The role of child restraints and seatbelts in passenger deaths of children aged 0-12 years in NSW

A report under section 34H

***Community Services (Complaints, Reviews and Monitoring) Act 1993*.**

5 June 2019

Prepared for the NSW Child Death Review Team by Neuroscience Research Australia (2019)

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5 June 2019

The Hon John Ajaka MLC
President
Legislative Council
Parliament House
SYDNEY NSW 2000

The Hon Jonathan O'Dea MP
Speaker
Legislative Assembly
Parliament House
SYDNEY NSW 2000

Dear Mr President and Mr Speaker,

As Convener of the NSW Child Death Review Team (CDRT), I am pleased to present a report for tabling in Parliament pursuant to section 34H of the *Community Services (Complaints, Reviews and Monitoring Act 1993* (the Act).

The role of child restraints and seatbelts in passenger deaths aged 0-12 years in NSW is the result of research commissioned by the CDRT under s 34 H of the Act. The report was prepared by the Australian Institute for Suicide Research and Prevention.

I draw your attention to the provisions of section 34 I of the Act in relation to the tabling of this report and request that you make the report public forthwith.

Yours sincerely

Michael Barnes

Convenor, NSW Child Death Review Team
NSW Ombudsman

Foreword

Road crashes are one of the main causes of injury-related deaths of children in NSW. It is well known that factors such as speeding, fatigue, and driving under the influence of alcohol or other drugs are significant risks on the road. We also know that despite the strong message to 'buckle up safely', children continue to be placed at risk through failure to use – properly or at all – seatbelts and child restraints.

In that context, we asked Dr Julie Brown, a senior research scientist from Neuroscience Research Australia, to review the role of seatbelts and child restraints in passenger fatalities of children aged less than 13 years in NSW. This report provides the findings of that review.

The report concludes that just over half of the 66 children who died in crashes over the 10-year period 2007 – 2016 were not properly restrained in the vehicle. Moreover, the lack or inappropriate use of seatbelts or restraints played a primary role in the death of almost one-third (20) of the children. In other words, many of the deaths could likely have been prevented if the children had been properly buckled up.

Like many of our reviews, the report shows that the likelihood of death as a passenger was greater for Aboriginal and Torres Strait Islander children, children whose families lived in the most disadvantaged areas of the state, and children living in remote areas.

Clearly, much more needs to be done to prevent the deaths of children in vehicle crashes, and the report makes a number of recommendations to this end. The recommendations have been endorsed and adopted by the Child Death Review Team, and we will monitor how agencies progress their implementation.

I would like to acknowledge and thank Dr Brown and her team for their work on this important project.

Michael Barnes

Convenor, NSW Child Death Review Team
NSW Ombudsman

Contents

Executive summary

This report provides a detailed analysis of the factors involved in fatal crashes to 66 child passengers (aged 0–12 years) in NSW during the ten-year period from 2007-16, using in-depth data collected by the NSW Child Death Review Team (CDRT).

The analysis examined whether or not children were restrained, and if restrained, whether they were properly restrained – that is, using an age appropriate and correctly fitted restraint.

The measure of 'inappropriate' restraint in the review is if the child was in a restraint type not applicable to their age according to current NSW legislation. The measure of 'misuse' of a restraint is use of an incorrectly fitted restraint.

The review considers how many of these deaths may have been prevented if the children had been properly restrained.

The review also considers demographic characteristics of the children and drivers, and the role other crash factors played in the deaths of the children. In addition, the review canvasses the current legislative environment and available literature on the major risk and protective factors for injuries to child passengers involved in motor vehicle crashes.

Review of CDRT data: findings

Restraint factors

The review found that 35 of the 66 child passengers were not properly restrained in the vehicle – they were either unrestrained, in a restraint that was not appropriate for their age, or in a restraint that was not fitted correctly. In many (15) cases, the crash severity was such that an appropriate and well-fitted seatbelt or restraint would likely not have prevented the fatality. However, for almost one in three of the children (20, 30%), the improper use or failure to use a child restraint or seatbelt, played a primary contributing role in their death.

In relation to all 66 children:

- Almost half (29) the children were properly restrained (age appropriate and correctly fitted).
- Approximately one in five (15) children were unrestrained in the vehicle.
- Almost one-third (20) of the children were not properly restrained:
  - Fourteen children were using an appropriate form of restraint for their age, but the restraints were incorrectly fitted. Issues identified included seat belts placed under the arm, children laying across the seat with the seat belt on, poor routing of sash belts through booster seats, tethers not anchored correctly, not used, twisted or loose in booster seats and forward facing child restraint systems, poor adjustment of harnesses in forward facing child restraints – that is, harnesses positioned too high for the child, positioned unevenly across the child, or only partially used.
  - Six children were in restraints that were inappropriate for their age. All of the inappropriate use occurred in children aged between two and six years, and almost all involved the use of seat belts by children who should have been using a dedicated child restraint system.
- Correct use of a restraint may have prevented the deaths of 20 children.

Socio-economic status

Two thirds (41) of the children who died lived in the lowest socio-economic areas of NSW (Quintile 1 and 2 of the Index of Socioeconomic Disadvantage). The mortality rate was five times as high for children from the most disadvantaged areas compared to those from areas of least disadvantage (Quintile 1 compared with Quintile 5).

Remoteness

Most – four of every five – of the children died in crashes that occurred outside of major cities in NSW. Most children (56) also died in crashes that occurred on high-speed roads with speed limits of 80km/hr or more.

Aboriginal and Torres Strait Islander status

Of the 66 children, 13 (20%) were identified as Aboriginal and Torres Strait Islander, and 53 (80%) were non-Indigenous according to data provided by the Register of Births, Deaths and Marriages. Indigenous children were over-represented in child passenger fatalities, given that of all children in NSW, approximately 5% are Indigenous. In the 10-year period, the rate for child passenger deaths of Aboriginal and Torres Strait Islander children was 4.2 times as high compared with non-Indigenous children (2 versus 0.5 deaths per 100,000 children).

Driver factors

One fifth (13) of the drivers of vehicles in which the child was travelling were found to have drugs in their system at the time of the crash. In some cases (4), the driver of the other vehicle had drugs in their system. Much fewer cases involved alcohol – two drivers of the child's vehicle and three drivers of other vehicles.

Other known risk factors for crash involvement – such as driver impairment, fatigue and distraction – were also commonly identified among the drivers of both the vehicle the child was travelling in and other vehicles. Broad measures to combat these features across the population are therefore important for reducing deaths among child passengers.

Literature and Legislation

Over the last three decades, there have been numerous studies consistently reporting the effectiveness of restraint systems in reducing risk of death and injury among children in crashes compared to unrestrained children.

Australia has comprehensive legislation – introduced in 2010 – which requires appropriate use of child restraint systems by children up to the age of 7. The quality of child restraint systems available in Australia is assured through the unique Australian/New Zealand product standard, and consumers are provided with information to discriminate between products through a comprehensive consumer information program. The review of CDRT data found that the proportion of children inappropriately restrained decreased over the ten-year period, from 21% prior to 2010 to 5% post 2010.

There is consistent evidence in the literature that people from lower socio-economic groups are less likely to wear seat belts in cars, and that historically, parents of higher socio-economic status are more likely to use restraints for their children. Groups with a low socio-economic position have been found to be less likely to use an age-appropriate child restraint.

Recent studies both in Australia and other developed countries have investigated barriers to both appropriate and correct restraint use by children. In addition to socio-economic status, identified

factors include parental risk perception, awareness and education, child restraint design, parenting style, child preferences and comfort.

There is no doubt that the use of a restraint is an effective way to reduce the risk of injury in a crash. To see further reductions in deaths among child passengers, consideration should be given to implementing interventions to increase restraint use both among drivers and child passengers in the lower socio-economic sectors of the community and other vulnerable population groups – including families living in the most disadvantaged areas of NSW and outside major cities.

To see further reductions, there is a need to understand the continued impact of restraint on serious injury outcomes and to identify other potentially modifiable factors. However, there have been no further in-depth examinations of child passenger outcomes in crashes in Australia since the studies that led to the introduction of that new legislation.

Recommendations

Stemming from this review, it is recommended that:

1. Regular monitoring of child restraint practices across NSW should be introduced, particularly in areas of socio-economic disadvantage and outside major cities.

   There has been no population estimate of restraint use among NSW children since 2008, yet significant legislative reform has been introduced since that time. There is a need to understand if the practices observed among fatally injured children reflect population trends or are a marker of other risk factors associated with involvement in high severity and fatal crashes.

2. Measures to increase restraint use should be developed and implemented.

3. Programs and policies ensuring the high quality and performance of child restraints sold in Australia should continue.

4. Greater attention should be given to identifying and implementing measures to reduce misuse through restraint design and product standard requirements – and to removing barriers to vulnerable population groups accessing restraint fitting programs and services. Access to programs like the NSW Restraint Fitting Stations Network, and Restraint Fitting Checks should be expanded in areas of most need.

   It is also imperative that families at highest risk of serious crash involvement and misuse of restraint be identified.

5. Current legislative controls over minimum restraint use should be maintained, alongside wider dissemination of information on best practice for restraining children – particularly children over the age of seven. Dissemination strategies must ensure these messages reach and are understood by those sectors of the community most in need.

   Road safety initiatives should account for the higher involvement of people from the lowest areas of socio-economic disadvantage in transport-related deaths.

Introduction

Injury is the leading cause of death and hospitalisation of children aged over one year in Australia and in all developed countries. Injuries associated with transport account for a substantial proportion of this health burden. In high income countries, approximately 50% of these injuries are to child passengers in motor vehicle crashes [1]. This is despite substantial reductions in child passenger casualties in most high income countries over the last few decades. For example, in NSW in the 1970s, approximately 3000 child passengers were seriously injured each year in crashes. By 2005-09, this number had dropped to well under 1500 – with an average of 17 children fatally injured and a further 1130 seriously injured [2].

Restraining children when they travel in cars is the most effective way to reduce the risk of injury in a crash [3, 4]. Mandatory restraint laws for child occupants were first introduced into Australia in 1977, and by the late 1990s most Australian children (>98%) used some form of restraint when they travelled in a car [2]. It is likely that the introduction of widespread mandatory restraint use laws in Australia and in other jurisdictions has played a role in achieving these casualty reductions.

However, for children to receive maximum benefit from a restraint system they need to be optimally restrained. Optimal restraint requires a child to use the most appropriate restraint for their size and to use that restraint exactly as intended by the manufacturer. This was highlighted in an in-depth examination of crash factors associated with serious injury outcomes among child passengers in crashes in NSW in 2003. This study found more serious injuries among those sub optimally restrained compared to optimally restrained children [5]. High levels of suboptimal restraint use were also reported – both among children admitted to hospitals after a crash (>80% sub optimally restrained) [5], and in the broader population of children travelling in cars (50% sub optimally restrained) [6].

The importance of appropriate restraint use for optimal crash protection was recognised in new Australian Road Rules published in 2009 and implemented in most Australian states including NSW in 2010. These rules mandated the type of restraint used and seating position by age of child up to 7 years of age. Australia-wide child passenger fatality numbers indicate that – since the introduction of these new laws – fatality numbers have dropped from approximately 70 children per year to closer to 40 per year [7]. To see further reductions, there is a need to understand the continued impact of restraint on serious injury outcomes and to identify other potentially modifiable factors. However, there have been no further in-depth examinations of child passenger outcomes in crashes in Australia since the studies that led to the introduction of that new legislation – eg Brown et al [5].

This report provides a detailed evaluation of the factors involved in fatal crashes to child passengers in NSW during the ten-year period from 2007-16, using in-depth data collected by the NSW Child Death Review Team (CDRT). It also considers the current legislative environment and available literature on the major risk and protective factors for injuries to child passengers involved in motor vehicle crashes.

1.1 Aims

The main aims of this report were to examine:

- The mechanisms and source of fatal injuries to children 0-12 years of age in car and truck crashes in NSW, and particularly the role of restraint factors.
- Variations in the use of restraints among children from vulnerable population groups.

The report also examines:

- The rate of child passenger deaths per year from 2007 to 2016, and among children affected and not affected by legislative changes in 2010 – ie under and over the age of 7 years.
- The demographic profile of children killed as passengers in cars from 2007-16.
- Crash factors including location, severity, vehicle factors, crash type and driver characteristics.

The research for this report had three parts:

- An analysis of the CDRT data about 66 child motor vehicle passengers (aged 0-12 years) who died in NSW in 2007-16.
- A review of current legislative requirements for the use of child restraints and seatbelts for children.
- A review of literature about the use of child restraints and seatbelts to reduce injuries and deaths associated with motor vehicle crashes.

1.2 Analysis of CDRT data

The CDRT, convened by the NSW Ombudsman, maintains a registry of child of deaths in NSW. The register is populated with data collected from public agencies (such as NSW Police) who are required by legislation to provide the CDRT with full and unrestricted access to relevant records. In NSW (and most other states) almost all crashes involving fatally injured occupants are examined in-depth by crash investigation and forensic police officers for law enforcement purposes. For child passengers, this detailed level of information is included in the information routinely collected by the CDRT. They use this data to review child deaths, identify trends and patterns, and undertake research to prevent or reduce the likelihood of child deaths.

The NSW CDRT used the data collected for all child (0-12 years) passenger deaths in NSW between 2007 and 2016 to construct a non-identifiable dataset that summarises relevant crash and restraint data in sufficient detail to examine factors influencing the severity of outcome. Group data only is reported to minimise the risk of identifying specific crashes or individuals. If cell sizes are less than three, these are reported as three or fewer children to prevent the possible identification of individual cases.

The list of variables included in the NSW CDRT dataset and used in this analysis is provided in Appendix 1 and 2.

The primary variables of interest in this analysis were related to restraint factors – including restraint use, type of restraint used, appropriateness of the restraint type for the child's age, and the correctness of restraint use.

The definitions of the categories of restraint status at the time of the crash are shown in Table 1.

Table 1: Categories for restraints at the time of the crash

Categories	Definition
Restraint status	
Unrestrained	The evidence provided confirmed that the child was unrestrained, or indicated that the child was in all probability unrestrained, at the time of the crash.
Restrained	The evidence provided confirmed that the child was in all probability in a restraint the time of the crash. This term can be used regardless of if it was the correct restraint for their age according to the current NSW legislation, or whether it was being used correctly at the time (as per manufacturer's instructions).
Restraint type	
Rear facing child restraint	A restraint for children from birth, with a built-in harness, where the child faces the rear of the car. Sometimes known as 'baby capsule', 'infant restraint' or 'baby carrier'. Type A in the Australian Standard
Forward child restraint	A child restraint with a built-in harness where the child faces the front of the car. Sometime known as 'child safety seat', 'forward-facing restraint'. Type B in the Australian Standard
Booster	A child restraint that boosts the child up and positions the adult lap sash belt properly over the child's hips and chest. It can be a booster cushion' (backless), or a high back booster seat. Sometime known as: 'Belt positioning booster', 'booster cushion' Type E, F in the Australian Standard
Adult lap belt	A seatbelt that has no sash or shoulder part and only restrains the hips. Sometimes known as: '2-point seatbelt'.
Adult seat belt	A seat belt in the car that has a part of the belt that goes across the lap as well as a part that goes over the shoulder. Sometimes known as: 'Lap and shoulder belt', '3 point seat belt'.
Restraint age appropriateness	
Inappropriate restraint	Child was in the wrong restraint type for their age according to current NSW legislation eg in a forward facing restraint under the age of 6 months, in a booster seat while under the age of 4 years, or in an adult seat belt only under the age of 7 years.
Appropriate restraint	Child was in a restraint type appropriate for their age according to current NSW legislation.
Correct use of restraints	
Incorrectly fitted	The evidence provided confirmed that the restraint being used by the child was not fitted correctly, or was in all probability not fitted correctly, at the time of the crash. For example: • Adult seat belts – misplacement of the seat belt sash under the arm, or the child was lying across the seat with the seat belt on.

	• Booster seats – incorrect position of the sash belt, poor routing of the sash belt under side wings, top tether anchored to the wrong point, very twisted or loose tether strap or non-use of the top tether. • Forward facing or rear facing child restraints – errors in top tether use (eg anchored to the wrong point, very twisted or loose tether strap), non-use of the top tether, non-use or partial use of the internal harness, poor adjustment of the harness height (ie harness threaded through shoulder slots that are too high for the child, or through uneven slots), or the seat belt anchoring the restraint to the vehicle seat being unbuckled.
Correctly fitted	Installation and use of the restraint was exactly as the manufacturer intended.
Suboptimal restraint	
	A restraint was either misused and/or inappropriate for their age.
Primary contributor to death	
Restraint factors	Factors associated with the restraint including non-use of a restraint, the wrong type of type of restraint for the child's age (as per the NSW legislation), or misuse of the restraint in terms of not it not being installed correctly or the child not being secured in it correctly according to the manufacturers' instructions.
Intrusion	An object protruding into the internal space of the car.
Ejection	Upon impact the child was thrown from the car to outside the car.
Fire/explosion	Post-crash fire or explosion that was due to the crash.

With the approval of the NSW Ombudsman and the UNSW Human Research Ethics Committee, this dataset was analysed for:

- The role restraint factors played in the death of each child
- Demographic characteristics of the children fatally injured as passengers – ie socio-economic status, remoteness, Aboriginality, child protection history
- The proportion of crashes involving known crash risk factors such as geographic location (rurality), driver demographics and other driver characteristics including impairment by alcohol or drugs, inattention and fatigue, and speed
- The role other crash factors played in the death of each child.

A child is considered to have a child protection history if – within three years before their death – the child and/or their siblings were the subject of a report about safety, welfare or wellbeing made to FACS or a Child Wellbeing Unit.

1.3 Review of current legislative requirements and literature

This part of the research had two main aims. They were to:

- identify the current state of child passenger safety in Australia
- describe how this compares internationally.

Data for this section of the report was collected by reviewing Australian and international product standards, and developing a layperson's interpretation of legislation as outlined on road authority and child safety advocate websites.

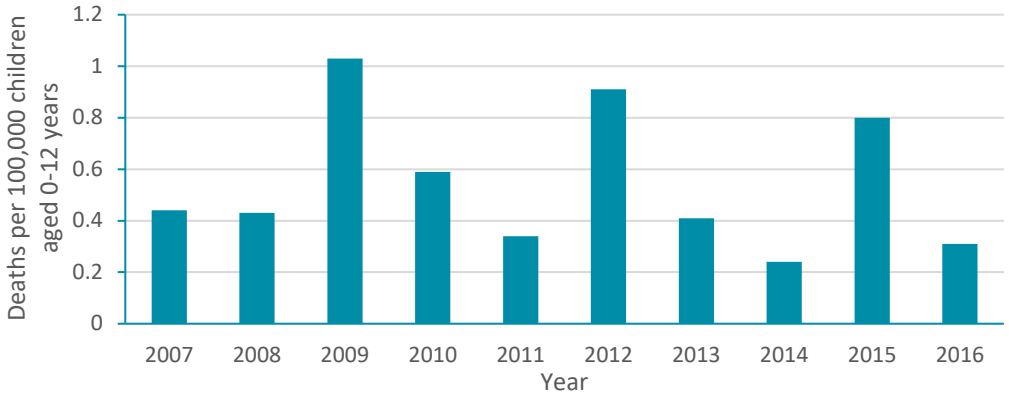
A broad review of available literature was also undertaken on factors affecting crash protection, risk factors for optimal restraint practices, measures to increase optimal use of restraints and measures specifically aimed at increasing the correct use of restraints.

2. Findings from the analysis of CDRT data in NSW 2007-16

This section presents the findings and analysis of ten years of CDRT data on child passenger deaths in NSW.

There were 66 children aged 0-12 years who died as passengers in motor vehicle crashes in NSW from 1 January 2007 to 31 December 2016. Figure 1 shows the rate of passenger deaths per 100,000 children for the 10-year period.

Figure 1. Passenger deaths of children aged 0-12 years in NSW, 2007-16



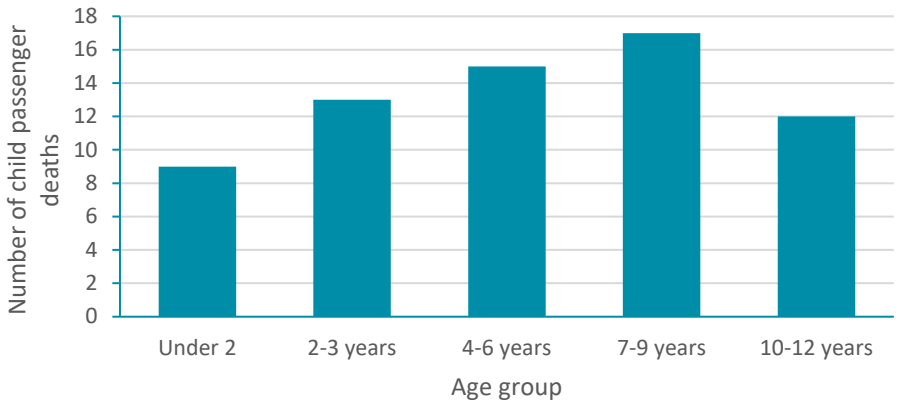
2.1 Demographics

2.1.1 Age and gender

The 66 children included 38 females (58%) and 28 (42%) males.

There were 37 children aged 0-6 years and 29 children aged 7-12 years. Figure 2 shows the age distribution of this sample.

Figure 2. Passenger deaths of children aged 0-12 years in NSW, 2007-16



2.1.2 Aboriginal and Torres Strait Islander children

Of the 66 children, 13 (20%) were identified as Aboriginal and Torres Strait Islander, and 53 (80%) were non-Indigenous according to data provided by the Register of Births, Deaths and Marriages.

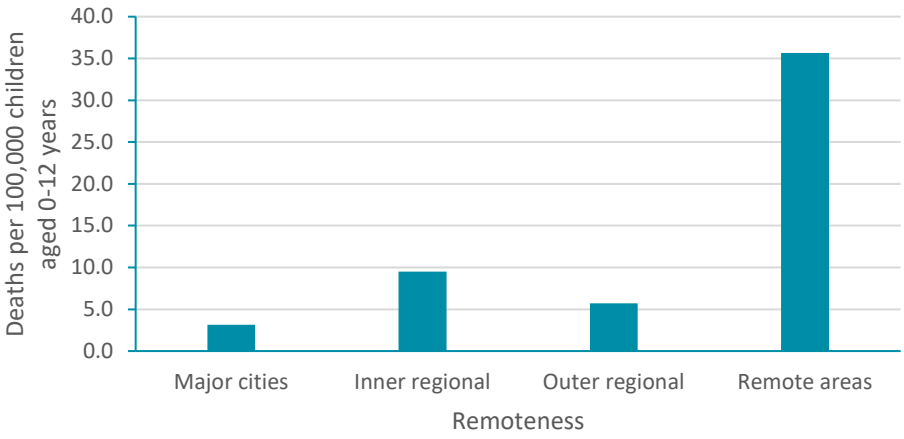
Indigenous children are over-represented, given that of all children in NSW, approximately 5% are Indigenous [8]. In the 10-year period, the rate for Aboriginal and Torres Strait Islander children was 4.2 times as high (two deaths per 100,000 children) compared with non-Indigenous children (0.5 deaths per 100,000 children).

2.1.3 Remoteness

Of the 66 children, almost half (32, 48%) lived in major cities, and a further 26 lived in inner regional areas. Five children lived in outer regional areas, and three in remote areas. Remoteness was determined from the ABS Accessibility Index of Australia (ARIA+) – remote areas include remote and very remote areas.

Although almost half of the children lived in major cities, Figure 3 shows the mortality rate for child passenger deaths was highest in remote areas. In the 10-year period, the rate was 11 times as high for children in remote areas as for those in major cities.

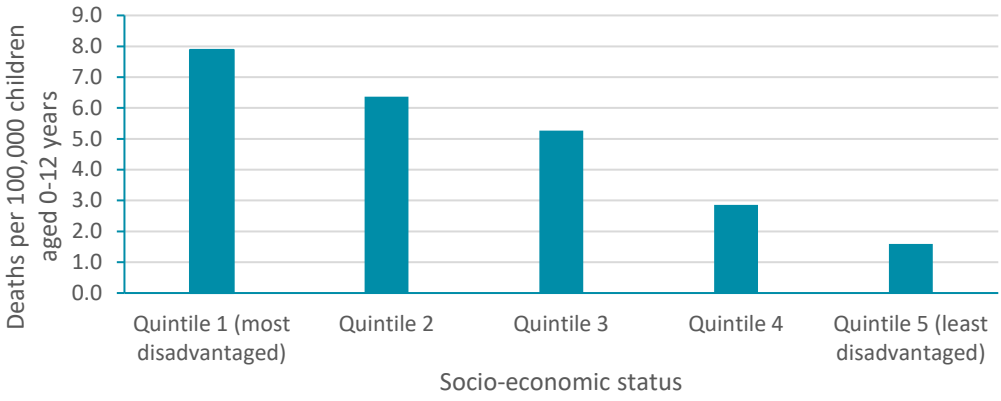
Figure 3. Passenger deaths of children aged 0-12 years in NSW by remoteness, 2007-16



2.1.4 Socio-economic status

Two thirds of children who died (41) were living in the most disadvantaged areas (Quintile 1 and 2 of the Index of Socio-economic Disadvantage). This is higher than the proportion in NSW for all child deaths – 50% of children who died from all causes over the past 15 years were living in Quintiles 1 and 2.[9] As shown in Figure 4, the mortality rate was five times as high for children in the most disadvantaged areas as for those in least disadvantaged areas (Quintile 1 compared with Quintile 5).

Figure 4. Passenger deaths of children aged 0-12 years in NSW by socio-economic status, 2007-16



2.1.5 Child protection history

Of the 66 children, 20 (30%) had a child protection history.

2.2 Restraints

2.2.1 Restraint status

The majority (51, 77%) of the 66 children were using or likely using some form of restraint at the time of the crash. However, in many cases, there were problems with the type of restraint used, or the way in which the restraint was being used. Of the 66 children:

- 29 children (44%) were properly restrained – that is, using an age appropriate restraint that was correctly fitted.
- 20 children (30%) were using a restraint that was either inappropriate for their age (6) or was not correctly fitted (14).
- 15 children (23%) were unrestrained or likely to be unrestrained.

For two children (3%), there was insufficient information to determine whether the restraint used was age appropriate and/or correctly fitted.

Analysis of crash information for the 35 children who were either unrestrained or not properly restrained identified that in most (20) cases, correct use of a restraint could have prevented the child's death. This included:

- nine children using age appropriate restraints that were not fitted correctly
- eight children who were unrestrained
- three children using restraints that were inappropriate for their age.

The correct use of an age appropriate restraint would not have prevented the deaths of the other 15 children due to the nature and severity of the crashes, with factors such as intrusion – an object or part of the vehicle protruding into the internal space of the car – and post-crash fire the primary factors in these fatalities.

Non-use of restraints was higher among children aged less than seven (27%) compared with children aged over seven years (19%), however, overall there was no significant difference in the proper use of restraints for age. No significant differences were found in restraint use comparing Aboriginal and Torres Strait Islander children and non-Indigenous children, for remoteness or socio-economic status.

In addition, there was no difference in the restraint status of children involved in single and multiple fatality crashes. Unrestrained children were, however, significantly more likely to have been killed in rollover crashes than in impacts with another crash partner. One in three children killed in rollover crashes were unrestrained compared to only one in six unrestrained in all other crash types.

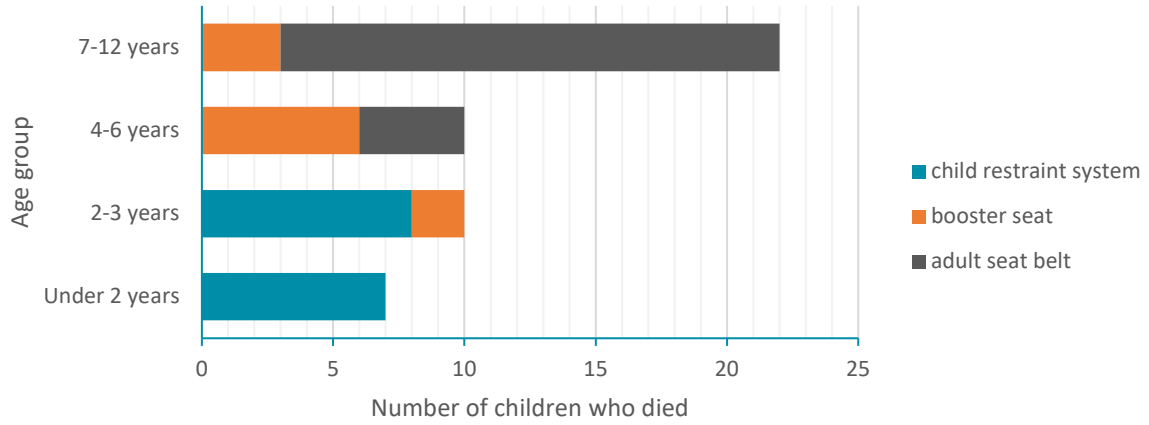
Unrestrained children were also significantly more likely than those who were restrained to be in vehicles driven by an unrestrained driver and significantly more likely to be in a car driven by an unlicensed/disqualified or provisional driver.

2.2.2 Inappropriate restraints for age

Figure 5 shows the type of restraints used by children who died as passengers.

Six children were using restraints that were inappropriate for their age – all were between 2 and 6 years old. They included two children using booster seats who required a dedicated child restraint system, and four children using adult seat belts without a booster seat or child restraint system. Of these, the correct use of an age appropriate restraint may have prevented the deaths of three children.

Figure 5. Types of restraints used in NSW child passenger deaths, 2007-16



2.2.3 Incorrectly fitted restraints

Fourteen children were using age appropriate restraints that were incorrectly fitted (Figure 6). Of these, correct use of the restraint may have prevented the deaths of nine children.

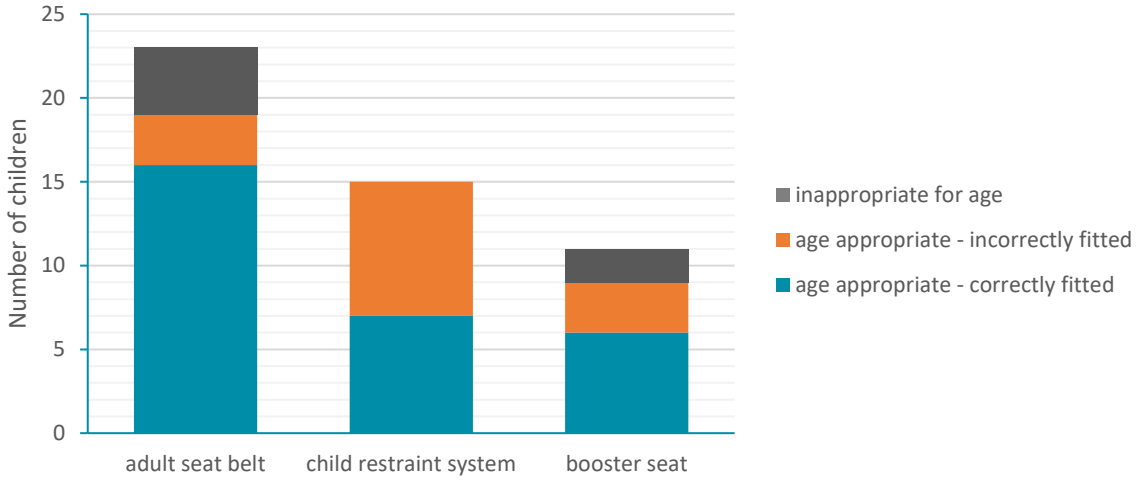
Incorrect use occurred in most restraint types – adult seat belts, booster seats, and front facing child restraints systems. The most common type of restraint that was incorrectly used were front facing child restraints. For all restraint types, issues identified included:

- seat belts placed under the arm
- children laying across the seat with the seat belt on
- poor routing of sash belts through booster seats

- tethers not anchored correctly, not used, twisted or loose in booster seats and forward facing child restraint systems
- poor adjustment of harnesses in forward facing child restraint systems – that is, harnesses positioned too high for the child, positioned unevenly across the child, or only partially used.

No incorrect use was identified in rearward facing child restraints.

Figure 6. Incorrect use of restraints in NSW child passenger deaths, 2007-16



2.3 Crashes

The 66 children were involved in 62 crashes. Most (58) crashes involved a single child fatality. Four crashes resulted in the deaths of two children in the same crash and the same vehicle.

Twenty-four children (over one-third of cases) were involved in crashes in which additional fatalities occurred in the vehicle in which the child was travelling, indicating the high severity of these crashes. This included 14 cases (21%) with one additional fatality, and six children (11%) in crashes with two additional fatalities. Three children died in crashes with three or more additional fatalities.

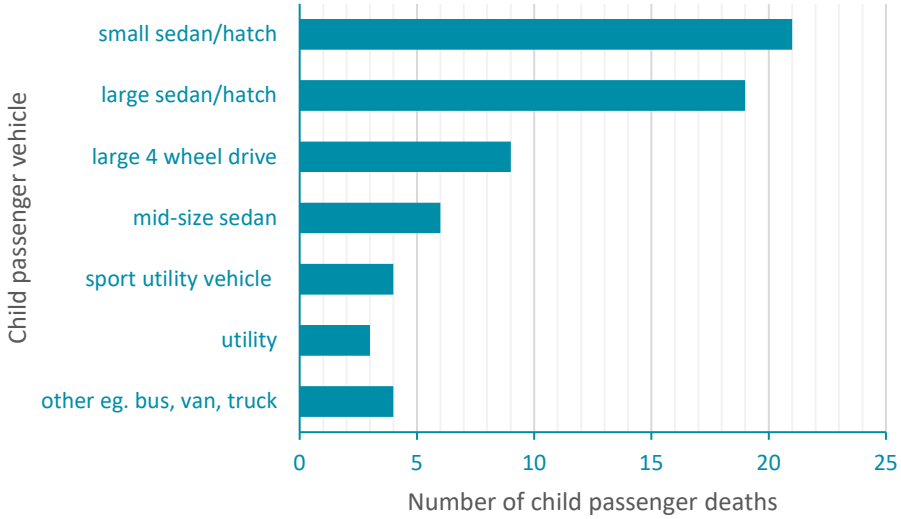
Twenty-six children who died (39%) were involved in a single vehicle crash, with a further 38 children (58%) were involved in a two-vehicle crash.

2.3.1 Type of vehicle

For the child passenger deaths that occurred between 2007-16, the year of manufacture of the vehicles in which the children were travelling ranged from 1988 to 2015. The average age of the vehicle was 10 years, and ranged between less than a year and 22 years old.

Figure 7 shows the distribution of vehicle types in which the children were travelling. Almost one-third (21, 32%) were travelling in a small sedan or hatchback, and a further 19 (29%) were travelling in a large sedan or station wagon.

Figure 7: Vehicles in NSW child passenger deaths, 2007-16



2.3.2 Type of impact

Of the 66 children:

- 16 died after their vehicle impacted with a tree or pole
- 16 were in vehicles that impacted with another car
- 13 were in vehicles that impacted with a utility, small truck or van, and
- 8 were in vehicles that impacted with a large truck.

Ten children were involved in vehicle rollovers.

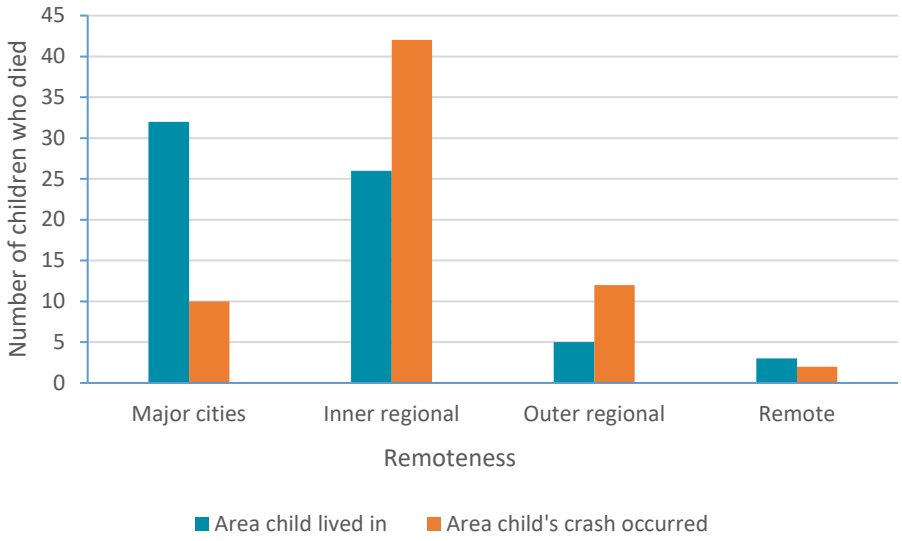
Vehicle-to-vehicle incompatibility played a significant role in many crashes. In collisions involving two or more vehicles, the child was often travelling in the smaller or lighter vehicle.

The area of primary damage as a result of the crash was most often the side of the vehicle (58%), followed by the front (20%). In a further ten cases (15%) no primary area of damage could be established as damage occurred to the entire vehicle, and this largely involved rollovers (8 cases). The primary area of damage was to the roof in five cases overall. Significant damage to the roof occurred in 14 cases (around one in five). Together, significant intrusion or intrusion affecting the space occupied by the child, was a factor in almost three-quarters of the fatalities.

2.3.3 Crash location

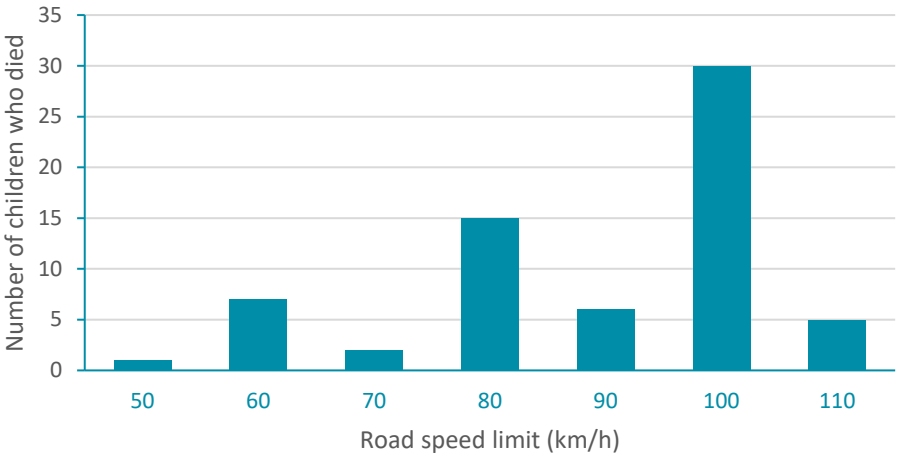
While the majority of children lived in major cities, Figure 8 shows most children (56, 85%) died in crashes that occurred outside of major cities in NSW.

Figure 8. Crash location of NSW child passenger deaths, 2007-16



Of the 66 children, 56 (85%) died in crashes on roads with a posted speed limit of 80km/hr or more. This includes 35 (54%) children who died on roads with a posted speed limit of 100-110km/hr (Figure 9). Only one in twelve cases occurred in the vicinity of an intersection.

Figure 9: Road speed limit of child passenger deaths in NSW, 2007-16s



2.4 Seating position

Almost three-quarters of children (49) occupied a rear seating position (rear or rear third row). Eleven children (17%) occupied the front passenger position at the time of the crash – of these, four children were under seven years old. The remaining six children were either in unknown positions (3) or were travelling in a large vehicle such as a truck.

2.5 Driver factors

The age of the driver of the vehicle in which the child was travelling ranged from 13 years to 75 years, with average age of 36 years. Approximately two-thirds (45, 68%) of the drivers were parents of the child/ren who died. Other drivers included grandparents (8, 12%), related adults (4, 6%), and non-family members, such as friends of the parent (9, 13%). There were similar numbers of male and female drivers – 35 females and 31 males. The vast majority (90%) of male drivers were the father of the child, whereas female drivers had a wider range of relationships with the child (just over half (51%) the female drivers were the mother of the child).

Table 4 shows that most drivers were restrained. In cases where the driver was unrestrained, the children were also unrestrained.

Table 4. Restraint status of driver's vs child passengers who died in NSW, 2007-16

Driver restraint status	Child restrained	Child not restrained
Restrained	51	6
Not restrained	5	5
Unknown	10	4
Total	**51**	**15**

Driver licence status was known in 60 cases, and of these, most drivers (48) held unrestricted licences. Seven drivers were unlicensed, including a small number who had been disqualified from driving. In addition, a small number of drivers were either unsupervised learners, under age drivers, or held provisional licences.

Toxicology reports were available for 60 drivers. Drugs and/or alcohol were detected for 15 drivers, including 13 drivers where drugs were detected, one driver with alcohol, and one driver where both drugs and alcohol were detected. Drugs identified included methamphetamine, ice, cannabis, methadone and oxycodone.

Driver fatigue (of the vehicle in which the child travelled) was identified as a likely factor in 11 cases (17% of all cases) and driver distraction was noted as a likely factor in a further 10 cases (15%). Examples of driver distraction included using a mobile phone, being distracted by children in the car, animals on the roadway, and trying to find the correct direction.

The driver of the vehicle in which the child travelled was deemed to be at fault in 46 (70%) cases.

Of these, 41 cases involved another vehicle. Among the drivers of the other vehicle, drugs were detected for four drivers and alcohol was found for three drivers. The other driver's fatigue was identified as a factor in three of the multivehicle crashes, and inattention was noted in two of these cases – phone use and being part of a police pursuit.

2.6 Injuries

The most commonly listed cause of death was 'multiple injuries'. Of the 66 children, primary cause of death identified included:

- Multiple injuries – 28 children (42%)
- Head injuries – 24 children (36%)
- Other injuries – 14 children (21%), including spinal (4), chest (3) and other primary causes such as burns (7)

Many of the children sustained multiple additional significant injuries – such as multiple fractures, internal organ and abdominal injuries – that were not listed as the primary cause of death.

2.7 Deaths 2007-09 vs 2010-16

From 2010, all children under the age of seven have been required by law to use a correctly fitted, appropriate restraint for their age.

As shown in Figure 10, from 2010 the rate for children 0-6 years old has remained less than 0.6 deaths per 100,000 children. However, there was no similar trend for older children – as the rate peaked at 1.7 and 1.1 deaths per 100,000 children in 2012 and 2015, respectively, showing notable variation over time.

Figure 10: Child passenger deaths in NSW, by age group, 2007-16

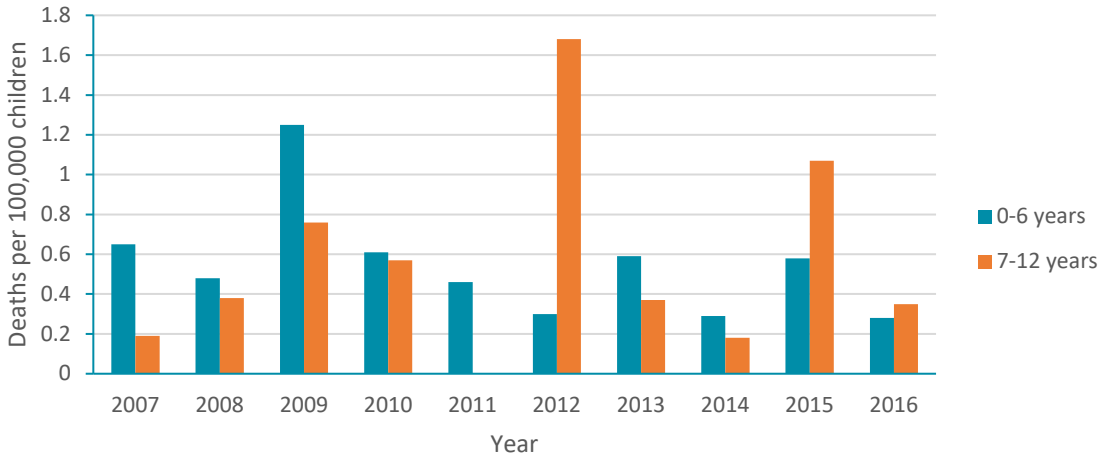
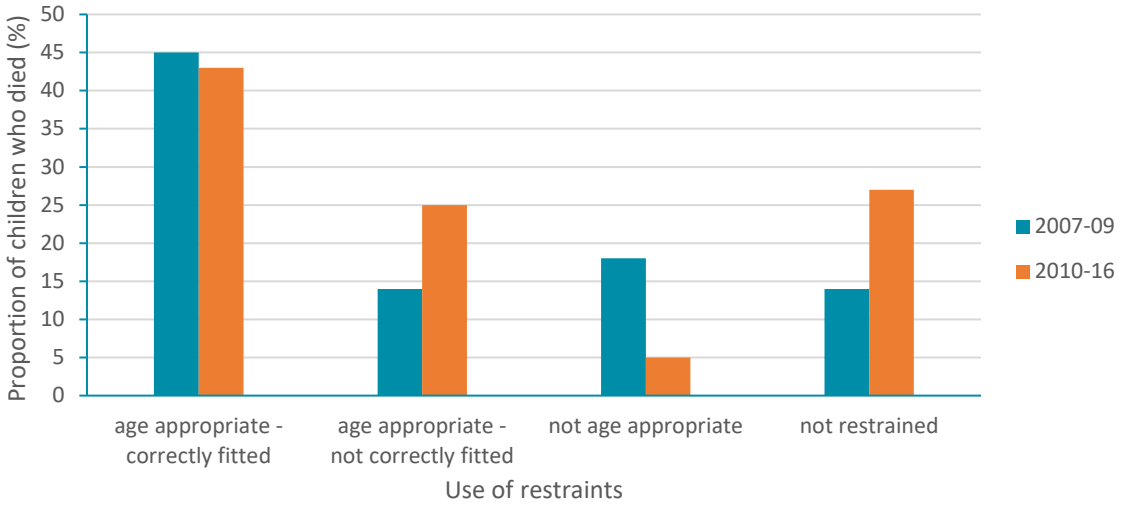


Figure 11 compares the use of restraints in child passenger deaths in the period 2007-09, and the period after the law was introduced, 2010-16. As shown, the proportion of properly restrained children – those using age appropriate restraints that are correctly fitted – has remained the same (45% vs 43%).

On a positive note, the proportion of children using age appropriate restraints has increased from 59% to 68% since 2010, and the proportion of children using inappropriate restraints for their age has decreased from 18% to 5%.

However, there was an increase in the proportion of children using restraints that were not correctly fitted (14% to 25%), as well as an increase in the proportion of children who were unrestrained (14% to 27%).

Figure 11: Restraint use in NSW child passenger deaths, 2007-09 vs 2010-16



3. Discussion

Overall, the rate of child passenger deaths in NSW over the ten-year period remained unchanged. Notwithstanding with, from 2010 the rate for younger children under seven years of age has remained lower than 0.6 deaths per 100,000 children, while the rate for older children has continued to fluctuate.

Key findings from the review of CDRT data are that:

Restraint factors

- While the majority of children were using some form of restraint, only 29 of the 66 children (44%) were properly restrained.
- Nearly one-third (20) of the 66 children were using a restraint that was inappropriate for their age or was incorrectly fitted.
- Almost one-quarter (15) of the 66 children were unrestrained in the vehicles they were travelling in.
- Incorrect, or non-use of, a restraint was the primary contributing factor in the deaths of many children. Crash information indicates that correct use of a restraint may have prevented the death of more than half (20) the 35 children who were not properly restrained or who were unrestrained.
- All the children who were using inappropriate restraints for their age were between 2 and 6 years old.
- Incorrect use of restraints occurred in most restraint types, with front facing child restraint systems proving the most problematic.

Other factors

- The vast majority (85%) of children died in crashes that occurred outside of major cities in NSW. Most children (56 of 66) also died on roads with posted speed limits of 80km/hr or more.
- Indigenous children were over-represented in child passenger fatalities (the rate was 4.2 times as high, compared with non-Indigenous children).
- Two-thirds (41) of the 66 deaths involved children from the lowest socio-economic areas of NSW, with the mortality rate 5 times as high for children from the most disadvantaged areas compared to those from areas of least disadvantage.
- Almost one-quarter of the drivers of vehicles in which the child was travelling were found to have drugs in their system at the time of the crash. In some cases (10%), the driver of the other vehicle had drugs in their system. Much fewer cases involved alcohol – less than 5% of drivers of the child's vehicle and 7% of other drivers.
- Driver factors identified included unlicensed drivers, provisional licence holders, unsupervised learners, and under age drivers. Driver fatigue and distraction were also identified in some cases.

3.1 Socio-economic inequalities

Globally, it is well established that the burden of road trauma is not equally shared [10] and that children from the most disadvantaged socio-economic areas are most at risk from traffic injury generally [11]. Our findings on the over-involvement of children from lower socio-economic areas is therefore not surprising against this background. What is less clear are the mechanisms underlying these disparities and – without a clear understanding of why this disparity exists – it is difficult to implement measures to address this problem. What is clear is the need to encourage increased attention to understanding these underlying mechanisms and to try to start to address these disparities. At the very least, there is a need to ensure that measures introduced to reduce road traffic deaths and injury do not increase this disparity. In other countries, there is evidence that socio-economic differences in fatality rates are increasing [12].

To date in Australia, there has been little focus on the overall disparity in socio-economic status among motor vehicle passengers fatally or otherwise injured in motor vehicle crashes. Road safety strategies have begun to prioritise urban/rural differences in crash location [13] and this is encouraging – given our finding that 85% of children died in crashes that occurred in regional and rural NSW. However, increasing the safety of rural roads will only address social inequality in casualty rates if the majority of those crashes on rural roads involve people living in those areas of lowest socio-economic disadvantage. Although more than half of the children who died as passengers in NSW lived outside major cities, focusing on the safety of rural residents alone may not adequately address social inequalities in traffic injury risk.

For example, one Australian study that has confirmed socio-economic disparities among hospitalised young drivers in Australia [14] reported that the higher risk of crash-related hospitalisation from low socio-economic areas is independent of rural/urban dwelling differences. Laflamme et al. [11] noted that – for children internationally – for most types of traffic user, deaths and injury are often higher among children from lower socio-economic areas and most often occur in areas of most disadvantage. However, it remains unclear whether it is simply a phenomenon of the risk associated with the area or the risk associated with social and economic disadvantage. To see further reductions in child deaths among children in NSW, this issue requires further investigation – and it is possible that road safety strategies require an increased focus on people from lower socio-economic areas.

One-third of the children who died as passengers in NSW over the ten-year period were identified as having had previous contact with child protection services. This potentially vulnerable group is rarely discussed from a road injury prevention perspective. However, initial contact with child protection services may be a potential delivery point for interventions aimed at reducing death and injury among children in cars. This is an area that is worthy of further investigation.

One vulnerable group that has received recent increased attention from public health researchers and road safety agencies are Aboriginal and Torres Strait Islander road users [15]. There is clear and consistent evidence that injury rates overall and from transport are higher among these groups in both Australia and other developed countries [16]. Continued action to address disparities among members of these communities in NSW should be encouraged, given the clear over-representation of children identified as Aboriginal or Torres Strait Islander among child passenger deaths. Specific areas of possible action are discussed in more detail in later sections related to restraint factors.

3.2 Non-use of restraints

Just over one-in-five (22%) of the children who died as passengers in NSW between 2007 and 2016 were unrestrained. The most recent population level estimates for child restraint use were made in 2008 and reported in 2010 [6]. These estimates indicate population level rates of restraint use are much higher than observed in this sample – indicating a likely over-representation of unrestrained children in this sample. High relative rates of non-use of restraints are consistently reported among samples of fatally injured adult drivers and occupants [17, 18]. In this sample, relatively high rates of restraint non-use were also observed, but the confirmed non-use of restraints by drivers was lower than that among the fatally injured children.

There is no doubt that the use of a restraint is an effective way to reduce the risk of injury in a crash. To see further reductions in deaths among child passengers, consideration should be given to implementing interventions to increase restraint use both among drivers and child passengers in the lower socio-economic sectors of the community and other vulnerable population groups – including families living in the most disadvantaged areas of NSW and outside major cities.

There is also a need to understand if the high rate of non-use observed in this sample reflects relatively high rates of non-use of restraints generally by children among the sectors of the community represented in this sample. Estimates made by Brown et al [6] did not examine restraint use by sociodemographic factors, and it is possible those estimates do not accurately reflect the state of restraint use across all sectors of the community. Similarly, in comparing restraint status of children who died before and after the introduction of new restraint use legislation in 2010, there was a greater proportion of children unrestrained post-2010. There is an urgent need for updated population estimates like that made by Brown et al [6] to ensure this does not reflect a population level trend.

3.3 Age inappropriate restraint use

Across the ten-year period (2007 to 2016), 9% of children were found to have been using an inappropriate restraint for their age. This exclusively occurred in children aged 2 to 6 years and was more common in the pre-2010 period. Among the children who died after 2010, only 5% were using restraints inappropriately. These proportions of age inappropriate use are much lower than reported previously by Brown et al [5] among crash involved children and Brown et al [6] in population estimates. This may reflect slight differences in the way age appropriate use was defined in the earlier studies and how it is defined in this review.

Earlier studies examined age inappropriate use taking into account height and weight and design specifications of different restraint types, whereas in this review the definition of age appropriate use is based on the current law and is defined by age. Regardless of this, it appears there may have been changes in the types of restraints being used by children under seven years since the introduction of legislation in 2010. Interestingly, from the literature, the determinants for age appropriate restraint use are reported to be similar to restraint use in general. However, observations during this review indicate an increase in the proportion of children using age appropriate restraints. This remains to be confirmed at the population level for children not involved in fatal crashes.

A common factor in the deaths of the children who were using appropriate restraints for their age was misuse of the restraint and this is discussed in more detail below. The most common source of fatal injury in children who correctly used age appropriate restraint systems was intrusion into the child's occupant space.

3.4 Incorrectly fitted restraints

Incorrectly fitted restraints were confirmed in 21% of cases over the ten-year period. For the children in forward facing restraints, this largely involved misuse of the internal harness system. Misuse of the top tether was also common in children using forward facing restraints and booster seats. For children using booster seats and seat belts, misuse of the sash belt was common. These reflect the same common errors observed by Brown et al [19] in their 2008 study.

The overall involvement of misuse in this sample seems to be lower than the 50% estimated by Brown et al [19], but identifying misuse retrospectively is difficult. In this review, misuse was reported as being confirmed if police witnessed and accurately described the misuse – and likely if misuse was described in the witness statements and/or obvious from evidence of webbing loading on the child's body in post mortem injury descriptions.

Incorrectly fitted internal harness systems in restraints – and misuse of the seatbelt in booster seat and seat belt users – are referred to as 'use' errors. These are unlikely to be influenced by countermeasures targeting errors associated with installation, such as ISOFIX compatible anchorage systems and possibly even restraint fitting stations. There is an urgent need to identify measures to reduce common use errors as well as installation errors.

From the literature reviewed (see section 4), increases in misuse have been observed with restraint types as they increase in complexity from seat belts to booster seats, to forward facing seats and convertible restraints [19, 20]. Increases in appropriate use, particularly for children under 4 may therefore be associated with increases in the use of more complex systems and therefore a potential for increases in misuse overall. In this sample of fatally injured children, the proportion of children using incorrectly fitted restraints has increased since the introduction of the legislation in 2010 – rising from 14% to 25%. However as noted above misuse is difficult to identify retrospectively. As noted previously, there have been no population estimates for restraint use among children in NSW since 2008. It is therefore unknown what effect any changes in the types of restraint being used have had on rates of misuse at the population level.

3.5 Scope for increasing crash protection for children aged seven years and over

Overall, the rate of deaths of children as passengers over the 10-year period 2007-16 has remained unchanged. It is important to note that these observations are largely descriptive in nature and do not take into account the background situation. For example, there may have been changes to travel patterns affecting exposure as well as other external influences working to increase the overall number of crashes. However, these effects are likely to be small as the effects on children over and under 7 would be expected to the same – but the trends appear different in these two groups.

In this sample, non-use of restraints was higher among children aged less than seven (27%) compared with children aged over seven years (19%). However, non-use of restraints by older children remains an issue. Efforts to increase use of restraints should target older children as well as younger children. In terms of appropriate restraint, by law all children aged 7 years and over can use adult seat belts. It has been well established that three-point belt or lap/sash belts provide better levels of crash protection than lap only belts. Recommendations from the best practice guidelines for the safe restraint of children travelling in motor vehicles address this issue, and this recommendation should be communicated broadly in any campaigns or programs aimed at increasing restraint use in older children.

In terms of optimal crash protection, whether a child aged over seven years of age is provided optimal protection by the available seat belt will depend on the match between that particular child's size and the geometry of the vehicle seat and seat belt system. The best practice guidelines and advice provided in NSW Government material recommend children continue to use a booster seat until they can achieve a good fit in the seat belt, as assessed by the '5 Step Test'. In this sample, three children aged over 7 years used a booster and these were all children who died after 2010. It is possible that more children in this age group could have been more optimally restrained in boosters, but it was not possible to assess the adequacy of restraint in terms of the child's size and the vehicle geometry. Previous work has demonstrated wide variations in the seat and seat belt geometry in the rear seat of vehicles – and also that many children up to age 12 may still need the assistance of a booster seat to achieve a good seat belt fit [21]. Material developed to support the best practice guidelines includes information about how to conduct a five-step test to ensure a child is achieving adequate seat belt fit without a booster. This test asks the parent five easy questions – and if the answer to any of them is no, the guidelines recommend the child continue to use a booster. Increased dissemination of this information is needed, particularly among children from communities reflected in this sample of children who were fatally injured as passengers.

3.6 Other restraint factors

It is notable that there was no evidence of any inadequacy in the design or performance of any of the child restraints used by the children in this sample. This most likely reflects the success of programs and policies such as CREP and the mandatory Australian product standard covering the design and performance of child restraints sold on the Australian market.

One other restraint factor often discussed is the adequacy of current legislation about when children should be able to use forward facing restraints. Australian legislation requires children to use rearward facing restraints to a minimum age of 6 months, but best practice recommendations both in Australia and in the US recommend children remain rear facing for as long as they fit in in the rear facing restraint. As noted by the American Academy of Pediatrics (AAP) [22], it is difficult to gather statistical evidence for any specific age based criteria for when children would be best protected in a rearward facing restraint.

There are three types of rear facing restraint now available in Australia. They are Type A1 – suitable for children from 0 to approximately 6 months, Type A2 – suitable for children from 0 to approximately 12 months, and Type A4 – suitable for children from 0 to approximately 30 months.

In this sample of child passenger deaths in NSW, only three children who died were confirmed to be using rearward facing restraints and all were aged under 6 months – no misuse was identified. In the others, intrusion into the child's occupant compartment was the primary source of fatal injury. A further four children under the age of two years died while using forward facing restraints. Misuse was confirmed in two of these cases and likely in a third case. The remaining case involved significant intrusion. Based on the data reviewed, misuse of the internal harness system appears to be a more important factor than the direction the child was facing. However, in the rearward facing restraint, the misuse involved non-use or non-engagement of the harness – while in the forward facing cases it involved partial use or poor adjustment of the harness.

3.7 Driver factors

Known risk factors for crash involvement – such as driver impairment, fatigue and distraction – were also commonly identified among the drivers of both the vehicle the child was travelling in and other vehicles. Broad measures to combat these features across the population is therefore important for reducing deaths among child passengers.

In this sample of child passenger deaths, a substantially greater number of drivers were identified with potential performance degrading drugs in their system than those with elevated blood alcohol levels. This appears to reflect a population level trend. In 2015, the NSW Centre for Road Safety reported that about 10% of mobile drug tests were positive, compared with less than 1% of random breath tests for alcohol. However, it is important to note that – although the data available for this review allowed 21% of the drivers of the vehicles in which the children travelled to be identified as having drugs in their system – definitive information about the likely impact on performance was not always available. The NSW Centre for Road Safety has previously estimated illicit drugs to be a contributing factor in 16% of all fatalities [23], and it seems likely the involvement of illicit drugs in child passenger fatalities may be similar.

Although the involvement of illicit drugs in fatalities involving child passengers seems comparable to the involvement of illicit drugs in all fatal crashes, there appears to be much less involvement of alcohol in fatalities involving children. The NSW Centre for Road Safety estimated alcohol was a factor in 15.5% of fatalities across NSW in 2016 – but in this sample of child fatalities only 3% of the drivers of the vehicles in which the child travelled had alcohol in their system, and this was generally at low levels. The difference in comparable involvement between drugs and alcohol in fatalities involving child passengers is interesting as understanding the reason for this difference may provide insight into how this behaviour might be reduced in the future.

Just over 10% of the children in this sample were travelling in a car with an unlicensed driver, and almost 8% of the drivers of the other vehicle in the crash were unlicensed. This is similar to that reported in a study of risk factors for fatal crashes in rural Queensland by Siskind et al [18], where 14% involved unlicensed drivers. This indicates this is likely to be a broader road safety problem than one just affecting child passengers.

3.8 Vehicle factors

Based on the speed of the roads on which the crashes happened and the high proportion of multiple fatality crashes, the crashes in which the children died were generally high energy crashes. It is therefore not surprising that intrusion was the primary source of the child's fatal injury in just over half of the cases. Intrusion occurs when the energy of the crash exceeds the strength of the vehicle frame [24]. Other studies of samples of fatally injured children have also reported intrusion and loss of vehicle integrity as a primary cause of death among child occupants [25].

Vehicles can be designed to manage crash energy and there is good evidence that modern vehicles are better at doing this than older vehicles [26-28]. The median age of the vehicles in which the children travelled was 10 years, which is similar to the age of the vehicle fleet across Australia. The overall level of crashworthiness of the individual vehicles was not investigated here, but it would appear likely that many of the vehicles did not provide adequate structural integrity and were not equipped with features like side curtain airbags. This may be largely attributable to the age of the vehicles involved, but it may also reflect the socio-economic disparity discussed before. In the US, Girasek

and Taylor [29] examined the association between the socio-economic status of vehicle owners and the safety of their motor vehicle, and found a clear link between vehicle safety features and socio-economic status. Vehicle manufacturers should be encouraged to provide comprehensive safety features as standard in all vehicles supplied for sale in Australia, rather than omitting some safety features in cheaper base models.

Post-crash fire was the primary cause of death in some cases. These crashes all involved heavy vehicles. In this sample, this source of fatal injury accounted for four (6%) of the deaths. The extent of fire involvement in road fatalities across NSW and elsewhere in Australia is unknown, but as noted by Viklund et al [30] post-crash fires are particularly harmful to young people occupying rear seats who otherwise may have escaped fatal injury in the crash. In their examination of all fatal crashes involving fire in Sweden from 1998-2008, they found two thirds of those who died in the rear seat in crash related fires died due to the fire – rather than injuries sustained in the crash. For child passenger safety, this in an area of vehicle safety that may warrant further investigation.

3.9 Road environment factors

This review did not provide a detailed analysis of the contribution of road environment factors. However, from the data provided it was clear that most crashes occurred outside of major cities and on high speed roads (>80km/h). Most crashes also occurred on roads with a single lane of traffic in each direction and without any physical separation between vehicles travelling in both directions. Mooren et al [31] noted that Australian governments had adopted the Safe System approach to underpin all road safety strategies from 2004 onwards. The Safe System approach dictates that 'speed limits for the road traffic system use human biomechanical and human competency as the design parameter to set the values'. However, Mooren et al [31] noted that much of the speed zoning across Australia does not comply with these parameters. This issue appears relevant to this sample of child deaths over 10 years in NSW – given that best practice speed zoning from a Safe System perspective would limit speeds to 70km/hr when there is no separation between opposing flows of traffic [31].

4. Review of the current legislative and policy environment governing the use of car restraints among children in NSW

For child passengers in NSW, the legislative environment consists of two main components. The first relates to the availability of child restraints, regulated by federal mandatory product standards. The second relates to the use of restraints when travelling in a car, regulated by road rules and implemented as state law. Both product standards and laws related to how children should travel in cars represent minimum standards. There are therefore further non-regulatory programs and documents that need to be taken into account when considering the current child restraint environment in NSW. These include the Australian Child Restraint Evaluation Program (CREP) and the National Health and Medical Research Council (NHMRC) approved *Best Practice Guidelines for the Safe Restraint of Children Travelling in Motor Vehicles* [32]. This section of the report reviews these aspects of the current environment.

4.1 Child restraint designs in Australia

In Australia, the design and performance of child restraints is regulated by Federal Consumer Law and overseen by the Australian Competition and Consumer Commission (ACCC), which requires all child restraints sold in Australia to comply with Australian Standard, AS/NZS 1754 – Child Restraint Systems for Use in Motor Vehicles. Since its inception in 1970, the Australian product standard has designated specific restraint types. These restraint types can be broadly grouped into restraints for infants, restraints for toddlers/pre-schoolers, and restraints for young children. In general, these categories relate to rearward facing restraints for infants, forward facing restraints for toddlers and pre-schoolers, and booster seats and add-on child safety harness systems for older children. The type designations, and therefore the designs of each type of restraint, originate from the first Australian standard released in 1970. Since then, the product standard has been through significant revisions. The current version of the standard is AS/NZS 1754:2013, and the preceding version was AS/NZS 1754:2010. Before the introduction of AS/NZS 1754:2010, type designations specified in the standard were based on the weight of the child. As part of the 2010 version of the standard, the type designation specifications were revised to be based on the child's age as well as being guided by shoulder height markers fixed to the restraint. Child restraint types as specified in the current 2013 standard are described in Table 7.

AS/NZS 1754 applies to all child restraint systems sold as aftermarket or add-on devices. As aftermarket devices, child restraints need to be installed into a vehicle. Historically, Australian child restraints have been installed using the adult seat belt and a top tether strap. The seat belt acts to anchor the lower part of the restraint to the vehicle, and the top tether acts to anchor the upper part of the restraint. Top tether straps have been mandatory on all rearward and forward facing restraints – and booster seats over a certain mass – since the 1980s. This historical condition is unique to the Australian environment. A notable addition to the revision of AS/NZS 1754 in 2013 was the inclusion of provisions for an alternative method of anchoring restraints to vehicles via ISOFIX connectors provided in the vehicle and ISOFIX compatible connectors provided on the restraint. In Australia, all parts of a vehicle are regulated through the Australian Design Rules (ADRs) system – and therefore

the design and performance of ISOFIX connectors provided in the vehicle is governed by the ADRs. However, ISOFIX compatible connectors provided on the restraint are governed by AS/NZS 1754. These ADRs also govern the performance of seat belt systems used by older children who have outgrown child restraints.

Table 7: Type designations specified in AS/NZS 1754:2013

AS/NZS 1754	2013	Suitable Age Range	Anchorage System
Type A1	**Rearward-facing restraint** with a harness or other means of retaining the occupant – suitable for infants of supine length up to 70cm. The term 'supine' refers to (a person) lying on their back, face or front upwards.	0 to approximately 6 months	A1: Seatbelt and ISOFIX compatible + top tether A1/B: Seatbelt and ISOFIX compatible + top tether
Type A2	**Rearward-facing restraint** with a harness or other means of retaining the occupant, suitable for infants of supine length up to 80cm.	0 to approximately 12 months	A2: Seatbelt and ISOFIX compatible + top tether A2/B: Seatbelt and ISOFIX compatible + top tether
Type A3	**Transversely installed restraint** with a harness or other means of retaining the occupant, suitable for infants of supine length of up to 70cm.	0 to approximately 6 months	Seatbelt + top tether
Type A4	**Rearward-facing restraint** with a harness or other means of retaining the occupant.	0 to approximately 30 months	A4: Seatbelt and ISOFIX compatible + top tether A4/B: Seatbelt and ISOFIX compatible + top tether
Type A/0	Criteria as above for rearward facing restraints and suitable for infants of low birth weight.	Corresponds with above ranges	Seatbelt and ISOFIX compatible + top tether
Type B	**Forward-facing chair** with harness.	Approximately 6 months to 4 years	Seatbelt and ISOFIX compatible + top tether
Type C	**A harness** that meets either or both of the following: Type C1: **Forward-facing harness** to be used in conjunction with a booster seat – suitable for children approximately 4 to 10 years of age depending on whether the booster seat is Type E or F.	Type C1: Approximately 4 to 10 years Type C2: Approximately 7 to 10 years	C1: Seatbelt + suitable booster seat + top tether anchorage C2: seatbelt + top tether anchorage

AS/NZS 1754	2013	Suitable Age Range	Anchorage System
	Type C2: **Forward-facing harness** without chair. Used with just the vehicle seat and seatbelt, but not suitable for use with a booster seat.		
Type D	**Rearward-facing chair with harness**.	Approximately 6 months to 4 years	Seatbelt and ISOFIX compatible + top tether
Type E	**A booster seat** used in conjunction with a lap-sash seatbelt – suitable for children whose height is less than 128cm. May also be used in conjunction with a seatbelt and a child harness that meets the requirements of C1.	Approximately 4 to 8 years	Only seatbelt compatible + top tether (if fitted)
Type F	**A booster seat** used in conjunction with a lap-sash seatbelt – suitable for children whose height is less than 138cm. May also be used in conjunction with a seatbelt and a child harness that meets the requirements of Type C1.	Approximately 4 to 10 years	Only seatbelt compatible + top tether (if fitted)
Type G	**Forward-facing chair** with harness.	Approximately 6 months to 8 years	Only seatbelt compatible + top tether
Type H	**A converter used with a booster seat**.	Approximately 4 to 7 years when used with a booster seat. Approximately 7 to 10 years when used with a seat belt.	Only seatbelt compatible + top tether (if fitted)
Combination type:	Child restraints can also be a combination of the above types – e.g. A/B, A/G, B/E, B/F.	Suitable for use up to upper age limit of combined age range.	Booster seats and their combinations cannot use ISOFIX anchorages.

In Australia, ISOFIX compatible connectors can be rigid (similar to systems used in Europe) or flexible (similar to systems used in North America). AS/NZS 1754: 2013 requires all ISOFIX compatible systems to incorporate a top tether as the upper anchorage component and use either the ISOFIX connectors or the seat belt as the lower anchorage component. Currently, AS/NZS 1754 allows the provision of ISOFIX compatible connectors on rearward facing restraints (Type A, see Table 7) and some forward facing restraints (Type B, Table 7). Large forward facing restraints (Type G, see Table 7) and booster seats (Type E and F, see Table 7) can only use the seat belt system and top tether as the anchorage system – due to concerns about exceeding the design load limits on the ISOFIX connectors in the vehicle stipulated in the ADR.

ISOFIX systems aim to reduce the incidence of misuse associated with the installation of the restraint in the vehicle. When correctly installed, they provide comparable levels of protection to the traditional vehicle seatbelt attachment method [33-37]. Rigid systems provide superior side impact performance compared to anchorage systems incorporating the seat belt or flexible connectors as the lower anchorage component.

Historically, two types of aftermarket (add-on) booster seats were available in Australia – one with a high back and side wings, and the backless booster cushion. Due to the increasing stringency of the Australian standard's requirements related to head protection provided during side impact, booster cushions no longer meet the crash performance requirements. Therefore, all add-on boosters currently sold in Australia are high-back boosters.

More recently, a third type of booster seat – integrated into the rear vehicle seat (integrated booster) – has become available in a small number of vehicles sold on the Australian market. Unlike international regulatory regimes, the Australian standard does not cover restraints integrated into a vehicle. This is because the child restraint standard (AS/NZS 1754 administered by Standards Australia) is separate to the vehicle standard system (ADRs, administered by the Federal Government). In Australia, integrated restraints fall under the ADRs. Although there is no ADR specifically covering integrated child restraints, ADR 34/01 requires any integrated booster seat in cars sold in Australia to comply with the specifications of the European Standard (ECE R44). All integrated booster seats currently available in Australia are effectively booster cushions.

Recent work examining the comparative performance of integrated and add-on boosters found no evidence of differences in performance of integrated boosters compared to add-on boosters in the real world – provided a side curtain airbag is present [38]**.** In dynamic testing, the integrated booster examined was as good as or better than current design high-back add-on boosters in frontal impact and for struck side occupants in side impact [38]. However, the good performance in side impact is reliant on the outboard seating position and the presence of a side curtain airbag. Therefore, good performance of integrated boosters appears to rely on the positioning of these restraints in a vehicle and the safety systems within the vehicle.

4.2 Child passenger restraint legislation in Australia

Children under 8 years were initially exempt from laws requiring the compulsory use of seat belts introduced into Australia in the early 1970s. Mandatory use of restraints by Australian children began in Victoria in 1976 and extended to NSW in March 1977 – when the exemptions were removed and it became compulsory for all children under eight to use an appropriate restraint where one was available. By 1982, this legislation had extended to all Australian states and territories [39]. The law at that time required that all children be restrained by an appropriate restraint when travelling in a vehicle. The legislation defined 'an appropriate' restraint differently for children under and over 12 months of age. For children under 12 months, the law defined an appropriate restraint as a standards approved child restraint. For children over 12 months, an appropriate restraint was defined as being either an approved child restraint or an adult seat belt [39].

In 2007, the National Transport Commission (the body governing the Australian road rules) published a review of legislation covering the restraint of children in cars [40] . This document recommended extending legislation requiring the use of child restraint and booster seats to children up to age seven years in the near future and up to age nine at some later time. In 2009, new Australian road rules

were released that specified use of age-appropriate restraints for children up to 7 years. These rules have now been implemented as updated laws in all Australian states. The specifics of the new rule vary slightly from state to state.

In NSW, the NSW Centre for Road Safety interprets the current legislation as follows:

- Children up to the age of six months must be secured in an approved rearward facing restraint.
- Children aged from six months old but under four years old must be secured in either a rear or forward facing approved child restraint with an inbuilt harness.
- Children aged from four years old but under seven years old must be secured in a forward facing approved child restraint with an inbuilt harness or an approved booster seat.
- Children in booster seats must be restrained by a suitable lap and sash type approved seatbelt that is properly adjusted and fastened, or by a suitable approved child safety harness that is properly adjusted and fastened.

NSW Government child restraint advice materials also strongly recommend the use of an approved booster seat by children aged from 7-16 years of age who are too small to be restrained by a seatbelt when properly adjusted and fastened [41].

With the introduction of mandatory restraint use laws in Australia in the 1970s, there was also legislation in some states and territories related to seating position. These laws varied in scope and detail from jurisdiction to jurisdiction. For example, in NSW from March 1977, children aged less than eight years were prohibited from riding unrestrained in the front passenger seat. The 2007 review of Australian road rules also addressed seating position, and more stringent seating position laws have now been implemented in all Australian states. In NSW, the NSW Centre for Road Safety interprets laws related to seating position as follows:

- Children under four years old cannot travel in the front seat of a vehicle with two or more rows.
- Children aged from four years old but under seven years old cannot travel in the front seat of a vehicle with two or more rows, unless all other back seats are occupied by children younger than seven years in an approved child restraint or booster seat [41].

4.3 Child restraint use in Australia

Before the introduction of mandatory restraint laws for children in Australia in the 1970s, only about 30% of children travelling in cars used some form of restraint. This increased to almost 60% in NSW by 1980 [42] and – with ongoing targeted educational campaigns – usage rates continued to increase to reach between 80% and 90% in NSW in 1994. By 2010, children in NSW had restraint usage rates beyond 98% [6]. Similar usage rates were reported in other states [43]. However, before about 2005, little attention was given to the type of restraint being used.

Studies conducted in NSW, South Australia and Victoria between 2005 and 2010 all identified high rates of inappropriate restraint among children travelling in cars in Australia [6, 43-45]. In 2008, Brown et al [6] conducted a cross-sectional population referenced observational survey of child restraint practices across NSW that reported overall very high rates of restraint use (>99%), but also relatively high rates of inappropriate restraint use (51.2% among children aged 0-12years) – particularly among children aged 4-8 years (73%).

After the introduction of new mandatory appropriate use laws in NSW in 2010, data from observations made by Brown et al in 2008 [6] was compared with observations made in the immediate post-legislation period. Due to the nature of the post-legislation observations, this comparison was limited to children aged 2-5 years within urban low socio-economic areas in 2010. Based on that comparison, age-appropriate restraint use appeared to have increased among these children from 41% to 73%.

The observational study reported by Brown et al [6] also highlighted the widespread nature of incorrect use of restraints in NSW, with 51% of children aged 0-12 observed to have at least one error in how they were using the restraint and/or how the restraint was installed in the vehicle. The pre-legislation/post-legislation comparison of observed child restraint use among children aged 2-5 years in low socio-economic areas of Sydney demonstrated only a modest 9% increase in correct use in the post-legislation period.

To date, there have been no further observational studies of child restraint practices conducted in NSW.

4.4 The Australian Child Restraint Evaluation Program (CREP)

AS/NZS 1754 describes the required minimum set of design and performance requirements for child restraints sold on the Australian market. Observations made by the test house conducting assessments of child restraints coming onto the market in the early 1990s indicated a wide range of performance beyond this minimum set of requirements. Some restraints far surpassed the required levels of protection and others were barely able to comply with the minimum requirements. This led to the formation of a program aimed at providing independent advice to consumers about the relative performance of child restraints on the Australian market. This program became known as CREP, and aims to provide consumers with information to help choose child restraints that perform beyond the minimum standard requirements and are easy to use correctly. As with all consumer safety programs, it is believed that market pressure will encourage child restraint manufacturers to provide child restraints on the market that perform well beyond the mandatory requirements of AS/NZ 1754. The assessments cover both dynamic performance or crash protection in sled tests – the test that simulates crash conditions – and ease-of-use evaluations. Since its introduction in 1992, CREP has undergone a number of revisions and refinements to ensure the program continues to meet its aim.

In addition to providing consumers with important information and encouraging manufacturers to continually improve their products, the evolution of CREP and its assessment methods over the last 20 years has also driven improvement in the minimum performance required by the Australian mandatory product standard (implemented through sequential revisions of AS/NZS 1754). By operating relatively consistently over the last 20 years, CREP has also inherently monitored the evolution of the design and performance of child restraints available on the Australian market. Together, CREP and AS/NZS 1754 have worked to influence some dramatic improvements in theperformance of child restraints now available in Australia. This is most evident in the head protection provided in side impact in forward facing restraints and high back boosters – and the performance of high back boosters in frontal impact.

The program also continues to highlight emerging areas of concern. Currently this includes the head protection provided by rearward facing restraints in side impact, the inability of rearward facing restraints to adequately distribute crash forces in frontal impact, and the tendency for poor head containment in forward facing restraints during rebound in frontal testing. Although it is clear that there are substantial variations in performance of restraints currently on the market in these areas, the impact of this on the real-world crash protection of children remains unclear – as there is no routine surveillance of injury outcomes among children involved in crashes in Australia.

4.5 Best practice guidelines for the safe restraint of children travelling in motor vehicles

Information about best practice in restraining children is provided by several organisations across Australia – including state government transport and roads departments, health departments, motoring clubs and child injury prevention not-for-profit organisations such as Kidsafe. To address the need for providing consistent advice – and to reduce key points of confusion, contention and often contradiction for safely restraining children in cars – Neuroscience Research Australia (NeuRA) and Kidsafe joined forces in 2011-13 to develop national best practice guidelines – the *Best Practice Guidelines for the Safe Restraint of Children Travelling in Motor Vehicles* [32].

The purpose of the guidelines was to provide evidence-based and nationally consistent recommendations and model advice on how best to safely restrain children up to 12 years of age. The guidelines were drafted by a technical working group based on a systematic review of the literature. Where good evidence was available, this was used to establish recommendations and – if there were no or very few robust studies – the technical group identified consensus based recommendations. The rigorous method used to develop the guidelines aligned with the processes used by the NHMRC in establishing other health related and prevention guidelines. The guidelines were approved by the NHMRC in 2013.

The guidelines address questions about what type of restraints should be used when, how to use them correctly, and where children should sit in the car. They also provide model advice on how to deal with specific situations that might make meeting best practice recommendations and/or legislation problematic.

Specific recommendations for restraint use are summarised into the following 10 essential steps:

1. The use of any restraint is preferable to not using a restraint. It is the law that each person in a motor vehicle has their own restraint.
2. Infants are safest if they remain in their rear facing restraint as long as they still fit in it. While the law allows children over 6 months to use either a rear facing restraint or a forward facing restraint, the rear facing restraint offers better protection as long as the child fits in it.
3. Once a child is too tall for their rear facing child restraint, they should use a forward-facing child restraint (with built-in 6-point harness) until they are too tall for it. While the law allows children 4 years and older to use either a forward-facing child restraint or a booster seat, the forward-facing child restraint offers better protection as long as the child fits in it.

4. Once a child is too tall for a forward facing child restraint, they should use a booster seat with a lap sash seatbelt until they are tall enough to fit properly into an adult seatbelt. While the law allows children 7 years and older to use either a booster seat or a seatbelt by itself, a booster seat offers better protection as long as the child fits in it.
5. For a child in a booster seat or an adult seatbelt, using a seating position with a lap-sash belt (lap and shoulder) is safer than one with a lap-only belt.
6. All child restraints and booster seats must be installed correctly and the child strapped in correctly according to the manufacturer's instructions:
    a. Always use a top tether strap for all rearward facing child restraints, forward facing child restraints and booster seats that have them.
    b. Always thread the seatbelt through the correct path – follow colour coding available for newer restraints.
    c. Ensure there is no slack or looseness in any part of the system. Check the harness straps around the child, the top tether, the seatbelt anchoring the restraint to the vehicle, and the seatbelt used by a child in a booster seat.
    d. Check that the seatbelt is buckled before each trip.
7. Children 12 years of age and under are safest in the rear seat.
8. Seatbelts should never be used with the sash belt under the child's arm or behind the child's back, whether they are being used alone or with a booster seat.
9. When planning any journey with children, use a motor vehicle which allows each child to be in the appropriate restraint for their size.
10. Regularly check that child restraints are correctly installed and that the restraint is adjusted properly for the child's size according to the restraint user manual. Using a restraint fitting service will help ensure that everything is used correctly and that your child is as safe as possible.

The guidelines were released in 2013 and will be updated in 2019.

4.6 Child restraint legislation in other OECD countries

The following provides a brief summary of minimum use requirements for child restraints in the USA, Canada, Sweden and the European Union generally.

In the USA, the majority of states legally require child restraint use up until the age of 7 or below 4'9" or 57" tall or weighing less than 80lbs. Some states require child restraint use up until the age of 8 years or less than 4"9' while a few states only require child restraint use until 6 years, some 5 years or 60 lbs, and at least one (South Dakota) only requires child restraint use until the age of 4 or less than 40 lbs.

For the transition from rearward to forward facing, legislation requirements are also state dependent. Some examples of states with specific legislation about this transition include:

- Oregon – younger than 2 years must be in rear-facing.
- California and Illinois – younger than 2 years, less than 40 lbs, less than 40'' must be in rear-facing.

- North and South Carolina/Oklahoma/Nebraska/Virginia/Pennsylvania – younger than 2 years, or outgrown manufacturers height/weight must be in rear-facing.
- New Mexico – less than 1 year in rear-facing.
- Wisconsin/Tennessee/Alabama/Vermont – 1 year or less than 20 lbs in rear-facing.
- New Jersey – younger than 2 years and less than 30 lbs in rear-facing [46].

The American Academy of Pediatrics had previously recommended best practice as keeping children rearward facing until at least 2 years of age. However, updated recommendations published online in August 2018 [22] recommends children 'remain in a rear-facing car safety seat as long as possible, until they reach the highest weight or height allowed by their seat'. The primary reason for this change appears to be a retraction of a scientific paper used to underpin the previous recommendation [47], and a new analysis of North American data [48] that could not find a significant difference between rear and forward facing restraint use by children beyond 12 months to support a specific age-based recommendation.

Canadian regulations related to how children must travel in cars also vary by province. The regulations differ both in terms of requirements and how requirements are stipulated. For example, some provinces stipulate mandatory use of restraints by age and others by weights. One or two also use height-based recommendations.

Table 8 provides a summary of the regulations across Canadian states, sourced from the Child Passenger Association of Canada (https://www.cpsac.org).

Table 8: A summary of regulatory requirements for child passengers in Canada

Province/Territory	Rear and Forward-Facing Requirements	Booster Seat Requirements/ Other Notes
Alberta	Child is under 6 years old – must be properly restrained	No booster law Must wear seat belt properly
British Columbia	May forward face at one year and 20lbs	Obligation is on the driver Booster until at least 4'9" or nine years old Must use lap/shoulder belt if one available
Manitoba	Follow manufacturer's directions	Booster until 4'9" or 80lbs or 9 years old
New Brunswick	Use a car seat until 5 years old or 40lbs	Booster until 4'9" or 80lbs or 9 years old
Newfoundland & Labrador	Use a car seat until 5 years old or 40lbs	Obligation is on the driver Booster until 9 years old and 4'9" and 81lbs
Northwest Territories	May forward face at 20lbs Under 40lbs must be in a car seat	No booster law
Nova Scotia	May forward face at one year and 22lbs Under 40lbs must be in a car seat	Booster until 4'9" or 9 years old
Nunavut	May forward face at 20lbs Under 40lbs must be in a car seat	No booster law

Ontario	May forward face at 20lbs Under 40lbs must be in a car seat	Obligation on the driver Booster until 4'9" or 80lbs or 8 years old
Prince Edward Island	May forward face at one year and 22lbs Under 40lbs must be in a car seat	Booster until 4'9" or 10 years old or exceeds manufacturer's weight limit
Québec	Must ride in a car seat or booster seat until the seated height (bum to top of head) is at least 25"	Must ride in booster seat or car seat until the seated height (bum to top of head) is at least 25" Seat belt must be worn properly
Saskatchewan	Must ride in a car seat until at least 40lbs	Must ride in a booster until age 7, or until 80lbs and 4'9"
Yukon	'Child' is under 6 years old Child must be in a harnessed seat	May not use a booster until 48lbs

In Sweden, the law states that children less than 135cm must use a UNECE Regulation 44 or R129 approved child restraint. There appears to be no specific age-appropriate use laws. However, in 2017, Sweden released a document outlining recommendations about protecting children in cars. They recommended that children be seated rear-facing at least until the age of four. From the age of four to twelve, children should use booster seats, booster cushions or integrated child seats (https://www.folksam.se).

Across the European Union, the European Directive 2003/20/EC effective since 2006 prohibits children under three from travelling in any vehicle that is not equipped with a child restraining system suitable for their age and weight. The child restraint must be approved by the Product Standard R44-04 or R-129. This Standard, R129, bases fit on stature classification rather than mass and does not permit forward-facing transport before 15 months. However, R44 allows forward-facing heavier than 9kg and follows a mass based classification. Every country within the EU can permit, within its territory, children under 150 cm but at least 135 cm in height to use adult seatbelts. (https://babyseat.fundacionmapfre.org/children/regulations/european-union-legislation/)

5. Review of the literature

Correctly restraining children when they travel in cars is accepted as the most effective way to reduce the risk of injury in a crash [3, 49]. While using any type of restraint provides more protection than being unrestrained, optimal levels of crash protection require correct use of the most appropriate type of restraint for a child's size [3, 50, 51]. The following section summarises the literature about restraint effectiveness and the need for optimal restraint use.

Restraint factors have an important influence on a car passenger's outcome in a crash, but there are also a number of others factors that are likely to have a significant influence. The following section also summarises the literature about other crash, vehicle and restraint factors important to child passenger outcomes in crashes.

Finally, the knowledge base has expanded significantly over the last few decades about barriers and facilitators to optimal restraint of children in cars, and preventing deaths and injury among child passengers. We also review the evidence on the determinants of restraint use, as well evidence of successful measures for increasing restraint use and optimal restraint use among child passengers.

5.1 Factors affecting crash protection provided to child passengers

5.1.1 Restraint use

Over the last three decades, there have been numerous studies consistently reporting the effectiveness of restraint systems in reducing risk of death and injury among children in crashes compared to unrestrained children [51-60]. However, the highest levels of crash protection are provided when children are optimally restrained [3, 5, 50]. To be optimally restrained, a child must use a restraint designed for their size (appropriate restraint use*)* and there must not be any errors in the way the restraint is installed or used (correct use*).* The risk of death and injury to child passengers is reduced by more than half with optimal child restraint use [3, 50, 61].

In Australia and other developed countries, restraint use has been steadily increasing [6]. However, both inappropriate and incorrect use were also observed to be widespread [6]. Significant (23%) increases in appropriate use were observed in children aged 2-5 years in low socio-economic areas of Sydney immediately after the introduction of the new legislation in 2010 requiring mandatory appropriate use up to age seven [6]. Small increases in correct use (11%) were also observed in this select population. However, as there have been no population-wide estimates made for restraint use among children across NSW since 2008, the current rates of restraint use, appropriate use and correct restraint use across NSW remain unclear.

Using population-level observation data about how children were travelling in cars in NSW in 2008, and observed reductions in death and serious injury among retrospective cohorts of children involved in crashes in the United States, Du et al [50] estimated that casualties and fatalities among Australian children could be reduced by up to 13% and 34% respectively by moving more children into appropriate restraints. They also estimated that further reductions could be made if the correct use of appropriate restraints increased [50]. Based on those estimations – for every 15% increase in

correct use – we can expect a 10% reduction in serious injury and death among children involved in car crashes. To date, there have been no formal examinations of the trend in death and serious and injury since the introduction of the new legislation in NSW or elsewhere in Australia.

5.1.2 Vehicle age and in-vehicle technology

There have been number of studies consistently reporting an increase in risk of injury in a crash with increasing vehicle age [26, 27, 62-66]. Several authors have noted some potentially unmeasured confounders in a number of studies – such as fewer kilometres driven in older vehicles and potential increases in positive driver behaviour over time – but most of the reduced risk of injury seen in newer model vehicles is attributed to improvements in vehicle design and technology. There is no doubt that newer vehicles provide many new and enhanced technologies that can have an impact on overall crash severity as well as occupant outcome [27, 67, 68].

It is important to note, however, that no studies examining the effect of vehicle age on passenger outcomes have specifically examined the influence on child passenger outcomes. The influence of age of vehicle may be less for rear-seated children as suggested by Bilston et al [69] – as up until recently much less attention has been given to implementing in-vehicle safety systems for rear seated passengers.

5.1.3 Crash severity

Crash severity, unsurprisingly, has a major influence on injury outcome for both adults and children. There are two main crash features responsible for crash severity. The first is the change in velocity felt by the occupants of the vehicle and this is governed by the pre-crash velocity and physical characteristics of the vehicles involved – that is mass, energy management and stiffness. The influence of change in velocity on overall injury severity [70-72] and in the occurrence of specific types of injuries [73, 74] has been studied broadly for adult occupants. However, a small number of studies have found similar increases in risk of injury with increasing change in velocity for child occupants [75, 76].

The second main determinant of crash severity is intrusion into the occupant compartment space. Although the impact speed will have some influence on the amount of vehicle deformation and therefore intrusion that occurs into the occupant compartment, this is also influenced by vehicle design and the mass, shape and stiffness of the opposing vehicle or object. Associations between increasing likelihood of injury with increasing passenger compartment intrusion have been reported among adult passengers [77, 78] and child passengers [75, 79].

Crashes where intrusion is so severe that there is effectively no room left in the passenger's seating position within the vehicle are sometimes referred to as non-survivable crashes for that passenger [25]. Both the location and direction of intrusion play a role in the injury mechanism for passengers.

5.1.4 Impact direction

In almost all studies of children in crashes, frontal impacts are most common [54, 60, 80]. However, as noted by Weber [81], there may be more children killed in frontal crashes – but side impacts are nearly twice as likely to result in a fatality and carry an increased risk of head injury [82, 83] [84]. An increased risk of serious injury in children in side impact compared to other impact directions has also been reported from other studies [82, 83, 85]. Arbogast et al [85] reported that the head, abdomen and extremities were more susceptible to injury in side impact. Orzechowski et al [83] went further to

describe a 'side impact syndrome' among child occupants that involves an increased frequency of head, cervical spine and chest injuries. There has been less analysis of injury risk and pattern of injury in other crash types. The exception to this is an analysis of children in rollover crashes reported by Rivera, Cummings and Mock [86]. These authors found that children in rollover crashes were 80% more likely to die and twice as likely to sustain a serious injury as children in non-rollover crashes.

Seating position is frequently considered in studies of injury outcome in side impact. Both adult and child occupants seated on the near side in a side impact have been reported to be at a greater risk of injury [82, 85, 87, 88]). This is likely to be due to the close proximity to the side structure of the vehicle and any intruding components. Adult occupants seated away from the side of impact also sustain serious injury regardless of restraint status, albeit to a lesser degree [89, 90]. The risk of injury to far side child occupants is less clear. Howard et al. [82] reported far sided children to be at risk of serious injury only when unrestrained. Others have noted a reduced risk of serious injury in far sided children compared to near side seated children [85, 91].

5.1.5 Seating position

Across all impact types, studies comparing injury outcomes among child occupants by seating position consistently report a significant protective effect for rear seated children [51, 92, 93]. However, this may depend on restraint use [94].

Multiple studies have highlighted a relationship between seating position and the type of restraint used. Children seated in the rear are often reported to be more likely to use child restraints than front seated children [95-97]. However, some countries have also observed less restraint use in the front seat [98] [94].

Data from children in crashes – and observational surveys generally – indicate that most children use rear seating positions [51, 60, 92, 93, 97, 99-101]. However, there appears to be differences in the proportions of children using front and rear seats between studies. In Australia, NSW based observational surveys [101] indicate high levels of rear seat use by children. However, a recent observational study from Queensland reported approximately 60% of children less than 12 years were using front seats [43]. Inter-city and inter-country comparisons of seating position between cities in America and Europe also demonstrate large differences in practices from location to location [102]. To date, there have been no studies examining the impact of legislation requiring the use of rear seats by children of certain ages on the actual seating positions occupied by children.

Historically, the protective effect of the rear seat position was not limited to children [103, 104]. However, as demonstrated by Bilston et al. [69], in most vehicles this protective effect may currently now only exist for children due to disparities in the implementation of new safety technologies in the front and rear seats of modern vehicles.

5.2 Risk factors for optimal restraint practices

As the use of a restraint is acknowledged as one of the most effective ways to reduce risk of injury in a crash, understanding barriers to restraint use is important. The combination of both appropriate and correct use of child restraints is central to optimal restraint of children, so it is also important to identify the risk factors for death and injury when travelling in cars on our roads.

As there have been reported to be high rates of restraint use among Australian children for many years, there have been few recent studies examining barriers to restraint use. Literature related to the determinants of seat belt use in cars, less recent Australian child restraint literature and literature from other countries has therefore been reviewed. However, many relatively recent studies both in Australia and other developed countries have investigated the barriers to both appropriate and correct restraint use by children. These factors include parental risk perception, awareness and education, child restraint design, parenting style, socio-economic status, child preferences and comfort [97, 105-110].

5.2.1 Barriers to use of restraints

There is consistent evidence in the literature that people from lower socio-economic groups, measured by education and/or income, are less likely to wear seat belts in cars [111-114]. Similarly, there is a relatively large body of evidence from Australia and elsewhere that historically parents of higher socio-economic status are more likely to use restraints for their children [115]. There are also consistent reports that parental use of seat belts is a significant predictor of restraint use by children [36, 116-119].

Several studies have also reported variations in the likelihood of children being restrained by cultural background, with minority groups often reported to be less likely to use seat belts [111, 112] and to demonstrate lower rates of child restraint use [116, 119-121].

Numerous studies have also reported regional variations in restraint use, with lower rates of seat belt use in rural areas [122, 123]. From observational studies [124] and studies of children involved in crashes [125] this also appears likely to be the case for child passengers.

There have also been a small number of studies examining associations between parental psychosocial factors and non-use of restraints among children. Witt et al [119] reported maternal distress (measured using a validated tool for assessing psychological distress) to be associated with non-use of restraints for children. Other studies have indicated specific parental attitudes and perceptions as being associated with non-use of restraints for children. These include fatalistic attitudes to control over what happens to children [115] and perceptions of restraint effectiveness and comfort.

5.2.2 Barriers to appropriate use

Associations between family demographic factors and appropriate restraint use among children have also been reported – and these patterns generally reflect the same associations seen with non-use of restraints [126]. Groups with a low socio-economic position are less likely to use an age-appropriate child restraint [126]. In North America, minority populations have lower appropriate restraint use than the rest of the population. This gap widens as children grow older [116, 124, 127].

In Australia, lower parental education level, non-English speaking background and large family size have been reported as specific risk factors for the inappropriate restraint of children aged 0 – 12 [128]. Other studies have also identified the cost of restraints and lower economic status as a barrier to appropriate restraint use [97]. Increasing child age has also been reported as a risk factor for inappropriate use [6, 97, 126].

Parental perceptions of size and comfort have been found to be responsible for premature restraint graduation in Australian children. Sixty-nine percent of surveyed parents in one study reported the child's size as a primary factor in deciding to move their child from a booster to a seat belt [106].

Parents who perceive their child to be uncomfortable in a booster seat are also more likely to have graduated their child to a seat belt [21, 97, 108].

A parent's knowledge of the best practice surrounding child restraint graduation has also been reported to be pivotal in appropriate restraint choice for a child. Parents are more likely to make sound restraint choices for their children if they possess restraint knowledge specific to their child's age and size. Age-specific parental knowledge of restraint transitions influences the appropriateness of child occupant restraint use. [128, 129].

5.2.3 Determinants of correct use

Barriers to correct restraint use have been shown to be similar to those associated with appropriate restraint choice. Education level, race (in North America) and non-English speaking background (in Australia) have been associated with the presence of restraint use errors [97, 130-132] [133, 134]. However, unlike the findings related to non-restraint use and choice of appropriate restraint choice, there is less consistent reporting of any association between low income and errors in use.

A person's knowledge of how to install and use a restraint, as well as false confidence about correct installation, has been identified as a significant predictor of child restraint misuse [133, 135, 136]. More recently, there is evidence of an increased likelihood of correct use with increased comprehension of instruction materials (Hall et al, unpublished data).

Less research has been done on factors contributing to restraint misuse in relation to child factors. However, older children have been found to be less likely to misuse their restraints [132, 133, 137, 138]. This is possibly due to the reduced complexity of booster seats compared to rearward and forward facing child restraints. Qualitative and quantitative results suggest the potential importance of comfort as a factor in correct use of restraints by children [106, 108, 139, 140] – and comfort appears likely to be influenced by aspects of restraint design [141].

There has been work indicating that some child restraint types [20, 142] and some design features may have a lower propensity for misuse than others [141] [143-145]. This has been found in errors introduced by both an adult installer and child user. It includes design features related to installation of a restraint, securing a child within a restraint, and the child's use of a restraint as influenced by comfort.

5.3 Measures to increase optimal use of restraints

5.3.1 Legislation and enforcement

Child restraint legislation was one of the key road safety outcomes in the Global Decade of Action for Road Safety. Mandatory child restraint legislation covers just 32% of the world's population [146].

Legislation for safe child passenger restraint use leads to increases in restraint of children travelling in motor vehicles [147, 148]. The level of enforcement of child restraint laws also has an impact on their effectiveness [147]. Legislation is also more effective when combined with educational activities [147, 149]. A Sydney-based study, conducted in a low socio-economic region immediately after the introduction of appropriate use legislation, found that – after implementation of the new law – children aged 2-5 years were 2.3 times more likely to be appropriately restrained than pre-legislation. Also, after mandatory child restraint laws, the odds of being correctly restrained were 1.6 times greater [150].

Historically, it has been observed that after the initial mandatory restraint laws for children travelling in cars were introduced in NSW, there was also an initial increase in restraint use – but this dropped with time. A continued increase in restraint use rates appeared to be achieved after sustained additional public awareness and education campaigns [151].

In summary, legislation is most effective in combination with multicomponent interventions including educational activities, awareness campaigns and enforcement [147, 152].

5.3.2 Community-based interventions

Community-based promotional campaigns delivered through settings such as schools, child care centres and retail outlets have been found to generally be effective in increasing booster seat use in the short term [153, 154] – although it has generally been found that their effectiveness erodes over time [154].

The elements of community-based approaches identified as being associated with effective outcomes are:

- a sustainable strategy delivered over the longer term which provides for the development of a range of local networks and programs
- the inclusion of effective focused leadership
- engaging a number of different agencies and stakeholders and involving the local community
- appropriate targeting [155].

Community-based strategies have been evaluated for their effectiveness in increasing the rate of booster seat use among 4-7 year olds [156]. A trial in the United States investigated the impact of combining education about the importance of booster seats for 4-7 year olds with instructional T-ball sessions in 20 communities across four states. A mix of educational approaches was used to promote the use of booster seats – including a training session, a demonstration and a baseball-themed brochure. Three-month follow-up using observational methods showed that booster seat use had increased by 56% in the intervention communities compared to the control group [156].

5.3.3 Providing incentives or product subsidies

Community-based interventions combining education with distributing child restraints, loaner programs or incentives have been found to lead to increased use [157] [153]. Two studies in NSW evaluating the community-based 'Buckle-Up Program' have provided promise for this strategy to increase correct use – particularly among people from CALD backgrounds and with Aboriginal communities [158, 159]. The 'Buckle-Up Program' examined in these studies consisted of educational resources including a DVD, training via a hands-on demonstration of correct use, and subsidised restraints and access to a restraint fitting station (RFS) – as well as professional development for educators. In one study, the intervention group was 70% more likely to have improved age-appropriate and correct use of child restraint systems as observed on arrival at the centre. When examining post-program rates of correct use, non-English speaking families in the intervention centres were compared to control centres after the intervention – 43% correct use vs. 17% ($p<0.02$) [159].

Hands-on demonstrations of correct installation and use by child passenger safety technicians in combination with education and a free car restraint have been evaluated – and appear to be more effective than education and a free restraint alone [160]. However, there was no evidence to suggest that this behaviour would be sustained long term – in this case, more than two months after birth.

There is evidence that campaigns that rely more on local resources may be better received in rural communities [156]. Efforts that incorporate Aboriginal views of health and Aboriginal culture, that take a tailored approach involving the community and use multiple strategies have been shown to be effective [158, 161]. Multi-component interventions tailored to culturally diverse communities – including providing translated materials – have also been found to significantly improve child passenger safety [159].

5.3.4 Targeting booster seats

A systematic review of the literature [162] examined strategies to promote the use of booster seats among 4-8 year olds. Findings from five controlled trials indicated that educational interventions, with and without incentives, had a positive effect on increasing booster seat use. Most beneficial appeared to be those interventions that combined educational approaches with the distribution of free booster seats – resulting in more than doubling of use. Educational strategies combined with incentives (such as discounts and coupons for certain products) were found to increase restraint use by around 30%. Educational strategies alone (including social marketing mass media, information and publicity, and public demonstration of correct use) were found to be associated with similar gains. One study included in the review – which examined increased legal enforcement of a booster seat law compared to no intervention – did not show a significant increase in booster seat use [162].

5.3.5 Targeting parents of infants

There is some evidence from studies conducted in China that educational interventions by hospital staff –combined with a free child restraint for parents of newborn babies before they leave hospital – can be effective in promoting restraint use. After a controlled trial conducted with parents of infants born in hospital, Chen et al [163] and Liu et al [164] reported that – three months after the intervention in hospital before the infant was discharged – the group that received educational information plus a free child restraint showed the greatest increase in knowledge and use of child restraints. The group with just information (a brochure) demonstrated increased knowledge but not increased use compared to the control group. Authors noted that participants started with quite a low level of knowledge about the use of child restraints to protect children in a crash. It is noteworthy that, except in a few localities, China does not have legislation requiring infants to be transported home from hospital in an approved child restraint.

5.4 Measures specifically aimed at increasing the correct use of restraints

5.4.1 Legislation since 2010

Legislation introduced in NSW and other Australian states in 2010 included requirements for appropriate restraints to be used correctly. The study by Brown et al [6] demonstrated some increase in correct use in a select population immediately after the implementation of that legislation in NSW. Other studies based on observations of children attending restraint fitting checking days have reported little improvement [165]. However, laws related to correct use of restraints are much more difficult to enforce than enforcing the use of restraints and the use of age appropriate restraints – as it requires a trained eye to identify errors. The modest increase in correct use observed in the Brown study was most likely attributable to public education campaigns accompanying the implementation of the legislation that raised the importance of correct use [6].

5.4.2 Education and information

There is limited evidence on the effectiveness of education to increase correct restraint use. This may be due in part to a lack of good quality studies evaluating the effectiveness of education-based measures, and the heterogeneity among education measures used in the past. One study assessed a mobile application designed to deliver targeted child restraint information to parents and carers and reported an increase in appropriate and correct child restraint use [166]. Two other studies have used information/education via video to increase knowledge of correct child restraint use, with varying results [167, 168] reported a very small mean difference in safety knowledge between intervention and control one month post intervention using a self-report questionnaire. Shenoi et al [167] used a simulated child safety seat recognition task, and reported that education was effective at increasing immediate correct child restraint knowledge in intervention compared to control for novice parents.

5.4.3 Product information

Instructions on how to use restraints correctly are supplied with child restraints systems in the form of instruction booklets, labels fixed to the restraints, and increasingly through on-line videos provided by child restraint manufacturers. The content, and sometimes the format of these materials, is regulated by different products standards in different jurisdictions. Work has been done in a number of countries examining the potential to increase correct use through the better design of these materials. Three studies from North America have targeted the re-design of product information, but with limited efficacy [135, 169, 170]. More recently, Australian work has taken a health literacy approach to the re-design of these materials with preliminary results demonstrating this approach may be promising (Hall et al, unpublished data). Prototypes designed using this approach are currently being evaluated in a large randomised controlled trial in NSW [171]. However, most studies examining the scope for reduction in errors through improved design of product information and instructions have noted the importance of also addressing the design features of the restraint systems.

5.4.4 Child restraint and anchorage design

Observational studies assessing child restraint misuse have reported that certain design factors were more likely to accompany misuse, both in controlled laboratory trials and in real-world observations [20, 169, 172, 173]. Although this work demonstrates a varying propensity for errors in the use of different types of restraints – eg in forward facing seats and convertible restraints versus other restraint types – to date there is a lack of evidence about which restraint features are related to different errors, and what aspects of design might be modifiable risk factors for errors in use.

Most countermeasure development work has focused on errors associated with installing restraints and has involved three key design concepts – universal anchorage systems such as ISOFIX, integrated booster seats, and add-on mechanisms to improve installation.

Early studies on a universal anchorage system aimed to identify a simple method for linking add-on restraints directly to vehicle ISOFIX anchorage to by-pass the need to route seat belts through restraint systems. However, the development of these systems took different pathways in Europe and in North America. In Europe, ISOFIX systems have rigid lower anchorages between the restraint and the vehicle and a third anchorage point that is either a top tether or a support leg. In North America, ISOFIX compatible systems use non-rigid webbing as the two lower anchorages and a top tether. The North American system is known as LATCH. Both types of ISOFIX system are available in

Australia, but currently the majority of ISOFIX compatible systems available in Australian use the LATCH approach – with rigid systems being limited to only two models of restraint. To date, there has been no Australian study examining the effectiveness of these systems in reducing errors in an Australian context.

However, since the earlier roll out of ISOFIX/LATCH in Europe and North America, there have been a number of studies. In the United States, the use of LATCH has been examined in crash samples [172] and in observation studies [174, 175]. Consistent errors in the use of LATCH have been reported. Decina and Loco [174] reported that 30% of LATCH-installed restraints were loose and 20% were installed using both LATCH and the seat belt. A further 21% of rearward-facing restraints were installed at an incorrect angle. More recently, 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 [174, 175]. This study demonstrated a lower propensity for errors in ISOFIX anchorage designs that minimise the force required to be used when attaching the system, had increased clearance angles, and reduced the depth of lower anchors with the seat belt. The Insurance Institute for Highway Safety (IIHS) in the US has subsequently released a consumer information program that rates vehicles on the usability of their anchorages. After the introduction of this program in 2015, the IIHS has reported substantial increases in the proportion of new vehicles supplying LATCH anchorages with the lowest propensity for errors [46]. Despite the higher take-up of LATCH-like ISOFIX compatible systems in Australia, no similar monitoring of the ISOFIX anchorages supplied in Australian vehicles is currently in place.

In Europe, recent observational studies have demonstrated reductions in installation errors using rigid ISOFIX systems compared to standard belt anchorage systems in both France and Belgium [176].

Integrated booster seats are part of the vehicle car seat and they remove the need for the traditional installation of add-on booster seats. Installation simply requires deploying the integrated system. Although there have only been limited attempts to examine the effectiveness of these systems in minimising errors in use, it has been reported that users find them easier to use than add-on restraints [140, 141] – and that integrated boosters are more likely to be used correctly [141]. However the impact of these restraint types on other types of error are less clear, with one study identifying an increase in errors induced by the child during travel in integrated systems compared to add-on boosters [141].

5.4.5 Child restraint fitting stations

Use of a child restraint fitting station (RFS) in Australia – and child safety seat technicians/checkpoints in the United States and Canada – have been reported to be associated with reductions in installation and use errors in the laboratory [177] and in the field [134, 178, 179].

The Australian RFSs are operated by commercial businesses. They are designed to help caregivers install and use child restraints correctly and also promote correct use by providing education and demonstrations. In Australia, RFSs have been available to users since the 1980s [178]. However, a 2010 study in NSW found that more than 70% of observed child restraint users had never used an RFS [178]. Data collected through an online survey conducted across Australia in 2014 demonstrated this rate of use appears to not have changed over time, with 31% of the 470 parents of children of child restraint age reporting they had used this service (Bilston et al 2018). Similarly, in the US, low rates of use of these services have been reported [134].

Recently, Bilston et al (2018) examined the demographics of those reporting the use of these services compared to non-users. They found fitting stations were more commonly used by more educated participants in this sample, and there was considerable scope to increase use of RFSs – particularly among families in lower socio-economic areas. One barrier to the use of fitting station services, particularly in regional areas, is access. Recent work [180] in North America has been examining the potential of an 'interactive virtual presence' to overcome this barrier. They examined the efficacy of providing direct access to a remotely located child passenger technician via a smart phone app to users when installing their child restraints [180]. The reported effectiveness of hands-on instruction in achieving correct use – as well as reductions in errors observed after using similar services [134, 177-179] – seems like a potentially effective approach to increase access to fitting services in a cost effective way.

6. Conclusions and recommendations

The aim of this work was to examine the role or possible role of child restraints and seatbelts in the deaths of children 12 years of age and under in car and truck crashes in NSW. The review found that non-use of restraints and the misuse of restraints to be relatively common factors in a number of the deaths of child passengers in NSW between 2007 and 2016. Over the entire period, inappropriate restraint use was less common than non-use or misuse. However, the proportion of children who died while using an age inappropriate restraint decreased in the post 2010 period when new child restraint laws were enacted in NSW, while the number children using incorrectly fitted restraints increased, as did the number of unrestrained children. Misuse of restraints was particularly common among children using dedicated child restraint systems and therefore mainly involved children under seven years old, but misuse of seat belts in older children was also identified.

The legislation introduced in 2010 requiring appropriate restraint use up to age seven is a minimum requirement, and best practice advice is that children continue to use booster seats until they achieve an adequate fit from the seat belt. No individual assessment of the adequacy of the seat belt for each of the children who died was possible due to the need to compare individual child anthropometry with vehicle interior geometry – and the retrospective nature of the review. However, it is likely that at least some of these children may have been better protected had they used a booster to assist with good seat belt fit. Inadequate restraint by lap only belts was able to be identified in a number of cases.

This review has also identified substantial socio-economic disparities in the children who died as motor vehicle passengers in NSW between 2007 and 2016. The mortality rate for children from areas of most disadvantage was 5 times that of children from the area of least disadvantage. More than 15% of the children were identified as Aboriginal or Torres Strait Islander compared to 3% of the overall NSW population. Two thirds of the children in the sample lived outside major cities and 80% of the crashes occurred outside major cities – highlighting the distinct rurality of the problem.

Based on the findings of this review, it is recommended that:

1. Regular monitoring of child restraint practices across NSW should be introduced, particularly in areas of socio-economic disadvantage and outside major cities.

   There has been no population estimate of restraint use among NSW children since 2008, yet significant legislative reform has been introduced since that time. There is a need to understand if the practices observed among fatally injured children reflect population trends or are a marker of other risk factors associated with involvement in high severity and fatal crashes.

2. Measures to increase restraint use should be developed and implemented.
3. Programs and policies ensuring the high quality and performance of child restraints sold in Australia should continue.
4. Greater attention should be given to identifying and implementing measures to reduce misuse through restraint design and product standard requirements – and to removing barriers to vulnerable population groups accessing restraint fitting programs and services. Access to programs like the NSW Restraint Fitting Stations Network, and Restraint Fitting Checks should be expanded in areas of most need.

It is also imperative that families at highest risk of serious crash involvement and misuse of restraint be identified.

5. Current legislative controls over minimum restraint use should be maintained, alongside wider dissemination of information on best practice for restraining children – particularly children over the age of seven. Dissemination strategies must ensure these messages reach and are understood by those sectors of the community most in need.
6. Road safety initiatives should account for the higher involvement of people from the lowest areas of socio-economic disadvantage in transport-related deaths.

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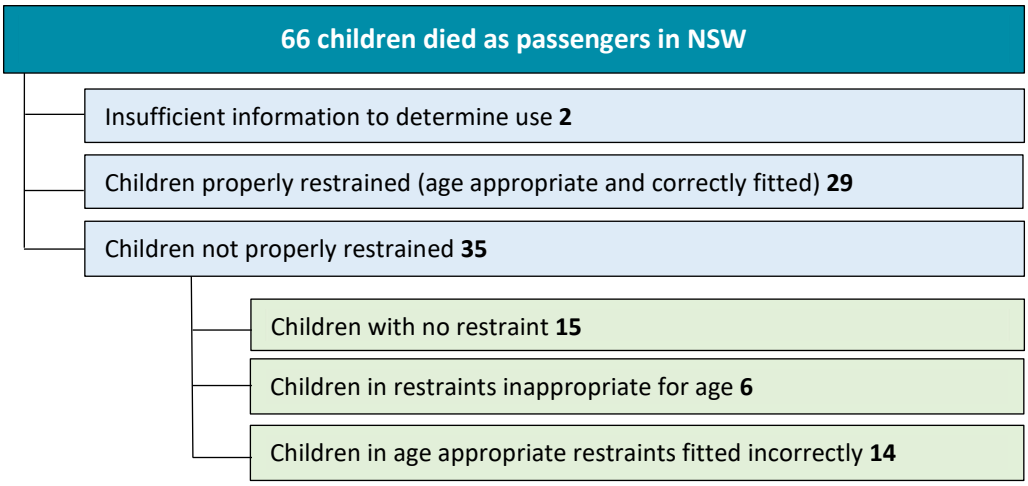
APPENDIX 1 – Variables included in the NSW CDRT child passenger death dataset

Child variables	Driver, crash and vehicle variables
Age at death	Driver age
Date of crash	Driver gender
Date of death	Relationship
Crash postcode	Restrained
Crash time	Outcome
Day of week	Alcohol
Rural crash (y/n)	Drugs
Gender	Fatigue
Indigenous	Inattention
CALD (y/n)	Driver licence status
Language spoken at home (y/n)	Vehicle make
Family contact with FACS last 3 years (y/n)	Model
Home postcode	Year
Height	Colour
Weight	Safety systems
Cause of death	Roadworthiness
Injury description	Description
Ejection (y/n)	Pre-crash
Died at scene (y/n)	Impact location
Restrained (y/n)	Crash type
Restraint type	Airbag fitted in case occupant position
Incorrectly fitted (y/n)	Air bag fired
Incorrect fitted description	
Level of evidence	**Other occupant variables**
Age appropriate restraint (y/n)	Age
Age appropriate restraint description	Gender
Intrusion	Seating position
Source of fatal injury	Restraint
	Outcome
Opposing vehicle and driver variables	
Opposing vehicle/object	**Crash variables**
Opposing vehicle make	Crash narrative
Model	Road type
Year	Location
Colour	Road and lighting conditions
Roadworthiness issue	Posted speed limit
Driver age	Pre-impact speed
Gender	Police listed at fault
Restrained	Post-crash fire
Outcome	Post-crash description
Alcohol	
Drugs	
Fatigue	
Inattention	
Pre-crash manoeuvre	

APPENDIX 2 – Use of restraints in child passenger deaths in NSW, 2007-16

Restraint use



Possible preventability of deaths