Child Restraint Systems and the transition to standard seatbelts: a review of the literature

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Title

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Abstract
Following a recent decision by the European Union to increase the child car restraint transition height from 135cm to 150cm, the Western Australia Child Car Restraint Reference Group requested that a literature review into the research base underpinning this was undertaken. The intent of the literature review was to establish the appropriate transition point for graduation from child restraint systems to standard seatbelts. Literature was sourced from government and academic databases, Google Scholar and online research repositories. Overall, the review demonstrated that there is relatively little evidence regarding the appropriate transition point to a standard seatbelt, but that this evidence, as well as ergonomic principles, suggests that booster seats should be used in children up the minimum height of 148cm. Recommendations from the review include using height, rather than age, to guide the transition to a standard seatbelt, promotion of the five step seatbelt fit test, and collection of data about the type of restraints used by children involved in crashes for use in future research.

Keywords
Child restraint system, Child car restraint, Child car seat, Road safety, Child injury

TABLE OF CONTENTS

TABLE OF FIGURES

EXECUTIVE SUMMARY

Introduction

Children are required to be restrained in suitable child restraint system up to the age of seven years old when travelling in a motor vehicle in Western Australia (State Law Publisher 2000). The Australian legislation has not been revised since the amendments of 2009 (National Transport Commission 2015), implemented in Western Australia in 2010.

The European Union (EU) recommends the appropriate transition point from child restraint system to standard seatbelt is a height of 150cm (European Union 2003). This has been put in place in several European countries including Germany and Ireland. A height of 150cm roughly equates to a 12 year old at the 50th percentile of growth in Australia.

The National Child Restraint Best Practice Guidelines (2013) are currently being updated, including consideration of transition ages.

Method

The aim of this project is to undertake a review of the existing published and grey literature, on the appropriate point for graduation from child restraint systems to standard seatbelts.
Specific objectives include:

1. Review relevant child restraint system legislation both nationally and internationally.
2. Review the basis for the European Union's decision to ensure that children reach the height of 150 cm before moving from child restraint systems to standard seatbelts.
3. Compare the use of age, height and weight as transition points from child restraint systems to standard seatbelts.
4. Make recommendations about the preferred age/height for transition from child restraint systems to standard seatbelts.

Multiple sources were used in the literature search including government documents, road safety information websites, grey literature (primarily technical reports and conference papers) and published, peer-reviewed journal articles.

Review of the literature

This review found that most studies into the effectiveness of booster seats, the child restraint system appropriate for older children, are limited to children from 4 to 7 or 8 years of age, most of whom are less than 150cm tall. Other research has confirmed that restraint by standard seatbelts is more effective than being unrestrained in older children (Halman, Chipman et al. 2002).

Of the few studies examining the effectiveness of booster seats in children aged 8 to 12 years, the two most relevant studies are by Brown and Bilston (2009) and Anderson and colleagues (2017). The results found significantly reduced serious injury (Brown and Bilston 2009) and reduced overall injury (Anderson, Carlson et al. 2017) with the use of booster seats rather than standard seatbelts alone.

No research studies were found which recommended the 150cm transition point endorsed in the EU directive (2003). A recommendation of 148cm as an appropriate minimum transition point to a standard seat originated from the anthropometric study by Klinich and colleagues (1994). They further recommended a minimum sitting height of 74cm and mass of 37kg (unless the child is relatively heavy for height). Studies suggested that height, rather than age or weight, was a more effective metric to decide the transition from child restraint system to standard seatbelt.

Discussion

Overall, the review demonstrates that there is relatively little evidence regarding the appropriate transition point from child restraint system to a standard seatbelt. The available studies, as well as ergonomic principles, suggest that booster seats should be used in children until they reach a height of 148cm (Neuroscience Research Australia and Kidsafe 2013).
The five step test provides a simple process to check for readiness to transition from a child restraint system to a standard seatbelt:
1. Does the child sit all the way back against the vehicle seat?
2. Do the child's knees bend comfortably at the edge of the seat?
3. Does the belt cross the shoulder between the neck and shoulder?
4. Is the lap belt as low as possible, touching the thighs?
5. Can the child stay seated like this for the whole trip?

Recommendations

- Recommendation 1: That advice on the transition from booster seat to standard seatbelt be based primarily on the height of the child, rather than age and weight.
- Recommendation 2: That age, height and weight recommendations be better aligned in future child restraint system guidelines for children.
- Recommendation 3: That parents be educated about the five step test to establish their children's readiness to progress from a child restraint system to a standard seatbelt.
- Recommendation 4: That the use of high-back booster seats be encouraged rather than backless (cushion only) booster seats.
- Recommendation 5: That the restraint status of all children involved in crashes be recorded as part of the crash record (no restraint, seatbelt, booster seat, combined, front-facing or rear-facing car seat).
- Recommendation 6: That the manufacture of booster seats which accommodate children up to a height of 148cm be considered.

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1 INTRODUCTION

The Australian laws regarding child restraint systems (CRS) were amended in 2009. The pre-2009 legislation required only children up to the age of one year to use a child restraint (Reeve, Zurynski et al. 2007). The 2009 amendments increased this requirement to all children up to the age of seven years old. These changes were enacted in Western Australia (WA) in section 234 of the *Road Traffic Code* (2000) in 2010. The amendments state that:

"(2) If the passenger has not reached the age of 6 months, the passenger must be restrained in a suitable and properly fastened and adjusted rearward facing child restraint.

(3) If the passenger has reached the age of 6 months, but has not reached the age of 4 years, the passenger must be restrained in a suitable and properly fastened and adjusted —

(a) rearward facing child restraint; or

(b) forward facing child restraint that has an inbuilt harness.

(4) If the passenger has reached the age of 4 years, but has not reached the age of 7 years, the passenger must —

(a) be restrained in a suitable and properly fastened and adjusted forward facing child restraint that has an inbuilt harness; or

(b) be placed on a properly positioned booster seat and be restrained by a seatbelt that is properly adjusted and fastened." (p. 267-268 State Law Publisher 2000).

The Australian laws, including those in WA, have not been revised since the amendments of 2009, but some researchers have suggested that a more suitable transition point from child restraints to standard seatbelts is when the child reaches a height of 150cm (Neuroscience Research Australia and Kidsafe 2013). A height of 150cm roughly equates to the height of a 12 year old on the 50th percentile of growth in Australia[1] (Ogden, Kuczmarski et al. 2002), with the average girl reaching this height perhaps a few months before the average boy. A 12 year old on the 50th percentile of growth for weight is 41kg (boys) to 42kg (girls)[1]. The growth charts used by the Department of Health of Western Australia are included in the Appendix.

Cars are engineered for adults, and child occupants require special consideration. There is currently a gap in protection for children too big for booster seats but too small to be optimally protected by the standard seatbelt (Brown and Bilston 2012).

[1] Using the Center for Disease Control (CDC) Stature-for-age and Weight-for-age percentiles for 2 to 20 year olds, as recommended by the Department of Health of Western Australia

In Europe, the minimum transition point is a height of 135cm, in line with Directive 2003/20/EC of the European Parliament (European Union 2003). A height of 135cm is approximately on the 50th percentile of growth for an Australian 9.5 year old. However, the recommended European transition point is 150cm, which equates approximately to the 50th percentile for an Australian 12 year old. This transition point has been put in place in some European nations such as Germany (BMVI) and Ireland (Galliers), and also some North American jurisdictions such as the Yukon Territory (Clek 2016).

1.1 Aims and objectives

The aim of this project is to undertake a review of the existing published and grey literature, from 1970 to 2017, on the appropriate point for graduation from child restraint systems to standard seatbelts.

Specific objectives include:

1. Review relevant child restraint system legislation both nationally and internationally.
2. Review the basis for the European Union's decision to ensure that children reach the height of 150 cm before moving from child restraint systems to standard seatbelts.
3. Compare the use of age, height and weight as transition points from child restraint systems to standard seatbelts.
4. Make recommendations about the preferred age/height for transition from child restraint systems to standard seatbelts.

1.2 Methods - Literature search and retrieval

Multiple sources were used to undertake the literature review from 1960 to 2017. These included government documents, road safety information websites, grey literature (primarily technical reports and conference papers) and published, peer-reviewed journal articles. The literature searched included children from birth up to the age of 18 years of age, although the majority of the literature only included children up to the age of 12 years old.

Government documents regarding child restraint legislation and standards were accessed from the European Union (EU) EUR-Lex website (EU directives), SAI Global (Australian Standards), and the Department of Transport and State Legislation websites for each state and territory in Australia.

Grey and peer-reviewed literature was obtained by searching Google Scholar, ResearchGate and various library databases included Scopus, ProQuest, Web of Science and Medline. The search terms used included the following: *"child car restraint", "child car seat", "child restraint system",* and *"child road safety"*. Furthermore, other relevant publications of authors who had published widely in the area or had a significant publication relevant to the topic, and publications citing or cited by relevant articles were also assessed.

1.3 Operational definitions

Rear-facing child restraint: an infant restraint with inbuilt five or six point harness (Figure 1). Designed to restrain infants and babies facing the rear of the vehicle (Neuroscience Research Australia and Kidsafe 2013). These include Types A (up to a supine length of 80cm, approximate age of 12 months) and B (for children approximately 6 months to 4 years of age) (Standards Australia Limited and Standards New Zealand 2016).

Figure 1: Rear-facing child restraint for a baby or infant

Source: (Kidsafe 2016)

Front-facing child restraint: a child restraint with six point inbuilt harness (Figure 2). Designed to restrain older babies and young children facing forwards (Neuroscience Research Australia and Kidsafe 2013). These are Type B restraints, for children aged 6 months to 4 years (Standards Australia Limited and Standards New Zealand 2016).

Figure 2: Front-facing child restraint for older babies and young children

Source: (Kidsafe 2016)

Booster seat: also known as ‘belt positioning booster seat’ or ‘high-back booster seat’ (Figure 3): a child restraint that raises the child and adapts the vehicle’s seatbelt to better fit the child (Neuroscience Research Australia and Kidsafe 2013). These are Type E (height less than 128cm, aged 4 to 8 years of age) and F (height less than 138cm, aged 4 to 10 years of age) restraints (Standards Australia Limited and Standards New Zealand 2016).

Figure 3: Booster seat for older children

Source: (Kidsafe 2016)

Booster cushion: also known as a 'backless booster seat' (Figure 4). A child restraint without a backrest. It raises the child and adapts the seatbelt to obtain a better fit (Neuroscience Research Australia and Kidsafe 2013).

Convertible child seat: also known as a combined child seat. A child restraint that combines two or more restraint types, for example a forward facing child restraint and a booster seat (Kidsafe 2016).

Lap seatbelt: only has two points of attachment to the vehicle. Does not constrain the upper torso (Neuroscience Research Australia and Kidsafe 2013).

Standard seatbelt: includes both a lap seatbelt and a shoulder seatbelt (which has two points of attachment: near the shoulder and on the opposite side of the body near the pelvis). Also known as a three-point seatbelts (Neuroscience Research Australia and Kidsafe 2013).

1.4 Structure of the report

Firstly, the history of seatbelts and child restraint systems, both in Australia and internationally, will be presented. The history and current status of child restraint system legislation in Australia will also be described, and then compared to legislation in several other countries. These included European countries (most of which were covered by the EU directive), and major English-speaking countries (New Zealand, the United States or US, and Canada). One Asian country with child restraint legislation (Singapore) was also included. Child restraint legislation for children from birth to the transition to standard seatbelts will be discussed in this section. The EU directive which stipulated 150cm as a suitable height for transition to a standard seatbelt will then be discussed. The literature relating to child safety and child restraints among children aged four years and older will be discussed, covering both laboratory-based and real-life research. Lastly, the implications of the literature review will be discussed, and recommendations made accordingly.

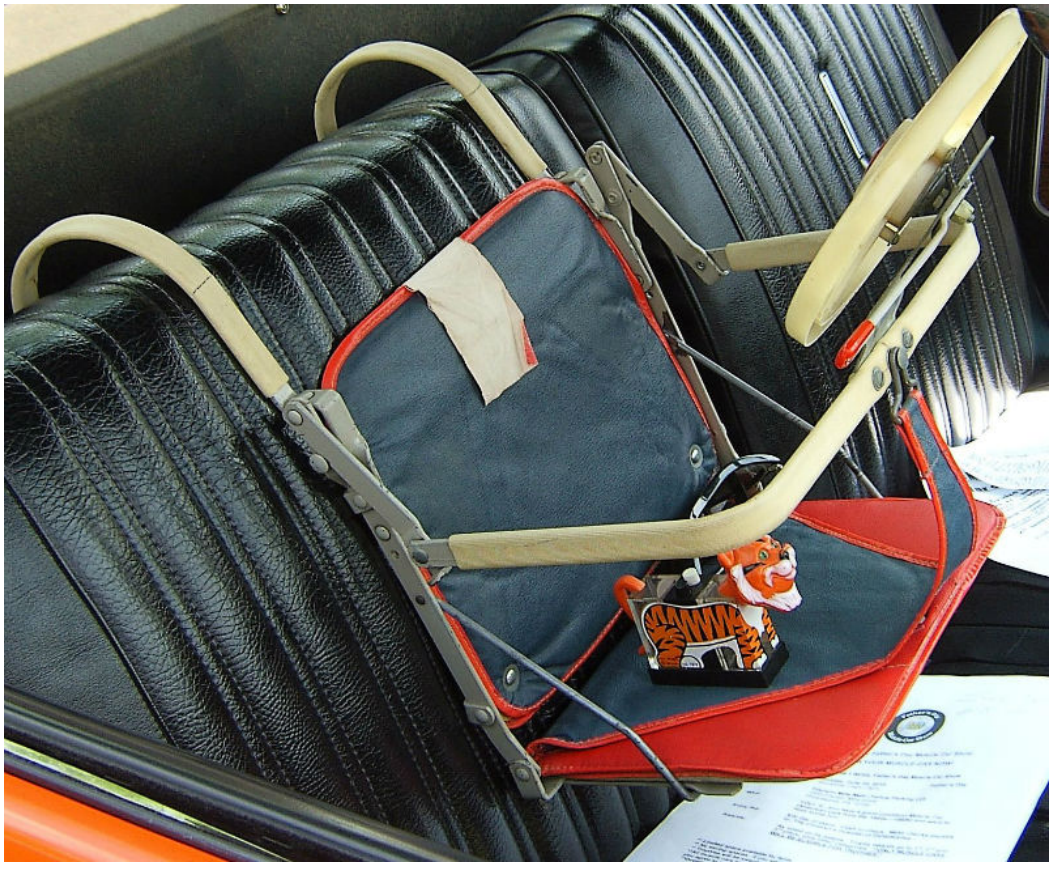
2 A REVIEW OF THE LITERATURE

2.1 History of seatbelts and child restraint systems

Seatbelts were invented by George Cayley in the mid-1800s and the first patent was granted to Edward J Claghorn in 1885. However, seatbelts were not offered as an option in cars until the late 1940s and early 1950s in the United States (US), and routinely in certain vehicles in Sweden from 1958 (Milne 1985, Heiman 1988). The world's first seatbelt law was introduced in Victoria, Australia in 1970 and across Australia by 1972 (Heiman 1988).

Early 'child seats' were made of hessian bags with drawstrings. In 1933, a child car seat, similar to a booster seat, was introduced (Kahane 1986), to prevent infants and toddlers from "*interfering"* with the driver, to enable the child to look out the window, and to protect the child in the event that the driver braked suddenly (Figure 5).

Figure 4: Early car seat by Bunny Bear Company in 1933



Source: (Lammle 2013)

The first child car seats designed specifically to prevent injury appeared in Sweden in the early 1960s (Tingvall 1987) and safety-focused child seats were introduced by Ford and General

Motors in the US in the mid-1960s. These earlier seats were designed for babies, infants and toddlers. The first rearward facing child seats, designed to protect babies and infants, were developed in 1964 (Aldman 1964) and forward-facing car seats were introduced at a similar time (Kahane 1986).

By the early 1980s, there was an increasing recognition that all passengers, including older children, needed to be restrained in both the front and rear seats (Arnberg 1981). Arnberg noted that the requirements of a restraint system for children aged 4 to 12 years differed from those of younger children. Unlike younger children, the older child can maintain their position and is less of a disturbance to the driver than a younger child. Booster cushions were developed in the 1980s to address the safety needs of children aged 4 to 12 years of age.

2.2 Child restraint system legislation in Australia – past and present

By 1972, all states and territories in Australia had legislation in place making the use of seatbelts compulsory. However, the initial legislation exempted children under eight years old from using seatbelts (Heiman 1988). 'Special chairs', which were produced for the use of children aged one to eleven years in cars in the late 1960s, were designed for improved comfort and visibility rather than to provide crash protection. As a result, the first Australian Standard AS E46 for child restraints which provided crash protection was produced in 1970. An amended Standard, AS 1754, was produced in 1975 (Heiman 1988). This standard has been updated and amended multiple times, with the latest version being AS/NZS1754:2013 Amendment 1:2016 (Standards Australia Limited and Standards New Zealand 2016). Sections of the 1995, 2000, 2004, 2010 and 2013 versions of the standard are mandatory.

In 1977, legislation changed so that children aged under eight years of age were required to use seatbelts when travelling in the front seat of cars (Heiman 1988). From 1988 onwards, legislation was introduced mandating the restraint of infants under one year of age by *"suitable devices"*. This included the 'baby safety capsule', invented in Australia in 1984 (Figure 6).

Figure 5: Baby safety capsule, designed in 1984, in Australia

Source: (Hutchison 2010)

Prior to 2009, the use of a child restraint or booster seat was not mandatory for children older than one years old (Reeve, Zurynski et al. 2007). In contrast, the use of child restraint systems (CRS) was mandatory in other countries up to the age of 5 to 12 years. However, the Australian guidelines recommended the use of a booster seat (with high back and wings) until the child fitted a standard seatbelt [at around the height of 145cm (Reeve, Zurynski et al. 2007)].

Laws regarding child restraint systems in Australia were revised in 2009 and these changes were implemented in WA legislation in 2010. The updates are included in the Australian Road Rules (Neuroscience Research Australia and Kidsafe 2013, National Transport Commission 2015). In summary, the changes were as follows:

- All children under the age of six months must be restrained in a rearward-facing approved CRS.
- All children aged between 6 months and 4 years must be restrained in either a rearward-facing *or* a forward-facing approved CRS, depending on the child's height and weight.
- All children aged 4 to 7 years must be restrained by either a forward-facing approved CRS *or* an approved seatbelt-positioning booster seat, depending on the child's size.

- All children aged 7 to 16 years must travel in either an approved child restraint *or* use a standard seatbelt, depending on the child's size.

2.3 Overview of current child restraint system legislation globally

Table 1 below gives an overview of current child restraint system legislation in Australia, New Zealand and other countries with well-established child road safety guidelines. The New Zealand legislation has similar transition points to Australia, which are also based on the age of the child. Singapore has similar guidelines to the EU Directive (2003) discussed below, with a transition height of 135cm from CRS to standard seatbelts. The Singapore legislation explicitly includes adults who are less than 135cm in its seatbelt recommendations.

European Union countries vary by country in their specific transition points from child restraint systems to standard seatbelts. Transition points are predominantly based on height of the child. Some countries use the minimum transition height (135cm) mandated by the EU Directive (2003). These include Denmark and the Netherlands. Other countries have adopted the upper, recommended transition height (150cm). These include Germany, Ireland and Italy. Switzerland, a non-EU country, has a transition height point of 150cm.

There is a wide range of child restraint laws across the provinces and territories of Canada and the states in the US. Canada tends to use weight to indicate transition points, while in the US age is the most commonly used metric. The Yukon Territory in Canada has the most stringent legislation, requiring the use of a booster seat up to a height of 145cm or 45kg. States in the US, such as Alabama, have the least strict requirements in North America, only requiring a child restraint system in children aged 5 years or younger.

Table 1: Comparison of current child restraint system legislation by country

Country	Age of passenger	Type of restraint
Australia[1]	< 6 months 6 months to 4 years 4 to 7 years 7 to 16 years	Rearward facing approved child restraint. Rearward of forward facing approved child restraint with inbuilt harness. Forward facing approved child restraint with inbuilt harness or booster seat with inbuilt harness or lap and sash type seatbelt. Must not be seated in front seat unless unavoidable. Approval child restraint or fitted with an approved seatbelt.
New Zealand[2]	Up to 7th birthday 7 years 8 to 14 years	Approved child restraint. Approved child restraint if available. If not, any child restraint or seatbelt. Safety belt.
Singapore[3]	<135cm (including adults)	Suitable child car seat or booster seat. Adults below this height may also use an approved adjustable seatbelt.
Austria[4]	<14 years and <150cm <14 years and 150cm or taller	Must use a suitable child restraint system Must wear a seatbelt
Denmark[5]	<135cm	Suitable approved child restraint, no rear-facing seat in the front seat unless airbag is deactivated.
France[6]	<13kg 9kg to 18kg 15kg to 36kg (up to 10 year or <1.4m)	Rear-facing child seat in back seat, or front seat with airbag turned off Child seat with harness or protection tray. Booster seat or cushion.
Germany[7]	< 12 years or 150cm	Approved child restraint, if not possible to fit more car seats, may be restrained in rear seats with a seatbelt if child >3 years.
Ireland[5]	< 3 years <150cm or <36kg	Child restraint. May not use rear-facing restraint in seat with active frontal airbag. Suitable approved child restraint (seat or booster cushion).

[1](National Transport Commission 2015) [2](New Zealand Tranport Agency 2015) [3](Singapore Police Force 2017) [4](HELP.gv.at 2018) [5](Galliers) [6](Driving France 2016)[7](BMVI)

Country	Age of passenger	Type of restraint
Italy[5]	<150cm	Suitable approved child restraint, no rear-facing seat in the front seat unless airbag is deactivated.
Netherlands[5]	<135cm	Approved child car seat.
Portugal[5]	< 12 years and <135cm	Approved child restraint, if no seatbelt in the back, child>3 years can sit in the front seat if airbag is deactivated.
Spain[8]	Up to 9 months (up 10kg) 9 months to 3 years (9kg to 18kg) 3 to 6 years old (15kg to 25kg) 6 to 12 years old (22kg to 36kg)	Carry in a carrycot, in the rear seat and secured using a safety belt Child seat facing frontwards or rearwards, in the rear of the car Use a booster seat with an approval seatbelt adaptor if necessary, in rear of car Use a booster seat or booster cushion so that seatbelt is comfortable, in rear of car
Sweden[9]	< 3 years old <135cm	May not travel in a vehicle where there is no means of using a child restraint system except over short distances Use an appropriate child restraint system (baby car seat, child car seat, booster seat or booster cushion)
Switzerland[10]	<12 years if under 150cm	Must be restrained in an appropriate car seat for their weight and age. May be seated in front seat at any age, but rear-facing car seats may only be used if the front passenger airbag is deactivated.
United Kingdom[11]	< 3 years 3 to 12 years (or 1.35m) 12 or 13 years (or 1.35m+)	Correct child restraint. Correct child restraint where seatbelts fitted (unless unexpected short distance or two restraints prevent fitment of a third). Child must be 125cm and at least 22kg to use a booster cushion. Seatbelt must be worn if available.

[5](Galliers) [8](Get Spain) [9](Trafikverket: Swedish Transport Administration) [10](ch.ch) [11](Department for Transport and Driver and Vehicle Standards Agency 2015)

Country	Age of passenger	Type of restraint
Canada[12] (Provinces and Territories)	18kg to 36kg	Must not be seated in the front if the front air bag has not or cannot be turned off.
Nova Scotia, British Columbia, Newfoundland & Labrador, New Brunswick, Ontario, Prince Edward Island, Saskatchewan, Manitoba	Until 9kg Until 18kg Until 36/7kg or 145cm or 7-10 years old	Rear-facing child seat. Must use car seat. Must use booster seat.
Yukon Territory	Until 10kg and walking unassisted Until 22kg Until 145cm or 45kg	Rear facing child restraint system. Child restraint system suitable to age, weight and height. Must use child restraint system or booster seat.
Nunavut Territory, Alberta, Northwest Territory	Up to 9kg Up to 18kg 18kg+	Rear facing (excluding Nanuvut Territory). Must use car seat. No booster seat law.
Quebec	Until seated height is 63cm	Must use car seat or booster seat suited to child's height and weight.
United States[12] (States)		
Alabama	<6 years	Child safety seat or booster seat.
California	<2 years < 8 years	Rear-facing car restraint system (not in the front seat if there is an active airbag). Child car restraint system in rear seat.
Delaware	<1.65m or <12 years <8 years and <30kg	May not occupy front seat with active airbag. Child car restraint system in rear seat.
Maryland	<8 years (unless 145cm or taller)	Child safety seat.

[12](Clek 2016)

2.4 The EU directive:

In April 2003, the European Union passed Directive 2003/20/EC of the European Parliament, which amended Council Directive 91/671/EEC on the approximation of the laws of the Member States *"relating to compulsory use of safety belts in vehicles of less than 3,5 tonnes"* (European Union 2003). Children were classified into five 'mass groups' of which the largest (group III) included children from 22kg to 36kg [Amended Article 1, section 3(e)]. In addition, the amended Article 2, stated that *"children less than 150cm in height, occupying M1, N1, N2 and N3*[2] *vehicles fitted with safety systems shall be restrained by an integral or non-integral child-restraint system…"* suitable for the child's mass [Section 1 (a) (i)]. Article 2 further allows member states to reduce this height requirement to 135cm, so that children between 135cm and 150cm may simply be restrained by a standard safety belt [Section 1 (a) (ii)]. This differs from the 1991 directive which uses age and height as transition points to standard seatbelts [under 12 years of age and less than 150cm tall (European Economic Community 1991)].

Notably, according to the Center for Disease Control (CDC) growth charts (Ogden, Kuczmarski et al. 2002), a height of 135cm is the median height of a 9 and a half year old, while 150cm is the median height of a 12 year old, while children on the 50th percentile reach 36kg at just under 11 years of age . There is, therefore, a disconnect between the median age at which the recommended maximum height (150cm) is reached and the age at which the upper limit of the highest 'mass group' in the 2003 directive is reached.

2.5 Research into CRS usage in older children

2.5.1 Studies using crash data

A study from nearly 40 years ago by Arnberg acknowledged the need for protection for older child passengers, aged 4 to 12 years of age (Arnberg 1981). However, the study only investigated booster cushion use (safety, comfort and handling) in 3, 6 and 8 year olds, and not in children aged 9 to 12 years.

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[2] M1: *"Vehicles designed and constructed for the carriage of passengers and comprising no more than eight seats in addition to the driver's seat, and having a maximum mass ("technically permissible maximum laden mass") not exceeding 3.5 tons"*
N1: *"Vehicles for the carriage of goods and having a maximum mass not exceeding 3.5 tonnes"*
N2: *'Vehicles for the carriage of goods and having a maximum mass exceeding 3.5 tonnes but not exceeding 12 tonnes"*
N3: *"Vehicles for the carriage of goods and having a maximum mass exceeding 12 tonnes"*
TransportPolicy.net. (2018). "EU: Vehicle definitions." from https://www.transportpolicy.net/standard/eu-vehicle-definitions/.

Subsequent studies followed this trend, with few studies including children aged above 8 years of age. Most studies including this older age group define standard seatbelt use, rather than booster seat use, as 'appropriate restraint use' for children aged above 8 years (e.g. Berg, Cook et al. 2000, Corden 2005, Durbin, Chen et al. 2005, Sauber-Schatz, Thomas et al. 2015). For example, Agran and colleagues investigated two age groups (4 to 9 year olds, n=755, and 10 to 14 year olds, n=726). They found that 10 to 14 year olds who were restrained (with a standard seatbelt or child restraint system) had significantly lower mean injury severity scores (ISS) and few intracranial injuries after involvement in a crash compared to unrestrained children in this age group.

Booster seats are the child restraint system designed and most appropriate for older children. Most studies into the effectiveness of booster seats only include children aged from 4 to 7 or 8 years of age (Winston 1999). For example, Arbogast and colleagues (2009) found a significant 45% lower odds of injury among 4 to 8 year olds in booster seats compared to those using standard seatbelts alone. Sivinski used 11 years of data from the US to report a significant 14% reduction in overall injuries in 4 to 8 year olds who were restrained in a motor vehicle using a booster seat (Sivinski 2010). Further studies among younger children which demonstrated the effectiveness of booster seats (including a reduction in the severity of an injury and fatalities) include those by Durbin and colleagues (2003), Corden (2005), Jermakian and colleagues (2007), Pressley and colleagues (2009) and Farmer and colleagues (2009).

Halman and colleagues explored the effectiveness of standard seatbelts in preventing injuries in 470 school-aged children (4 to 14 years) compared to 1,301 adults in Canada (Halman, Chipman et al. 2002). Children in booster seats were excluded from the analysis as less than 1% of children in the sample used them. This made it impossible to assess the effectiveness of booster seats in older children. The odds of a fatal or severe injury in the front seat of a vehicle was nine times higher among unrestrained children compared to children restrained with standard seatbelts and 2.4 higher among unrestrained adults compared to adults retrained with seatbelts. The odds of a fatal or severe injury in the rear seat was more than two times higher among unrestrained children vs children restrained with standard seatbelts, compared to 2.7 times higher among unrestrained adults vs adults restrained with seatbelts.

Miller and colleagues compared crash risk among 7,915 children (Miller, Zaloshnja et al. 2002). The study compared children aged 4 to 7 years in standard seatbelts compared to children aged 8 to 13 years in standard seatbelts, to assess if children aged 4 to 7 years would benefit from booster seats. The study hypothesised that if the younger age group had a higher crash risk than the older age group, they would benefit from booster seats. The authors were not able to demonstrate that the younger children were significantly more likely to be killed or seriously injured than the older children. The authors attempted to account for the possibility that both children aged 4 to 7 years and those aged 8 to 13 years might benefit from improved safety if they used booster seats. However, they were only able to demonstrate lower injury costs in injured children aged 4 to 13 years in standard seatbelts, compared to costs in 18 to 34 year old young adults using seatbelts.

One of the most highly cited studies into the effectiveness of booster seats was conducted in the US by Durbin and colleagues (2003) and included 4,243 children aged 4 to 7 years of age. The study compared children using booster seats to children using standard seatbelts and found a significant 59% lower odds of injury, and a reduction in injuries to the abdomen, spine and lower extremities, among 4 to 7 year olds using booster seats.

A study on 1,470 adult drivers (65% male and 35% female) conducted in the UK found a higher probability of more serious injuries to the head, pelvis and lower extremities among those 160cm or less compared to taller drivers involved in crashes (Welsh, Morris et al. 2003). The authors suggested that these differences might be due to the closer position of the steering wheel, and position and movement of the foot and ankle in shorter drivers. The study suggested the posture might also affect injury outcomes, but did not discuss how seatbelt position might be a factor affecting the severity and nature of the injuries in shorter drivers.

Jakobsson and colleagues conducted an analysis of 3,670 children from newborn to 15 years old involved in motor vehicle crashes between 1987 and 2004 in Sweden, using Volvo's crash database (Jakobsson, Isaksson-Hellman et al. 2005). The authors examined the risk of an injury among children aged 4 to 10 years who used booster seats compared to those using a standard seatbelt only. They found that those using booster seats had a 77% reduction in injuries compared to those using a standard seatbelt only. The study recommended the use of booster seats up the age of 10 years, but the results suggested that 11 and 12 year olds would probably also benefit from their use.

A study of 5,259 younger children (aged 4 to 7 years) in the US found that children in standard seatbelts were eight times more likely to sustain abdominal injuries than children using booster seats when involved in a crash (Jermakian, Kallan et al. 2007).

Brown and Bilston conducted a study of 72 children aged 2 to 16 years admitted to hospitals in Sydney with spinal trauma following involvement in a motor vehicle crash (Brown and Bilston 2009). All children were restrained, but only 10 (14%) were using a child restraint system. The study analysed the injury data using different age groupings: firstly by grouping the participants as aged 8 years and less, or more than 8 years; and secondly by grouping them as aged less than 12 years, or 12 years and more. The authors state that 8 years of age was used to define the first age grouping, as it is commonly used in age-based recommendations as the age for transition to a standard seatbelt. Twelve years of age was used as *"…this is the age when the 50th percentile child achieves the recommended 148 cm height for transition to an adult belt"* (p. 546 Brown and Bilston 2009). The results found that the odds of a serious spinal injury were more than seven times among those aged 12 years or less, compared to those older than 12 years. There was no significant association between age and serious spinal injury with comparing children aged 8 years and younger to children older than 8 years. These findings suggests that children aged 8 to 12 years might benefit from the protection offered by booster seats. The authors, however, note that the design of booster seats in most countries limit their use to children up to younger children.

Ma and colleagues (2013) examined the effectiveness of booster seats using 12 years of US crash data for children from birth to 10 years of age. Children in booster seats were matched to 475 children using standard seatbelts alone and 375 children using no restraint. The study found that children using booster seats had significantly fewer overall injuries, and injuries to all body regions except the neck (ISS>0), than those children who were unrestrained (RR=0.73, 95% CI=0.55-0.96). The risk of a neck (RR=1.86, 95% CI=1.43-16.00) or a thorax injury (RR=2.86, 95% CI=1.33-6.15) was higher among children using booster seats than among children restrained by standard seatbelts only. The authors note that the latter results were inconsistent with previous research. They suggest that the higher risk of neck and thorax injury may be because of the elevated centre of gravity of the child relative to the vehicle floor created by the booster seat. Approximately 72% of children in the study were aged 4 to 8 years old, and the mean age was 4.7 years, suggesting that few of the children included were aged 9 and 10 years.

A recent study conducted in Washington, US assessed the effectiveness of booster seat usage among children aged 8 to 12 years over a 14 year period (Anderson, Carlson et al. 2017). The study included 29,859 children, of which 5,932 (7.4%) were in a booster seat at the time of the crash, and the remainder (n=73,927, 92.6%) were restrained by a standard seatbelt. The results found that children using a booster seat were significantly less likely to sustain any injury (OR=0.814, 95% CI=0.749-0.884) compared to children using a standard seatbelt alone. This association remained significant when 8 to 9 year olds, and 10 to 12 year olds were analysed separately. Use of a booster seat was not associated with lower odds of fatal or incapacitating injury (OR=1.349, 95% CI=0.907-2.004).

2.5.2 Studies using anthropometric data, and restraint and vehicle measurements

In the 1990s, booster seat usage was low in children aged over 5 years of age (Winston 1999). As a result, the evidence supporting the need for using booster seats was derived using *"biomechanical considerations"* (including anthropometric studies) together with the findings of studies of the effectiveness of booster seats in children aged 5 years and younger (Miller, Zaloshnja et al. 2002). More recently, booster seats have been commonly used by children aged up to 7 or 8 years of age, because legislation in many jurisdictions requires their use in this age group. However, most children of this age may not reach minimum height recommendations for safely using standard seatbelts. As minimal research has examined the effectiveness of booster seats in children aged 8 or older, anthropometric studies may provide the necessary evidence regarding the appropriate transition from booster seats to standard seatbelts.

A seminal anthropometric study, on which many future recommendations and studies have relied, was conducted by Klinich and colleagues more than 20 years ago (1993, 1994). The first phase of the study used data from the United States National Accident Sampling System (NASS) from 1988 to 1991. This phase found that, while children aged 6 to 12 years made up only 43% of the child occupant population, they sustained 55% of the injuries. Nearly two thirds of uninjured 6 to 12 years olds were wearing restraints (99.5% in standard seatbelts and 0.5% in child car restraints).

The second phase of the study included 155 child volunteers aged 6 to 12 years from a primary school in Ohio (Klinich, Pritz et al. 1994, Klinich, Pritz et al. 1994). The children's height, weight, standing height and sitting height were benchmarked against previous measurement studies. The study used three different booster seats, and observed each child in each seat in

three different cars for: fit of shoulder and lap belt, slouch, seating position, leg angle, position of feet, sitting height, clothing effect, chest mark and belt mark. The researchers observed that, in the vehicles where children had the best belt fit, they had the worst postures (as assessed by slumping in the seat, sitting height and leg angle), and vice versa.

The results found that the minimum size for a child to use a three point seatbelt (that is, a shoulder and lap combined belt or standard seatbelt) was:

- Standing height of 148cm
- Sitting height of 74cm
- Mass of 37kg (unless the child is relatively heavy for height, that is has a higher body mass index)

Klinich and colleagues concluded that weight was less important than height; and that children of all ages needed to reach a height of 148cm to fit a standard seatbelt. They also noted that the children who best fitted the booster seats weighed 36kg or less. Wider booster seats were needed for heavier children who had not yet reached the required height of 148cm. The authors suggest that children slouch in seats because of the length of vehicle seat cushions: the widest part of a child's calves rest on the edge of the seat so the child slouches so he or she is more comfortable. Booster seats mitigate this problem by lifting the child, which makes the leg position more comfortable.

The recommendation of the National Highway Traffic Safety Administration (NHTSA) is that children use booster seats until the reaching a height of at least 145cm. Based on this 2004 recommendation by the NHTSA, Huang and Reed examined the use of booster seats in rear seats, compared to the use of seatbelts alone, using this height guideline in their analysis (Huang and Reed 2006). The authors noted that booster seats raise the child on the seat (Huang and Reed 2006) by about 100mm (Reed, Ebert-Hamilton et al. 2006), and improve the fit of both shoulder and lap belts. Klinich and colleagues (1994) suggest that booster seats effectively shorten seat cushion length, reducing slouching (Klinich, Pritz et al. 1994), and allowing a more comfortable posture (Reed, Ebert et al. 2009). Huang and Reed used a representative sample of national (US) crash data, anthropometric data and measurements of the second and third row vehicle seat cushions of 56 late model vehicles. The study found that the majority of second and third row cushion lengths were too long for most rear-seat occupants (measuring thigh length, that is, buttock-to-popliteal length), and this was particularly evident for children less

than 145cm tall. In fact, only 5% of second-row vehicle seats were the recommended cushion length of 440mm (which is the 5th percentile for adult female buttock-to-popliteal length). The authors recommend shortening rear seat length to cater for those under 145cm tall.

A subsequent study confirmed the results of Huang and Reed (2006). Bilston and Sagar (2007) measured rear seat and seatbelt geometry (anchorage locations and sash belt angles) for 50 late model vehicles (2005/06). The geometry of 17 child restraints (rear- and front-facing child seats and booster seats) were measured (including interior size and strap slot locations). The results found that the rear seat cushions of all the vehicles were too deep for children whose upper leg length was at the 50th percentile at age 11.5 years (i.e. 145cm in height). Half of the vehicle seat cushions were too deep for children on the 50th percentile, until the age of 15 years. Several of the booster seats examined were not tall enough for 8 year olds on the 50th percentile for height, while several were too narrow for children close to the maximum recommended age.

An on road observational study in Sweden observed six children, aged 6 to 13 years, and ranging in height from 138cm to 150cm (Jakobsson, Bohman et al. 2011). The researchers observed that only one child using a booster seat slouched, while three children slouched when using only a standard seatbelt. The authors observed that even when the child was in the slouched position, the booster seat helped to guide the lap belt below the abdomen. The booster seat positioned the seatbelt at mid shoulder and produced a more stable lateral sitting posture.

Reed and colleagues (2013) examined seatbelt fit for of 44 children aged 5 to 12 years. The study included four high back booster seats, one backless booster seat (that is, booster cushion only) and a vehicle seat without a booster seat. The study found that all booster seats produced a better fit of the lap belt than using a standard seatbelt alone. For example, the lap belt was not fully below the anterior superior iliac spines (ASIS or hip bones) in 42 of the 44 children for two of the boosters. The lap belt needs to fit below the ASIS to prevent submarining[3]. The authors also noted that reducing seat cushion length (but not cushion angle) improved lap belt fit. Shoulder belt fit was affected by position of the D-ring[4] and the routing clip.

[3] Submaring refers to when a child slides forward, under and out of the lap belt during a crash. Vesentini, L. and B. Willems (2007). "Premature graduation of children in child restraint systems: An observational study." Accident Analysis and Prevention **39**(5): 867-872..

[4] D-ring: upper anchorage, to assist securing the straps of the CRS to the vehicle

A study by Hu (2013) used computer simulation to test the effect of the configuration of child restraint systems in crash dummies that approximated the body measurements of 6, 9 and 12 year olds. Based on the data collected, they recommended various improvements to child restraint systems including lower, more rearward D-rings[4]; higher, more forward lap belt anchorages; and shorter, stiffer and thinner seat cushions to improve restraint anchorages. They also noted that reducing cushion length would be help improve fit. They recommended that children should remain in booster seats after the age of 8 years as this would improve their safety in the event of a frontal crash.

A subsequent study by Ramanathan, Hu and Reed (2016) used computer simulation to test seat and seatbelt performance in frontal crashes using a child model representing children with a range of sizes appropriate to those aged 6 to 12 years. Child size was the most important indicator of outcomes, with a reduction in submarining[3] as child size increased. A larger body size and older age was associated with increased head excursion and knee excursion. With increasing age, torso rotation and abdomen penetration decrease, reducing likelihood of submarining**Error! Bookmark not defined.**. Seatbelt anchorage locations, cushion length and seat stiffness were other significant factors for response to the crash impact.

Morse and colleagues recently examined 388 children aged 7 to 12 years in five vehicle types (a compact car, a small sports utility vehicle or SUV, a large SUV, a pickup truck and a minivan) in Arkansas, US (Morse, Aitken et al. 2017). The current American Academy of Pediatrics guidelines recommend transitioning from a child restraint system to a standard seatbelt at a height of 4 foot 9 inches (148cm), weight of 80 pounds (36kg) and age 8 years. Of the 388 children in the study, 28% were above 4 foot 9 inches, 45% were 80 pounds or more, and 91% were 8 years of age or older. The difference in these proportions highlights the variations in height, weight and age across a group of children. The study used the five point seatbelt fit test (Neuroscience Research Australia and Kidsafe 2013, National Highway Traffic Safety Administration 2017) in the 2nd row of each vehicle to assess fit of standard seatbelts:

1. Does the child sit all the way back against the vehicle seat?
2. Do the child's knees bend comfortably at the edge of the seat?
3. Does the belt cross the shoulder between the neck and shoulder?
4. Is the lap belt as low as possible, touching the thighs?
5. Can the child stay seated like this for the whole trip?

At a height above 4 foot 9 inches (that is, 148cm), over 90% of children passed these five criteria in the small SUV and compact car. Lower proportions of children fitted the standard seatbelts in the pickup truck and large SUV (83% and 77% respectively) using the five point test. A good seatbelt fit was not obtained by 90% of children using the recommended transition weight of 80 pounds (36kg) as the sole criteria for seatbelt use. The researchers concluded that weight and age were poor predictors of seatbelt fit.

2.6 Transition points to standard seatbelts

A technical report for the American Academy of Pediatrics made the following best-practice recommendation: "*all children whose weight or height is above the forward-facing limit for their car safety seat should use a belt-positioning booster seat until the vehicle lap-and-shoulder seat belt fits properly, typically when they have reached 4 feet 9 inches in height and are between 8 and 12 years of age"* (Durbin 2011). The authors note that this recommendation of a minimum height of 4 feet 9 inches or 148cm comes from Klinich and colleagues' anthropometric study from the early 1990s (Klinich, Pritz et al. 1994).

Furthermore, in 2014, New Zealand's Paediatric Society recommended that a child restraint system be used up to the height of 148cm, which they state is reached at the age of approximately 11 years old (Kool, Ryan et al. 2014). They referenced the Klinich study (1994) as the source of this height recommendation. It seems that the recommendation of 150cm in the relevant EU directive (European Union 2003), used in several European countries (see Table 1), may also have relied on this study, although the research basis for the directive was not available where requested directly from the EU by the author of this report.

A survey on booster seat used among 692 children aged 4 to 11 years, in New South Wales and Victoria in 2005, examined height and weight of children, and their restraint use (Fitzharris, Charlton et al. 2008). Of these, 91% (n=633) were within the recommended height range for using a booster seat (defined as 100cm to 145cm), but only 29% (n=182) were using the booster seats. In addition, 37% of children who were within the recommended height for booster seats exceeded the maximum weight in the then-current Australian safety standard. This is notable for future planning of booster seat use – there should be booster seats manufactured which fit the Australian children who are relatively heavy for their height.

A study by Anderson published in 2009 examined the selection of an appropriate child restraint system based on the weight and age of the child (Anderson and Hutchinson 2009). At the time, the Australian guidelines primarily used weight when promoting the use of child restraints. These guidelines have since changed to primarily using age to indicate transition points, as suggested by the authors (Anderson and Hutchinson 2009). The authors proposed that this would reduce the use of the incorrect child restraint for size.

Morse and colleagues recently examined the current American Academy of Pediatrics recommendations on transitioning from a child restraint system to a standard seatbelt at a height of 4 foot 9 inches (148cm), a weight of 80 pounds (36kg) and an age of 8 years (Morse, Aitken et al. 2017). They concluded that weight and age were poor predictors of fit of a standard seatbelt, while height was a better predictor of fit. This concurs with the conclusions of Klinich and colleagues (1994) who found that that height is the most important factor in determining the correct sized child restraint, with weight being a factor among a few relatively heavy children. However, as described above, the Australian guidelines do not use height as the primary measure for transition points.

A recent online survey of 569 Australian parents of children aged 1 to 8 years was conducted following the introduction of the updated child restraint legislation and guidelines for Australia (Cross, Charlton et al. 2017). The survey found that, while 85% of parents believed that a standard seatbelt was designed for children of a minimum height of 145cm, 41% of respondents were under the impression that their children would reach this height by the age of 7 years, while the CDC growth charts indicate that only half of all children reach this height by 11 years of age (Ogden, Kuczmarski et al. 2002, Anderson and Hutchinson 2009). This indicates that, while height may be the most important factor indicating correct transitioning to a standard seatbelt, parents may need additional education on the relationship between height and age in the average Australian child (see Appendix).

3 DISCUSSION

This literature review provided an in-depth examination of appropriate criteria to judge the height at which children should transition from a child restraint system to a standard seatbelt. The review used the EU directive of 2003, which specifies a height of 150cm as the appropriate transition point to a standard seatbelt (European Union 2003), as a starting point. A height of 150cm is the median height of a 12 year old (Ogden, Kuczmarski et al. 2002).

The review found that the majority of previous research into the effectiveness of child restraint systems appropriate for older children were limited to children from 4 to 7 or 8 years of age. Most of these children were less than 150cm tall. Therefore, directly examining the safety benefits of using a child restraint system compared to a standard seatbelt in children approaching the height of to 150cm was difficult. Previous studies have demonstrated the effectiveness and safety benefits of booster seats in this younger age group (4 to 8 years of age), most of whom were less than 150cm tall (for example, Durbin, Elliott et al. 2003). Other research has confirmed that older children were safer using standard seatbelts than being unrestrained (Halman, Chipman et al. 2002). Children of all ages were advised to sit in rear seats, mainly due to presence of air bags in front passenger seats which can be injurious to a child (Lennon, Siskind et al. 2008).

Few studies have examined the effectiveness of booster seats in children aged 8 to 12 years of age. The two most relevant studies are by Brown and Bilston (2009) and Anderson and colleagues (2017). The former is particularly relevant as it was conducted in Australia, although it had a relatively small sample size. The latter study had a large sample size, but was confined to a single state in the US. Both studies demonstrated that booster seats provided additional protection against injury (serious and all injury) than standard seats alone. The studies suggest that children between eight to twelve years of age who are under 150cm would benefit by remaining in a booster seat until they have grown taller.

Other studies examining the effectiveness of booster seats included a wide age-range of children (Halman, Chipman et al. 2002) or only children aged 8 year or under. Children's body proportions differ considerably to adults, and these proportions change as they grow, with sitting height representing 70% of total ('standing') height at birth, but dropping to 50% of standing height in 13 year old girls and 15 year old boys (Burdi, Huelke et al. 1969). Given the changes that occur in body proportions over the years between age 4 and 14 years, there might

be considerable variations in size within this age-group. Changes in the morphology of the pelvis as children grow, including the development of the anterior superior iliac spines, may also affect the fit of seatbelts (Trosseille, Cassan et al. 2001) and the possibility of submarining[3] during a crash (Vesentini and Willems 2007).

Because of the few effectiveness studies in the literature, two additional study types have been included in the review to provide evidence of the appropriate height required to transition to an adult seatbelt. The two study types were: i) studies using anthropometric data in combination with measurements of child restraint systems; and ii) studies using vehicle measurements in conjunction with measurements of child restraint systems.

The recommendation of 148cm as an appropriate transition point to a standard seat originated from the anthropometric study by Klinich and colleagues (1994). This study was conducted more than 20 years ago, in the US, and with a convenience sample of only 155 children, all factors which may limit the applicability of the study to Australia in the present day. More recently, however, Morse and colleagues (2017) confirmed that most children above the height of 148cm passed the five point seatbelt test, a test used internationally by practitioners to assess readiness to transition to a standard seatbelt. Both studies suggested that height, rather than age or weight, was a more effective metric for a transition point from child restraint systems to standard seatbelts. This provides a challenge in Australia, as Australian research has shown that many parents are not aware of the age at which their children would reach a height of 145cm (Cross, Charlton et al. 2017).

Studies measuring rear cushions in a range of vehicles have found that they are usually too deep for children of around 145cm (Huang and Reed 2006, Bilston and Sagar 2007), suggesting that rear seats should be designed with the knowledge that most rear seat occupants are children.

Overall, the review demonstrates that there is relatively little evidence regarding the appropriate transition point from child restraints systems to standard seatbelts alone, but that ergonomic principles suggest that booster seats should be used in children up the minimum height of 148cm (Neuroscience Research Australia and Kidsafe 2013). Children are usually ready for standard seatbelts when they can sit with their backs against the vehicle seat back with their knees bent over the vehicle seat edge (Klinich, Pritz et al. 1994). The five step seatbelt fit test provides a simple procedure to check for readiness for the transition to a standard seatbelt. The

shoulder belt should be positioned over the clavicle (collar bone) and the lap belt should positioned below the ASIS (hip bones) to restrain passenger during a crash [and avoid submarining[3] (Vesentini and Willems 2007, Reed and Klinich 2016)].

There are barriers to the use of booster seats, particularly in older children. These include lack of knowledge by parents and children about child restraint laws, but more particularly about the safe height to transition to a standard seatbelt, and the age at which this is reached among most children (Simpson, Moll et al. 2002, Mannix, Fleegler et al. 2012). Further concerns include the cost and comfort of booster seats. Moreover, attitudes towards booster seats by both parents and children can limit their use. Among parents, these include difficulties in installing and using booster seats, and concerns that booster seats are unsafe because of different anchoring methods to forward-facing child restraints (Simpson, Moll et al. 2002). Older children may be resistant to using booster seats as they feel they are too old for them. A survey among South Australian children aged up to 10 year olds in South Australia (Edwards, Anderson et al. 2006) showed that almost all of the 9 and 10 year olds did not used a booster seat as it was *"for babies"*. These barriers call for education of children and parents, and for a culture change around booster seat use in older children.

4 RECOMMENDATIONS

Recommendation 1: That advice on the transition from booster seat to standard seatbelt be based primarily on the height of the child, rather than age and weight

This will require adapting of the current child restraint system guidelines to focus on height, but also education of parents and children about median heights at different ages, to facilitate appropriate restraint use. Organisations such as Kidsafe (2016) and SDERA (2017) which provide information and assistance to parents on child safety, including the correct choice and use of child safety restraints, are well-placed to educate parents on updated guidelines. Further research is required to establish the ideal transition height from booster seats to standard seatbelts, but previous research suggests a height of approximately 148cm. Future legislation should consider using this height as a more appropriate transition point to standard seatbelts.

Recommendation 2: That age, height and weight recommendations be better aligned in future child restraint system guidelines for children

Australian children on the 50th percentile for height reach a height of 148cm just before their 12th birthday (around the end of primary school). Supplementary information on age and weight provided in future guidelines should also use median values of weight at around 12 years of age.

Recommendation 3: That parents be educated about the five step test to establish their children's readiness to progress from a child restraint system to a standard seatbelt

The use of this easy-to-use test should be promoted and encouraged among parents by health professionals, road safety practitioners and advocacy groups, and teachers.

Recommendation 4: That the use of high-back booster seats be encouraged rather than backless (cushion only) booster seats.

Although backless booster seats may provide a better lap belt fit, high-back booster seat have been found to provide a more consistent shoulder belt fit because of belt routing guides near shoulder (Reed, Ebert et al. 2009). High-back booster seats offer head support, especially important in older-model vehicles that do not have head restraints (Kuska 2011). Backless booster seats have the advantage that they are cheaper and are preferred by older children (and so compliance may be higher) because they look less like toddler child restraints (Kuska 2011). The use of backless booster seats could be considered in the future for children at the upper end of the height and weight recommendations

Recommendation 5: That the restraint status of all children involved in crashes be recorded as part of the crash record (no restraint, seatbelt, booster seat, combined, front-facing or rear-facing car seat)

This will enable research into the effectiveness of booster seat use in 8 to 12 year olds.

Recommendation 6: That the manufacture of booster seats which accommodate children up to a height of 148cm be considered.

Using the current growth charts, half of all children will reach this height just before the age of 12 years, and will weigh approximately 40kg. Booster seats should be available which accommodate at height of 148cm and a weight of 55kg (a body mass index or BMI of 25), given that some children are relatively heavy for their height. Brown and Bilston (2009), however, note that the design of booster seats in most countries limit their use to children up to age 8 years old.

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6 APPENDIX

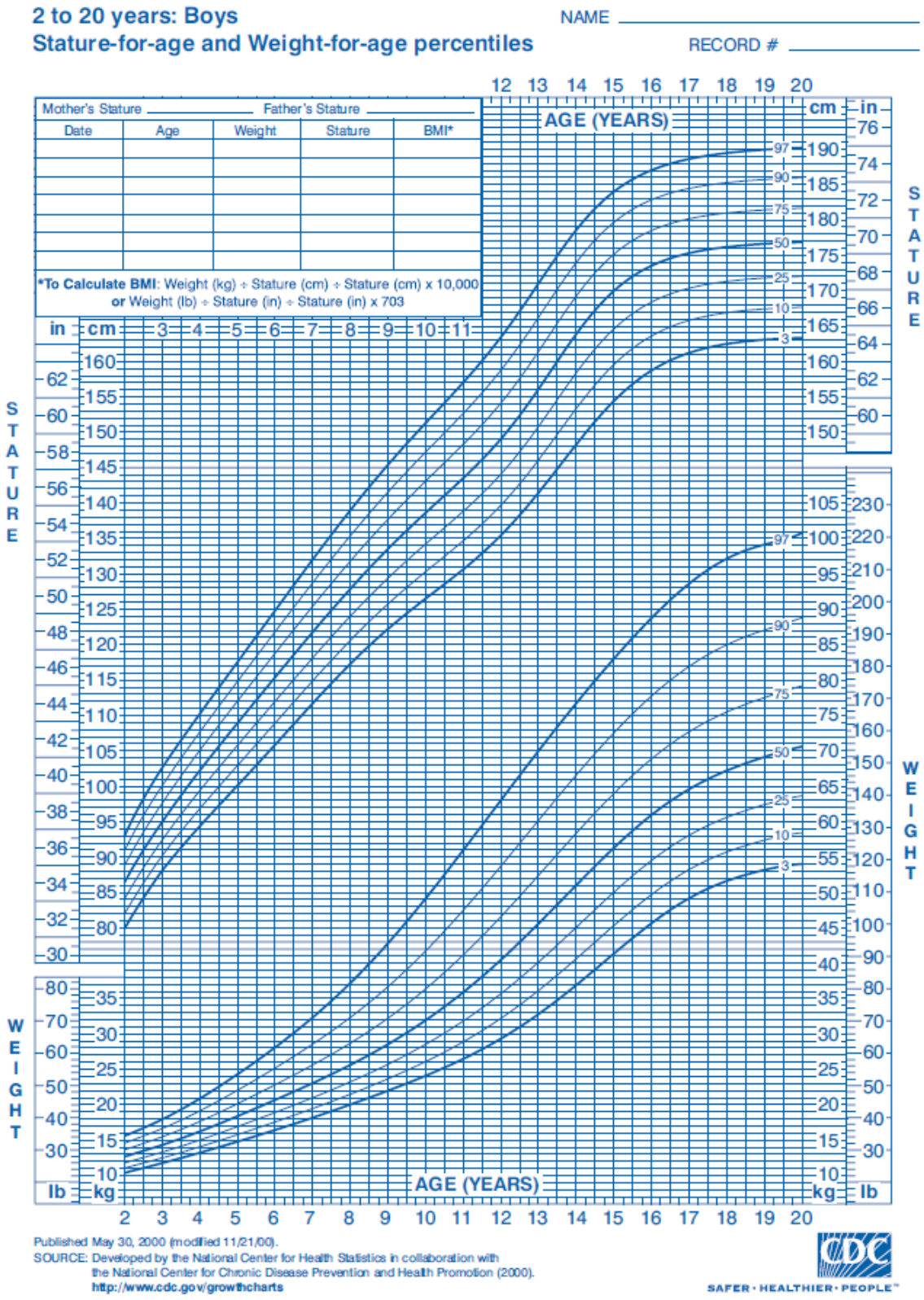

Figure 6: CDC growth charts for 2 to 20 year old boys, used by the Department of Health, Western Australia

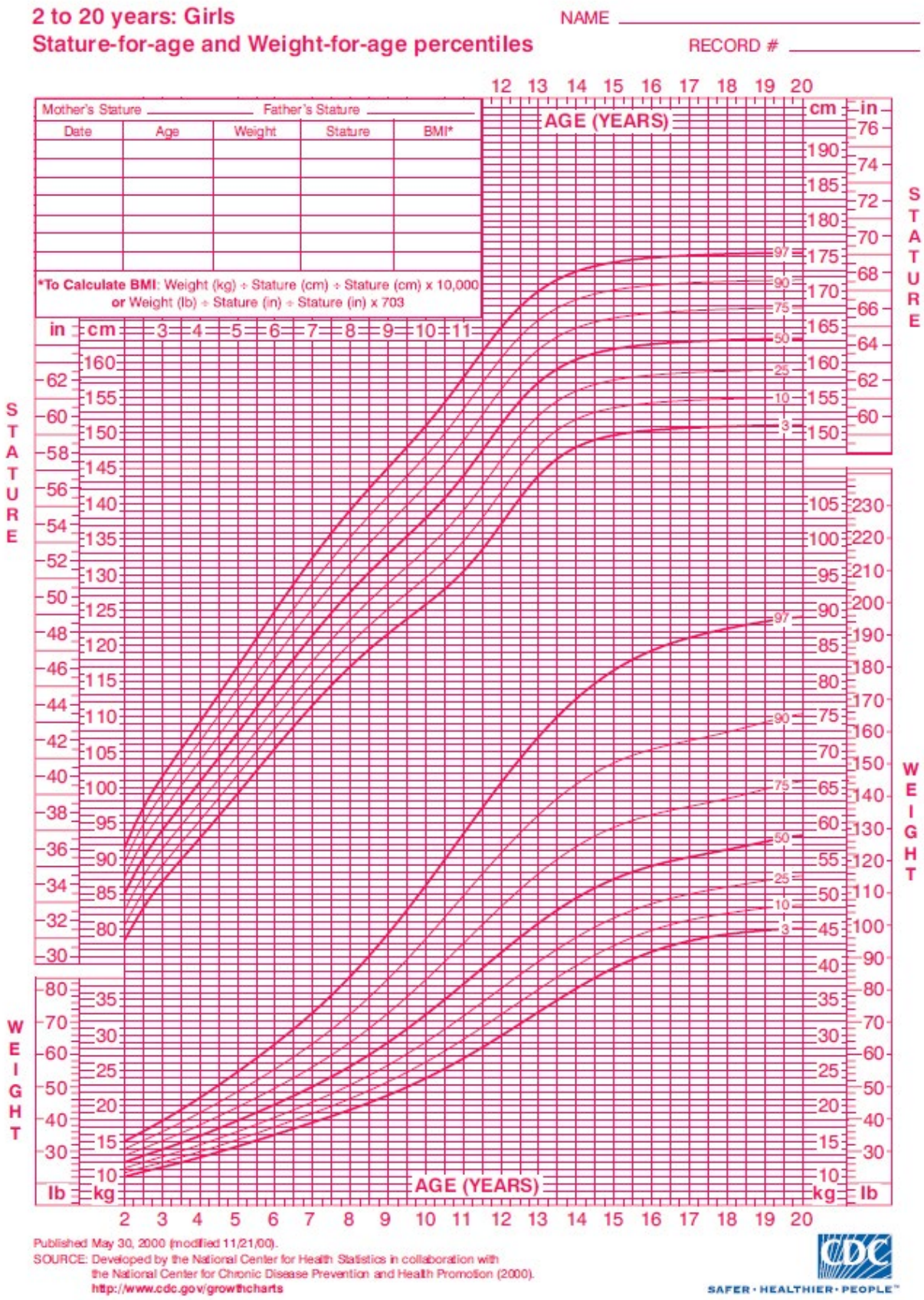

Figure 7: CDC growth charts for 2 to 20 year old girls, used by the Department of Health, Western Australia