

Contributed Articles

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Child restraints for cars in low and middle-income countries

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Key Findings

- Modern child restraints are designed to be compatible with modern cars such as those with ISOFIX/iSize and top-tether anchorages
- In low and middle-income countries (LMIC) most cars, including new models, do not have these advanced anchorage systems and many do not have seat belts in rear seats
- These LMIC vehicles can be retrofitted with rear seat belts and top-tether anchorages so that children can be safely transported in restraints appropriate for their age
- Schemes that encourage local automotive repair businesses to carry out these retrofits should be introduced in LMIC
- Low-cost child restraints with top-tethers and shoulder height labels should be encouraged

Abstract

When used correctly, modern child restraints provide exceptional protection for children in car crashes. Most vehicles sold in high-income countries (HIC) have top tether anchorages and/or ISOFIX lower anchorages that are intended to reduce the incidence of misuse, in addition to improving occupant protection. Most vehicles in LMIC do not have these features and many do not have seat belts in rear seats or have inferior lap-only seat belts in these seats. Children in these vehicles are at much greater risk of severe injury in the event of a crash. This paper examines ways to safely restrain children in these ill-equipped vehicles, mainly through retrofitting child restraint anchorages and seat belts.

Keywords

Child restraint, crashworthiness, seat belts

Introduction

Modern child restraints are designed to be compatible with modern cars that have i-Size anchorage systems (e.g. ISOFIX lower anchorages) or seat belts and top-tether anchorages (e.g. LATCH). These combinations provide exceptional crash protection for children as well as minimise risks due to incorrect installation in vehicles (Durbin, 2011). Most vehicles in LMIC do not have these modern features and many older vehicles do not have seat belts in rear seats or have inferior lap-only seat belts in these seats. Children in these vehicles are at much greater risk of severe injury in the event of a crash.

This paper examines ways to safely restrain children in these ill-equipped vehicles by drawing on experiences in Australia

in the 1980s and early 1990s when many ill-equipped vehicles were still in use on Australian roads.

Principles of child restraint

The principles for safe restraint of children in motor vehicles were described in an Australian in-depth study of children in car crashes (Henderson, 1994) and earlier research (Herbert et al., 1974):

- The child should be retained within the vehicle;
- The child's head and torso should be prevented from hitting the interior of the car;

Table 1. Risk of death or serious injury for a 3-4 year old child

Type of Restraint	Odds Ratio (3-pt seat belt = 1)	% Saved (if in child seat)	Reference
Child seat with integrated harness	0.22	0%	Abogast 2002
Booster with 3-point seat belt	0.55	60%	Durbin 2003, 2011
3-point seat belt	1	78%	Abogast 2002
2-point seat belt	2	89%	Abogast 2002
Unrestrained	3	93%	Durbin 2005

- The restraining systems in forward-facing devices should distribute the crash forces between the chest and pelvis, without heavy loading of other parts of the body.

Numerous studies have shown that it is very important that children be correctly restrained in safety devices that are appropriate for their age (Henderson 1994, Durbin 2005, Durbin 2011, Weber 2000). The following analysis considers children in the 3 to 4 year age range, which is when most children move from a child seat with integrated harness to a booster seat and adult seat belt, if one is available. It illustrates the benefits of remaining in a dedicated child seat for as long as possible. The analysis is based on a 2007 review of Australian child restraint laws by the National Transport Commission (NTC 2007) and data published by the US Centers for Disease Control and Prevention (CDC 2017). The baseline for the odds-ratio in Table 1 is the risk of death or serious injury for a 3-4 year old using a 3-point seat belt with no booster seat. The estimated savings in deaths and serious injuries (“% Saved”) are based on the risk for a 3-4 year old using a child seat with integrated harness since this is the safest configuration for this age group. For example, it is estimated that 93% of deaths and serious injuries could be prevented if unrestrained infants were properly restrained in a child seat with integrated harness. This is illustrated in Figure 1.

Rice and Anderson (2009) derive fatality risk ratios that are less than those in Table 1 but these are not directly comparable since they do not account for serious injury. The data presented in Table 1 are mostly based on crash data from the USA between 1990 and 2000 and include serious injuries. Modern cars in high-income countries are likely to be much safer than those in use during that period and so current effectiveness of child restraints in HIC may differ from those findings. However, the typical car now in use in LMIC is similar to those in the studies in Table 1 and therefore these data are considered relevant for the current analysis.

The safest configuration for an infant (age approximately 1 year to 4 years) is a child seat with integrated harness. The child seat needs to be securely anchored to the vehicle with a means to prevent it tipping forward (pitching) and so reduce head excursion and the risk of head and neck injury. This can be achieved by using a seat belt or ISOFIX lower anchorages to anchor the bottom of the child seat and a top tether to anchor the top of the child seat, as illustrated in Figure 2. This configuration has been used in Australia since the mid-1970s and has been found to provide exceptional protection (Henderson, 1994; Henderson et al., 1994; Brown et al., 2002; Paine et al., 2003). The use of a top tether provides much better protection than the use seat belts alone without another means of providing pitch control.

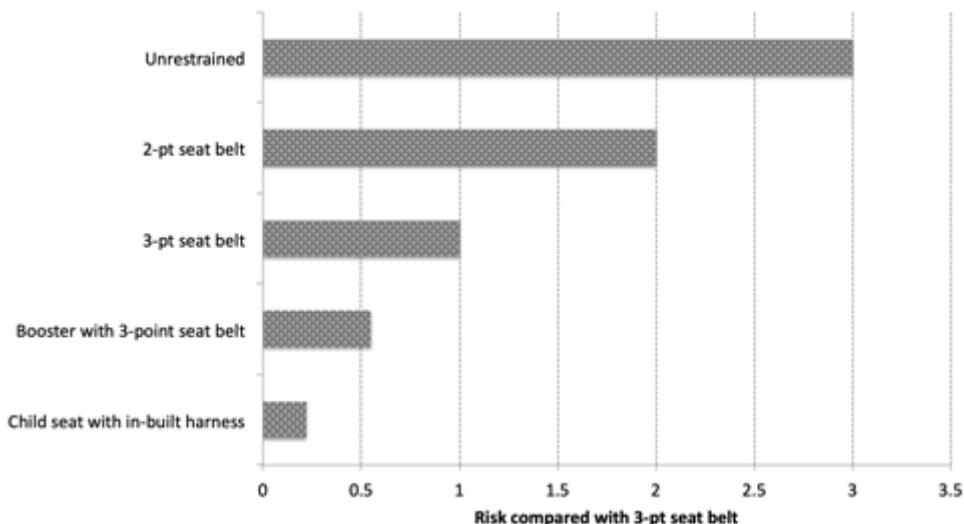
**Figure 1. Relative risk of death or serious injury for a 3-4 year old child**



Figure 2. Child seat with 6-point harness, anchored to vehicle with a top tether and seat belt

Child occupant safety in LMIC

In its 2018 Global Report on Road Safety, the World Health Organisation (WHO) lists the status of child restraint laws and usage rates for 181 countries (WHO 2018: Table A8). This indicates that only eleven out of about 150 LMIC have child restraint laws. Very few LMIC have any usage data and, where available, the percentage of children using child restraints is very low.

WHO/UNICEF reported that an estimated 262,000 children and youths aged up to 19 years died in traffic crashes in 2004 (Peden et al., 2008). It also reported that more than 90% of traffic fatalities occur in LMIC. Assuming that about 20% of the child/youth fatalities were in the one to four year age range and that around 30% of these were car occupants then it is estimated that in 2004 more than 14,000 children aged one to four died as car occupants in traffic crashes in LMIC.

Applying similar proportions to the estimated 10 million children aged up to 15 years who were hospitalised as a result of traffic crashes in 2004 (Peden et al., 2008) gives an estimated 675,000 children aged one to four who were seriously injured as car occupants in traffic crashes in LMIC. The actual number might be much higher than this because surveys from Africa and Asia that found for every child who died 254 children were presented to a hospital with injuries as a result of road traffic crashes (14,000 estimated fatalities times 254 equals more than 3 million serious injuries).

Most of these infant car occupants in LMIC would have been unrestrained (WHO, 2018). As shown in Figure 1, an unrestrained infant has a much higher risk of death or serious injury compared to an infant secured in a child seat with integrated harness. This suggests many child casualties in LMIC could be prevented by appropriate child restraint use. Child restraint use in LMIC may be improved via 1) equipping vehicles with child restraints and 2) assisting carers to acquire and use appropriate child restraints.

Equipping vehicles with child restraints

A child seat with integrated harness and top tether is intended for cars with 2-point or 3-point seat belts in the rear seat combined with a top tether anchorage. Seat belts and seat belt anchorages are specified in UN Regulations 14 and 16 and equivalent national regulations but WHO reports that around 70% of countries have not regulated for basic vehicle safety standards such as seat belts (WHO 2018). As a result many cars in LMIC have no seat belts in the rear seats and very few have top tether anchorages.

Most new cars that are designed for international markets already have provision for top tether anchorages. However new cars intended for domestic markets in LMIC are unlikely to have these anchorages. For example, Indian Automotive Industry Standard 72 specifies top tether anchorages but it appears that very few locally made cars in India have these anchorages (author's observations).

For those cars that do not have them, top tether anchorages are easily retrofitted to the rear parcel shelf of a sedan, as shown in Figure 2 (Henderson, 1994). There are simple installation solutions for other styles of vehicle. In Australia in the 1980s there was an extensive program of retrofitting top tether anchorages to vehicles. For example, in New South Wales, a network of "Restraint Fitting Stations" was established where private businesses such as automotive repair shops were trained and equipped for child restraint installation services, including retrofitting seat belts and top tether anchorages (Centre for Road Safety, 2017). These businesses also provide advice to clients on correct installation of child restraints. A similar system operates in the USA (<https://cert.safekids.org/find-tech-0>).

Other methods of preventing pitch rotation, such as support legs, are used in some regions but these tend to rely on ISOFIX lower anchorages that are not universally fitted. Furthermore, ISOFIX anchorages are not easily retrofitted to most vehicles. The preferred solution for most LMIC cars is to retrofit seat belts, where not fitted, and top tether anchorages.

Low-cost child restraints

Modern child restraints in HIC have tended to become relatively expensive, likely due to the addition of features or functions that are not directly related to safety. For example, many are promoted on the basis that they can be converted from one mode to another (e.g. rearward-facing to forward-



Figure 3. Early Australian child restraints - Safe-n-Sound Baby Capsule and Series 3 Child Seat with top tethers. The lap belt passes around the front of the Series 3 making it simple to install.

facing). This often involves compromises and tends to add complication to the design as well as increasing the risk of misuse. Evidently there is a need for simple, low-cost child restraints for widespread use in LMIC.

In Australia there have been at least two basic designs of child restraint that have proved to be highly effective in sled tests and real-world crashes but were relatively inexpensive to produce. These are the Safe-n-sound Baby Capsule and the Safe-n-Sound Series 3 child seat (Figure 3). They are

no longer in production but both appear to be well-suited to modern mass production techniques and could be considered as a basis for development of low-cost child restraints for LMIC (subject to patents and copyrights). The provision of low-cost child restraints is one of the strategies suggested by WHO to improve child occupant safety in LMIC (Peden et al., 2008)

In 2010 the Australian Standard for child restraints was revised to require shoulder height labels that indicate when a child is too small or too large for the restraint (Figure 4). These labels should be considered for child restraints in LMIC because they assist carers to select the appropriate type of restraint for the size of the child.

Summary of strategies to improve child occupant safety

A range of strategies should be considered in order to improve child occupant safety in LMIC. These include addressing shortcomings in regulations for new vehicles, retrofitting seat belts and child restraint anchorages to existing vehicles that lack these features, encouraging carers to use child restraints and giving guidance on the correct use of these restraints.

Child occupant deaths and serious injuries in LMIC may be prevented through the following steps:

Require all new light vehicles to be fitted with seat belts in accordance with UN Regulations 14 and 16 or equivalent

Where seat belts are fitted to rear seats, encourage the fitting of top tether anchorages to vehicles that do not have them

Where seat belts are not fitted, encourage the fitting of seat belts and top tether anchorages

Encourage schemes to support automotive repair shops and similar businesses that are able to retrofit top tether anchorages and seat belts to older vehicles



Figure 4. Shoulder height labels showing the size range for occupants.

Encourage the availability and purchase of child restraints with top tethers for use in vehicles with top tether anchorages and consider supporting the manufacture of simple, affordable child restraints with top tethers

Provide guidance to carers on the use of child restraints that are appropriate for the size of the child and consider the introduction of shoulder height labels to assist in correct selection of child restraints for the size of the child.

Conclusions

Many old and new vehicles in low and middle-income countries are unsuitable for safely transporting children due to a lack of seat belts in rear seats. Many also lack upper anchorages for top tethers or other means to secure child restraints and reduce head excursion. Many deaths and serious injuries could be prevented by addressing these shortcomings and by encouraging carers to acquire and correctly use child restraints.

This situation is similar to that in Australia in the 1980s and 1990s and some of the strategies introduced in Australia at that time can be applied to child occupant protection in LMIC. In particular a program for retrofitting seat belts and top tether anchorages through a network of approved automotive repair businesses could be implemented. This network could also provide guidance to carers on the correct use of child restraints.

In addition there is a need for low-cost child restraints with top tethers and shoulder height labels for use in these upgraded vehicles. This would provide a level of protection approaching that of child restraint systems in use in high-income countries.

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This document represents the author's views and does not represent the views or policies of any organisation. The advice and recommendations provided in this paper are of a general nature. Always check with local authorities when considering the restraint of children in vehicles.