lower anchorage system simulated was a single loop system.
(Klinich *et al.*, 2013)	Laboratory-based consumer testing of vehicle LATCH designs	III-3	USA	36 volunteer's fitted 4 restraints each into 3 different vehicles with different LATCH configurations (total of 12	Indicators of tight installation and correct lower	Study volunteers correctly used the lower anchors in 60% of LATCH installations and also used the top tether. When the top tether was	Results are from laboratory testing and may not reflect real-world error rates. Not all vehicles

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
	and 4 CRS for correctness of fit			different vehicles tested). Two modes of anchoring were tested: seat belt and ISOFIX compatible lower anchors.	anchor use, correct seat belt path and installation angle were examined.	used 46% were done properly (only 22% of the FF-CRS). Logistic regression indicated three characteristics of lower anchors provided in vehicles associated with fewer errors: Clearance angles greater than 54o, attachment forces less than 174 N, and anchor depth within the bite of less than 2cm. Visibility and labelling, of lower anchor points, and seat characteristics were also predictors of correct installation.	selected for inclusion were available. Prior experience with LATCH systems was only asked in terms of ever used them, rather than extent of experience.
(Raymond *et al.*, 2017)	Real-world observational study	III-2	USA	Observers, certified child passenger safety technicians, approached vehicles with at least one child passenger at standard points nationally. Data were collected from 4,167 vehicles on vehicle and driver characteristics, restraint type and how it was attached to the vehicle. Research questions included whether ISOFIX compatible lower anchorages were used more often than seat belts when both alternatives were available and whether the type of anchor (lower anchor or seat belt) impacted the looseness of installation by measuring the lateral movement of the car seat. Driver characteristics predictive of ISOFIX compatible lower anchorage use were also examined. Results presented separately for FFCRs and RFCRs.	Choice of attachment method and Lateral movement of the child car seat. Driver characteristics.	When both alternatives were available, ISOFIX compatible lower anchorage system was used significantly more often than the seatbelt, regardless of restraint type (FFCRs with and without the top tether, RFCRs) and regardless of broad vehicle type. In all, child restraints installed with lower anchors showed less lateral movement than those installed with seat belts. Across all seat types, (with and without lower anchors or lower anchor connectors), seats installed with lower anchors were associated with significantly less lateral movement than those installed using seat belts, $t(12)=10.71$, $p< .05$, standard error=0.08. This was also the case when limiting the analysis to those with both options. Driver demographics did not predict the use of ISOFIX compatible lower anchorages but confidence incorrect installation did. The odds of correct installation with lower anchors rather than seat belts were 2.15 times higher for drivers who reported that they were very confident that the seat was installed correctly compared to drivers who reported that they were not confident that the seat was installed correctly.	Authors acknowledge that this cross-sectional study does not prove causation - that there may be other factors that contribute to the lateral movement of the seat than just the type of anchor used.
(Kelly *et al.*, 1995a)	Sled testing with dummies (CRABI 6 m/o and P series) to assess head protection provided by Australian CRS in side impacts.	III-2	Australia	Program I Testing: to study the effect of top tether anchorage on the performance of RFCR & FFCR in side impact. 45 degree & 90 degree simulated side impacts test on CRABI 6 m/o dummy. Sled was calibrated to produce deceleration between 14g & 20g, velocity >49km/H. Real car body & window structure were used. Program II Testing: to evaluate performance of rearward facing infant restraints, forward facing child seats & booster cushions. 45 degree & 90 degree simulated side impacts test on	Head protection (HIC measurements and presence of head strikes with static side door)	The combination of top tether & adult seat belt can reduce forward movement in child restraints in oblique angle side impact. Top tethers do not play significant role in ensuring head retention within the child restraint but rigid lower anchorages with top tether significantly improves CRS performance.	The limitation of using HIC to assess the head protection in side impacts using less than ideal child dummies is acknowledged by the authors.

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
				TNO P3/4 dummy (infant restraints & forward facing seats) and TNO P3 (booster cushions). Simulated door & window structures were used. Program III Testing: to evaluate performance of forward facing, & rearward facing infant restraints. With and without rigid lower anchorages. Simulated 90 degree side impact on TNO P3/4 dummy in each restraint. Simulated door & window structures were used.			
(Bilston *et al.*, 2005)	Sled tests with dummies – CRABI 6 m/o and Hybrid III 3 y/o - to evaluate the potential for improved side impact protection in forward facing child restraints.	III-2	Australia	Simulated side impact crashes at 90 degrees (pure side impact) & at 45 degrees (oblique side/frontal impact) using half-sine crash pulse, with a peak acceleration of 14g, a change in velocity of 32km/hr, and pulse width of 85ms. Examined impact of alternative methods of anchorage, energy-absorbing materials in side wings and side wing geometry on side impact protection. Lower anchorage methods examined include rigid and two forms of semi-rigid – a dingle running loop of webbing and two fixed length pieces of webbing.	Dummy motion & head accelerations.	Completely rigid lower attachment of restraints offers the potential for great reductions in head injury risk. The addition of energy absorbing material in the side structure of restraint systems is effective when the head is fully contained within an adequately designed side wing structure.	The lack of a commercially available biofidelic side impact child dummy limits the ability to assess relationships between observed real-world injury patterns in children in side impacts and restraint performance. At the time of testing, there were no commercially available child side impact dummies.
(Charlton *et al.*, 2004)	Sled tests with dummies: Frontal tests- Crabi 6 month (RF CRS) & Hybrid III 3 y/o (FF CRS) Side impact tests- Crabi 6 month (RF) & TNO P3 (FF CRS)	III-2	Australia	This study examined the performance of three RFCRs and two FFCRs with three anchorage systems: standard seatbelt, LATCH (flexible) and ISOFIX (rigid). Frontal (64 km/h) and side impact (15 km/h) HyGe sled tests were conducted using a sedan buck.	Head accelerations (HIC36), neck flexion moments (Nm), restraint types.	Rigid ISOFIX system demonstrated superior performance to the standard seatbelt anchorage especially in side impacts. Compared to flexible LATCH system, rigid system reduce lateral excursion & rotation of the restraint & the dummy occupant. It also reduced potential head injury in frontal impacts of FFCRs.	HyGe sled tests do not demonstrate the likely effects of intrusions particularly in side impact crash. The validity of the results is constrained by the limited biofidelity of the dummies.
(Brown *et al.*, 1997)	Sled test with dummies (P3/4)	III-2	Australia	Test pulse used involved a change in velocity of 32km/h & peak deceleration of 16g. Restraints were tested in 90 and 45 degree side impacts. One RFCR and one FFCR tested with different forms of lower anchorage – rigid and fixed length semi rigid and compared to traditional seatbelt lower anchorage	Peak head acceleration and displacement.	The rigid lower system provided far superior protection than the other forms of lower anchorage. The semi rigid system tested provided some benefit in the 45 degree tests compared to the traditional system	Authors acknowledge that using only the absolute magnitude of head response as a measure of performance is inappropriate. Also, the door structure used in the tests is a non-uniform side door therefore the stiffness of any particular head impact depends on where on the door the impact occurred. NB the semi rigid system was 'mocked up' and the fixed

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
							length webbing components were not attached in-line with the belt path. This likely led to the improved performance of the semi rigid system over the traditional belt.
(Cicchino and Jermakian, 2015)	Real-world observation data used to study associations between vehicle features and correct use of LATCH, and difference in correct use between LATCH and traditional seatbelt	III-2	USA	Vehicle characteristics were extracted from prior surveys of top selling vehicles from 2010-13. LATCH use & misuse info of these vehicles were extracted from Safe Kids car seat checkup records from 14,000 observations during 2010-12. Logistic regression was used to examine association between vehicle features and use & correct use of lower anchors & top tethers, controlling for other relevant installation features.	Vehicle characteristics, LATCH use & misuse characteristics.	Lower anchors were more likely to be used and correctly used when the clearance angle around them was greater than 54°, the force required to attach them to the lower anchors was less than 178 N, and their depth within the seat bight was less than 4 cm. Restraints were more likely to be attached correctly when installed with the lower anchors than with the seat belt. After controlling for lower anchor use and other installation features, the likelihood of tether use and correct use in installations of FFCRs was significantly higher when there was no hardware present that could potentially be confused with the tether anchor or when the tether anchor was located on the rear deck, which is typical in sedans.	There is converging evidence from laboratory studies with volunteers and real-world child restraint installations that vehicle features are associated with correct LATCH use. Vehicle designs that improve the ease of installing child restraints with LATCH could improve LATCH use rates and reduce child restraint misuse.
(Decina and Lococo, 2007)	Observational study of LATCH use and misuse	III-2	USA	This study explored whether young children in CRSs are equipped with tether and lower anchor attachments, and If so, whether LATCH was being used, and being used properly, to secure the CRSs to vehicles equipped with LATCH anchors. CPS-certified observers record vehicle seating position configurations on a total of 1182 drivers/vehicles & 1351 child occupants less than 5 y/o. Sample taken at 66 sites – in 31 counties across 7 states between Apr-Oct 2005 in USA. Drivers' opinions on 'ease-of-use' with LATCH were also gathered.	Drivers/vehicles characteristics, LATCH use & misuse characteristics.	One-fifth of the CRSs did not have tether straps and one-sixth did not have lower attachments, in the vehicles equipped with LATCH. There is a percentage of parents purchasing newer vehicles, but not updating their CRSs to take advantage of the available LATCH technology. Even when their CRSs were LATCH equipped, approximately one-third of the drivers with LATCH-equipped vehicles stated that they couldn't use LATCH because there were no anchors in their vehicles. Tethers were used for 51% of the children when the FFCRs had tether straps and the vehicle had tether anchors. Lower anchors were used for 58% of the children when the CRS had lower attachments and the vehicle had lower anchors. The most common tether and lower attachment misuses were loose tether straps (18% of cases) and loose lower attachment installation (30% of the cases), respectively. These errors were common in both LATCH and traditional anchorage systems. Vehicle safety belts were used in combination with lower attachments in 20% of all lower anchor installations.	Lower anchors may not always be the safest choice for CRS attachment – the safest attachment is the one that results in a tight fit and will be used correctly & consistently.

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
(Roynard *et al.*, 2014)	Observational study of child restraint use	III-2	Belgium	Roadside observations by trained observers of 1461 children under 135cm (as reported by driver) tall. A multi-stage clustered sampling method was used to collect the data. 80 observation sites were randomly selected across Belgium, stratified by region and journey type	Appropriateness and correctness of restraint use	At least 50% of the children were not correctly restrained and 10% were unrestrained. Misuse rates varied by driver restraint status (31% of unrestrained children for unbelted drivers, compared to 7% for belted drivers - only 32% of correctly restrained children for unbelted drivers compared to 54% for belted drivers), purchase site (27% of misuse in restraints bought from specialist stores compared to 45% for CRS bought in non-specialist stores). Although the sample of ISOFIX users was small (n = 76), it appears that the ISOFIX system reduced misuse significantly (by ~20%). Little or no change in the level of correct CRS use over the last five years.	Child height reported by driver not measured. Well designed representative sample. Appropriate statistical analysis. ISOFix sample is small, and drivers using the ISOFIX system seemed to have a significantly different sociological profile, so this estimate has a high risk of bias.

6.6.6 Restraint fitting services

Recommendation 6.11	**Regular checking of restraint installation and the securing of a child in the restraint by a child restraint fitter is recommended. In addition to seeking expert advice, those transporting children should regularly check the restraint installation and fit of the child in the restraint.**
Overall Evidence Grade	**D**

Table 41: Evidence statements supporting recommendation 6.11

Evidence statement	***1. Use of an accredited restraint fitting station has been shown to halve incorrect use of restraints*** ***2. Free restraint checking days and hands-on demonstration lower misuse*** ***3. Longer time since restraint inspection is associated with increased odds of incorrect use*** ***(see corresponding references)***	
Grade	**D**	
Component	**Rating**	**Notes**
Evidence base	Satisfactory	One study has evaluated the use of restraint fitting stations as available in some Australian states, another two international studies of restraint fitting advice programs that are similar in purpose to fitting stations, but delivered differently, have found these reduce incorrect restraint use.

Consistency	Good	All three studies have consistent findings that expert fitting advice (albeit in different settings and in different formats for supplying restraint fitting advice) reduces restraint misuse. Only one study has examined the length of time since inspection.
Public Health Impact	Good	One Australian study showed that restraint misuse was halved among restraint fitting station users, one US study showed 18-64% reductions in errors, and another US study showed a four-fold lower rate of misuse among those receiving hands-on instruction. Separate studies have shown that misuse substantially increases the risk of serious injury, however no study has directly linked restraint fitting station use to injury outcome.
Generalisability	Satisfactory	The one Australian study that showed that restraint fitting station use substantially lowers restraint misuse may not be directly generalisable to other populations where there is no accreditation system for restraint fitters to assure quality of fitting advice, but it is unknown whether unaccredited fitters are more likely to give low quality advice. Other types of fitting advice studied overseas are likely to be reasonably generalisable.
Applicability	Satisfactory	The one Australian study was limited to participants arriving to a child focused facility –potential for some bias in the sample but modelling accounted for variations in demographics of participants.
Other factors		
References		1. (Brown *et al.*, 2011) 2. (Duchossois *et al.*, 2008; Tessier, 2010) 3. (Brown *et al.*, 2011)

There is evidence that child restraint fitting services, when conducted by accredited restraint fitters (who have completed one of two nationally accredited short courses), can substantially reduce incorrect use of child restraints (Brown *et al.*, 2011). Moreover, longer time since the restraint was inspected was associated with increased odds of incorrect use (Brown *et al.*, 2011), suggesting regular checks, perhaps at restraint transitions, are beneficial. International studies of other programs of providing direct child restraint fitting advice to carers (Duchossois *et al.*, 2008; Tessier, 2010), while not directly applicable to restraint fitting stations that are set up through a variety of organisations in Australia, provide additional evidence that these types of services assist in reducing incorrect use of child restraints. Separate studies have shown that incorrect use of restraints substantially increases the risk of serious injury in crashes (Sampson *et al.*, 1996; Lalande *et al.*, 2003; Lutz *et al.*, 2003; Manary *et al.*, 2006; Sherwood *et al.*, 2006; Brown and Bilston, 2007; Lucas *et al.*, 2008; Tai *et al.*, 2011). However, injury outcome has not been directly linked to use of a restraint fitting service. Moreover, quality assurance and training/qualifications of restraint fitting services varies widely in different states in Australia, so the effectiveness estimates from NSW (Brown *et al.*, 2011) may not apply in other contexts where the quality of the restraint fitting advice is not subject to quality assurance and accreditation. Evidence from other forms of personalised restraint use fitting advice (including those that aim to teach parents/carers how to use restraints) (Duchossois *et al.*, 2008; Tessier, 2010) suggest that such fitting advice is beneficial, even if the fitting service is not an accredited scheme such as that studied by Brown et al (2011). This underpins the advice that parents and carers should examine the installation of the restraint and the fit of the child in the restraint regularly also. However, the evidence for less well-controlled schemes such as those that exist in several Australian states, is not as strong, and studies have not been conducted in the Australian context. Any advice given by a restraint technician contrary to that stated in these guidelines should be checked with the road authority in that state/territory. Further research is required on this issue.

Table 42: Summary of articles providing evidence for recommendation 6.11

Reference	Study type	Level of Evidence	Country	Methods	Outcomes	Findings	Comments
(Brown *et al.*, 2011)	Observational ecological study	III-2	AUS	Observation of restraint system installation for 203 children from randomly selected vehicles – followed by a structured interview with the driver. Logistic regression was used to examine the association between parental report of ever having the restraint checked at a Restraint Fitting Station (RFS) and whether or not the restraint was used correctly. Sample selected from vehicles arriving to early childhood health centres, pre-schools etc, while controlling for potential confounders and accounting for the complex sample design. Odds ratios (ORs) and 95% confidence intervals (CIs) were calculated.	Correct restraint installation and use.	The children of respondents who reported not having had the restraint checked at RFS were 1.8 times more likely to be using their restraint incorrectly (95% CI = 1.1–2.8). The odds of the restraint being used incorrectly in a moderate/ serious way significantly increased with every year of restraint ownership, regardless of whether or not the restraint had been ever checked at a RFS, however this did not reach significance in the final model (OR = 1.3, 95% CI = 1.0–1.7). None of the other variables included in the model demonstrated a significant association with correctness of restraint use. Only 28% of the sample reported having had the restraint checked at a RFS. Exploration of the model variables and RFS use indicated that none of the demographic variables were significantly associated with reported RFS use. Longer time since the fitting check was associated with higher odds of incorrect use	No pre-intervention data leading to the possibility of ecological fallacy. Self-reporting of fitting station use may have errors, particularly if parent was not the driver at the time of the interview and if restraint checked was not the one being observed in the study.
(Duchossois *et al.*, 2008)	Pre-post only group design	IV	USA	Pre-post design to examine the change in prevalence, extent of, and severity of misuse between an initial and follow-up child safety seat checkpoint. 42 subjects of 160 who did the initial assessment completed the study by participating in the follow-up check 6-12 months after the intervention.	Child restraint misuse.	Of RFCR 100% of the 17 in the sample had at least one misuse at the pre-test and 18% had at least one at the follow-up. Total misuse score improved at follow-up. For FFCR the baseline and follow-up misuse rates went from 100% to 64%. There was also a significant improvement in misuse score.	No control group. Subjects volunteered to use the safety check – so possibility of bias including that they were aware that it was not right. High drop-out rate.
(Tessier, 2010)	Randomised controlled trial	II	USA	Randomised trial with 56 expectant parents in the intervention group and 55 in the control group. All parents participated in an educational session and were given a child restraint. The intervention group was given a demonstration session about how to correctly install the restraint while the control group was just given the restraint in a box with the manufacturer's instructions. Baseline and follow-up measures - correctness score at follow-up visit when child was 2 months old.	% correct use by parents in each group.	Intervention group, with hands-on demonstration of restraint use resulted in a significantly higher proportion who were totally correct in their use of the restraint (32% vs. 11%) (OR=4.2, p=0.007). Overall rate of errors was 33% less in the intervention group than the control group. Most common errors were harness straps not adequately tightened and restraint not fitted tightly enough within the vehicle.	Study only included one follow-up measure and no control group who received no educational input (which would be closer to most people in the population). Not able to control outside educational input – and both groups would have heightened awareness of this issue. Subjects self-selected themselves into the study.

6.7 Practice Points

In addition to the recommendations for specific practices when restraining children traveling in motor vehicles listed in the preceding sections, there are some additional issues that are important for professionals to consider when providing guidance to parents and carers who transport children. These issues, and the broader context of these practice points, are discussed in the guidelines in sections **Error! Reference source not found.**-**Error! Reference source not found.**.

6.7.1 Aboriginal and Torres Strait Islander peoples

While little is known about child restraint practices among Aboriginal and Torres Strait Islander populations, appropriately tailored strategies for working with specific Aboriginal and Torres Strait Islander communities, whether urban, rural or remote, to maximise optimal use of child restraints are likely to be required. For further discussion of the issues in these populations, see section 5.5 in the main guidelines document.

Some of the broader issues relating to indigenous road safety and broader road safety resources are discussed through the Indigenous Health Infonet portal and in the Active and Safe Guidelines (Clapham *et al.*, 2019): http://www.healthinfonet.ecu.edu.au/related-issues/road-safety/

Practice Point 1	**The recommendations for optimal restraint use for indigenous children are the same as for the broader community. However, implementation of these guidelines in Aboriginal and Torres Strait Islander communities requires tailored approaches, developed jointly with communities, that take consideration of their specific community and family structures, cultural practices and norms, languages spoken, and access to, and types of, restraints and motor vehicles that are available.**

6.7.2 Groups with additional needs

6.7.2.1 Culturally and linguistically diverse groups

Families from culturally and linguistically diverse backgrounds often have difficulty obtaining detailed information on child restraint practices in formats that match their language skills. This can result in sub-optimal child restraint practices. For further discussion of the issues and some effective solutions for these communities, see section **Error! Reference source not found.**. Note also that there are some people with limited literacy, whether their native language is English or not, and provision of information at an appropriate literacy level may also be beneficial for these people.

Practice Point 2	**Families from Culturally and Linguistically Diverse backgrounds may benefit from detailed information on optimal child restraint use provided in their own language. People with low literacy, whether in English or another language, may benefit from information presented at appropriate literacy levels.**

Further information on effective communication with CALD communities, and cultural competence is available from the Centre for Culture, Ethnicity and Health: http://www.ceh.org.au/knowledge-hub/

6.7.2.2 Groups experiencing socioeconomic disadvantage

Families experiencing socioeconomic disadvantage may face challenges in obtaining affordable high quality child restraints for use. A discussion of the issues surrounding restraint use in low socioeconomic groups can be found in section 5.6.2.

Practice Point 3	**Families experiencing socioeconomic disadvantage may benefit from assistance in identifying and/or obtaining affordable child restraints.**

6.7.2.3 Children with disabilities

Children with a disability, due to a medical condition or behaviours of concern, require specialist, multidisciplinary, case-by-case assessment, by qualified and experienced professionals, therefore general guidelines on restraint practices are not be sufficient for optimal safety during travel. Such children often require special consideration, for short or long term needs, when passengers in vehicles, and solutions need to be developed by these professionals in partnership with the child's carer(s). Broadly, it is recommended that the suitability of using an AS/NZS1754 child car restraint be explored in the first instance. If the child is at risk and their individual needs cannot be accommodated in an AS/NZS1754 approved child restraint, parents should partner with their child's allied health team to ensure correct prescription. The Australian Standard *AS/NZS 4370 Restraint of children with disabilities or medical conditions in motor vehicles* provides a guide for health professionals supporting children with disability in transport. This standard provides the prescriber with an assessment guide, outlining key aspects to consider when assessing an individual child's restraint needs for travelling in a motor vehicle. A suitable restraint is then prescribed, in the following order of preference:

1. AS/NZS 1754 compliant (i.e. 'regular') child restraint
2. AS/NZS 1754 compliant (i.e. 'regular') child restraint with modifications
3. Special purpose child restraint
4. Special purpose child restraint with modifications
5. A customized restraint/or other option

An AS/NZS 1754 compliant restraint meets the legal requirements for use in motor vehicles in all jurisdictions. If an AS/NZS 1754 compliant child restraint is not suitable, then an individual prescription is required by a suitable medical professional, and a medical certificate provided, that should be carried in the vehicle if required by the local jurisdiction. There are specialist services available for assessing the needs of children with disabilities in each state and territory, and these can be accessed by contacting the local road authority.

For children with behaviours of concern, individualised assessment should include (as appropriate) reviewing the child's behaviour management plan in the initial assessment phase, trialling of behavioural strategies before the prescriber considers a modified, special purpose or customised restraint or other option, choosing the least restrictive option, and obtaining appropriate approvals and consents as required by local and national regulations, such as the NDIS Act.

Further discussion of the issues relating to transporting children with disabilities can be found in section 5.6.3.

Practice Point 4	**Children with disability (whether medical, cognitive, physical or behavioural) require specialist, multidisciplinary, case-by-case assessment. Restraint use for these children should follow guidelines in AS/NZS 4370 “Restraint of children with disabilities or medical conditions in motor vehicles”.**

6.7.3 Encouraging families to plan for future restraint needs

When purchasing a restraint, families are faced with a multitude of options, and it can be confusing to choose the most appropriate restraint for the family’s current and future needs. Parents and carers should be advised to think about not only their child’s immediate needs, but also their likely future restraint needs, to minimise the need to buy multiple restraints in similar or overlapping categories as the child grows. This is particularly relevant for booster seats, since a child is recommended to use a booster seat up until they can achieve good adult belt fit. Different types of booster seat exist, not all of which will accommodate a child for this full period of time.

Practice Point 5	**Parents or carers should be encouraged to consider whether the restraint they intend to purchase will accommodate their child for the full duration that they are recommended to use it. This is particularly relevant for booster seat purchases, as not all booster seats will accommodate children until they achieve good adult seat belt fit.**

6.7.4 Transport of small infants

Very small infants (<2.5kg) may be difficult to securely harness in standard RFCRs (Brown *et al.*, 2017b). These infants may achieve a more secure fit in a seat specifically designed for them. The Australian/New Zealand Standard 1754:2013 includes specifications for child restraints for small infants below 2.5kg. These are designated as Type A1/0, Type A2/0, Type A3/0 and Type A4/0. There have also been concerns about an increased risk of apnoea (a stop in breathing) for premature infants and other children at risk of breathing difficulties in child restraints, and while the research evidence is mixed, minimising time in the car seat and having an adult (who is not driving the vehicle) observe the child whilst the child restraint is in use is advised (Davis, 2015). Further research is required on this issue.

Practice Point 6	**Parents or carers of small infants (<2.5kg) are advised to use a rearward facing restraint designed to accommodate low birthweight infants (Type A1/0, Type A2/0, or Type A4/0) until the child is large enough for a good fit in a standard rearward facing child restraint.**
Practice Point 7	**Parents or carers of premature infants should minimise the time babies are in a child restraint, and observe the child while in the seat when possible, to minimise the risk of apnoea (a stop in breathing).**

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