

Special  
issue  
Child safety

Vol 23 No 2, 2012



# Journal of the Australasian College of Road Safety

Formerly RoadWise — Australia's First Road Safety Journal



## Special issue - Child safety

### Contributed articles

- Bicycle safety for children and young people: An analysis of child deaths in Queensland
- A review of evaluations of bicycle safety education as a countermeasure for child cyclist injury

### Peer-reviewed papers

- Understanding the challenges facing child pedestrian trauma in Victoria 2000-2010
- Analysis of child pedestrian deaths and serious injuries in Malaysia
- Child occupant protection in Australia
- A cross sectional observational study of child restraint use in Queensland following changes in legislation
- Age-based selection of child restraints
- Prevalence of mobile phone vs. child-related driver distraction in a sample of families with young children

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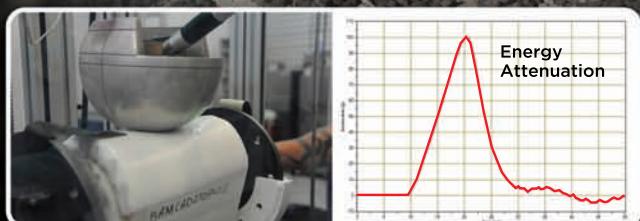
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**Cover photo:**

Ensuring the safety of children in the road environment is vital. Photo by Paha\_I (licensed for use by Dreamstime.com)

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**The Journal of the Australasian College of Road Safety**

(published as **RoadWise** from 1988-2004)

ISSN 1832-9497. Published quarterly by the Australasian College of Road Safety

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The College encourages interested persons and organisations to submit articles, photographs or letters for publication. Published letters would normally show the name of the writer and the state or territory of

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## From the President



Dear ACRS members,

In April, together with our Executive Officer, Claire Howe, and CEO of Kidsafe ACT, Eric Chalmers, I met with our patron, Her Excellency Ms Quentin Bryce, the Governor-General, at Government House.

We provided an update on the work of the College since we last met in April 2009 and on real progress in reducing road trauma as a result of so many efforts since that time.

We agreed there was more to do and that it was vital to have commitment to an overarching strategy such as the Safe System approach. The Governor-General was particularly interested in, and supportive of, our recent fact sheet on rural road safety which I would encourage you to circulate to local councils and community groups. Equally, she was supportive of the work of Kidsafe, as she had had considerable experience with this project in Queensland.

There was an appreciation that specific, well-identified, safety-related projects, under an umbrella of the Safe System

approach, had contributed to the recent general reductions in road trauma. Not that there is not more to be done. This special issue of the journal – guest edited by Professor Mark Stevenson - focuses specifically on issues, research and programs relating to child safety. When using the road transport system, our children are particularly vulnerable and are known to be at higher risk than most other road users. Child safety is an important area where we have made good progress and where we are translating that experience to other countries. At the end of May, I will participate in the Global NCAP support of a new car safety assessment program (ASEAN NCAP) in Malaysia. ANCAP will assist in transferring knowledge to ensure child safety is also assessed.

As we approach our ACRS conference in August, I encourage you to register. I also ask you to encourage colleagues and, importantly, others who have an interest and/or a role in road safety related activities to join us. Spreading the message widely will help us reduce road trauma.

*Lauchlan McIntosh AM FACRS  
President*

## Guest editorial – Professor Mark Stevenson



*Professor Mark Stevenson is an epidemiologist and the Director of the Monash University Accident Research Centre at the Monash Injury Research Institute. Professor Stevenson has extensive research experience in road trauma and public health. He applies epidemiological research methods - traditionally used to study disease in populations - to the study of injuries and their underlying causes and distributions within larger systems, so as to inform and effect change in public policy and practice. Mark is a member of the ACRS Executive Committee and a lifetime Fellow of the College.*

### Australian children: the most vulnerable on our road network

Over the past ten years, road fatalities involving children have declined by 5%[1]. Yet, despite the decline, children - whether a toddler in a child restraint, a child walking to school, or a teenager cycling - remain at an increased risk of injury when actively engaging in the road transport system. Importantly, what the reported decline in child road fatalities hides is the fact that using fatalities as a measure of success in relation to child road safety is not robust (due in part to the small numbers) and that the trend does not reflect changes in travel exposure over the period which, in the absence of comprehensive exposure

data, may merely reflect a reduced exposure to transport modes such as walking or cycling.

In this issue of the journal we focus on child road safety, with the respective papers covering topics such as child restraint use, child pedestrians, cycling and the use of legislation to support compliance with road rules governing a child's safety. What is striking from reading these papers is the ongoing opportunity to obtain measurable reductions in child road injury. Another important opportunity, although not captured in the current proffered papers in this series, is the role urban form can play in reducing child road injury.

At the time of writing this editorial, the COAG Reform Council released its report on the strategic planning systems of Australia's capital cities.[2] One of its recommendations was that cities needed to place greater emphasis on public transport and to integrate transport planning with land use decisions. This is certainly not a new finding, but it highlights again how land use decisions influence travel behaviours. We are well aware that low-density, single use, large area zoning usually found in most suburbs across our capital cities limits the ability of children and adults to walk or cycle for their daily travel requirements and that the location of suburban developments away from major activity centres results in reliance on the private car thereby decreasing the use of other travel modes, particularly public transport and active transport opportunities.[3] Given the well-documented relationships

between urban form and health outcomes besides road injury, such as cardiovascular disease [4] and respiratory illness, [5] more effort needs to be placed on ensuring Australia's urban form is conducive to safe active transport.

At the Accident Research Centre, we are about to initiate a cycling study; the study will provide a comprehensive understanding of the influences of urban form and how it affects the behaviour of cyclists as well as providing information on the interaction of cyclists with other road users. This information is required to develop and implement effective and appropriate real-world solutions providing a more 'crashworthy' travel environment for cyclists, with improved infrastructure and facilities. These include (i) measures to reduce vehicle travel speeds when cyclists are present, (ii) separation of vehicular and non-vehicular traffic in critical locations, (iii) improvements to intersection operation and design, and (iv) creation of convenient, continuous and sustainable bicycle-inclusive infrastructure and cycle networks. Importantly, this work needs to influence the strategic plans of our capital cities so that an efficient and safe transport system can be provided for the most vulnerable road users – Australian children. I urge you to consider how best we can advocate for land use decisions that will have demonstrable benefits in terms of travel behaviours for Australian children.

*Professor Mark Stevenson*

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## Diary

**9-10 August 2012, Sydney.** 2012 ACRS National Conference 'A safe system – Expanding the reach'. [www.acrs.org.au/activitiesandevents](http://www.acrs.org.au/activitiesandevents).

**29-31 August 2012, Groningen, Netherlands.** 5th International Conference on Traffic and Transport Psychology.

**6 September 2012, Brussels, Belgium.** BESTPOINT Final Conference.

**20-21 September 2012, Gold Coast, Queensland.** Occupational Safety in Transport (OSIT) Conference. <http://ositconference.com>.

**1-4 October 2012, Wellington, New Zealand.** World Health Organization Safety Conference. [www.conference.co.nz/worldsafety2012](http://www.conference.co.nz/worldsafety2012).

**4-6 October 2012, Wellington, New Zealand.** Australasian Road Safety Research, Policing and Education Conference. <http://rsw2012.transport.govt.nz>.

**1-2 November 2012, New Delhi, India.** 7th IRF Regional Conference - Road Safety in urban and rural roads.

**25 –28 August 2013, Brisbane, Queensland.** T2013: the 20th International Council on Alcohol, Drugs and Traffic Safety Conference.

# College news

## College delegates meet the Governor-General



*From left: Kidsafe CEO, Mr Eric Chalmers; Her Excellency, the Governor-General, Ms Quentin Bryce; Mr Lauchlan McIntosh and Ms Claire Howe from the ACRS*

On 16 April, ACRS President Lauchlan McIntosh and ACRS Executive Officer Claire Howe, accompanied by Kidsafe CEO Eric Chalmers, met the Governor-General and ACRS patron, Her Excellency Ms Quentin Bryce, at Government House. The meeting was extremely positive and the discussion diverse.

Lauchlan McIntosh was pleased to report that, since last meeting with the Governor-General in 2009, the annual number of deaths on Australian roads had fallen from around 1450 to 1300; however, while progress has been made, there is still much to be done. Her Excellency was generous with her time, enabling discussion of a wide range of issues, including

- acknowledgement of the enormous impact of road deaths and trauma on families and communities, together with associated financial costs
- the ACRS focus on communication, networking, professionalism and advocacy across all spheres of road safety to save lives and reduce injuries on our roads
- an increase in the breadth of ACRS membership, encompassing government organisations, multiple community groups, research organisations and many others
- the strong support provided by the ACRS for many road

safety initiatives such as the Australian Government's introduction of a 5-star rated safety fleet

- reporting on various college activities in conjunction with the UN Decade of Action and the NRSS, the annual ACRS conference, the ACRS Weekly Alert, the 3M-ACRS Diamond Road Safety Award and the ACRS Journal.

The Governor-General was impressed by, and very supportive of, the extensive work of members of the College which is focused on improving our national road safety record. Ms Bryce was keen to encourage the College to work together with other community groups, particularly in rural and regional Australia, to promote the Safe System approach in this Decade of Action for Road Safety. 'We can all be encouraged that our patron . . . will be helping us carry our messages to the wider community. All members should take inspiration from (her) ongoing support and encouragement in our endeavours to save lives and injuries on our roads', Mr McIntosh said.

The Governor-General will provide a video address to delegates at the 2012 ACRS National Conference in Sydney in August.

## Welcome to Silver and Bronze members 2012

The College offers different levels of corporate membership – Bronze, Silver, Gold and Platinum. These memberships offer additional benefits as a means of recognising and thanking member organisations which provide additional, and highly valued, financial support to the College.

The ACRS welcomes and thanks the following corporate members:

- ARRB – Silver membership
- Queensland Police Service - Silver membership
- Department of Planning, Transport and Infrastructure, SA – Silver membership
- SUNCORP – Bronze membership
- Mornington Peninsula Shire, Victoria – Bronze membership
- Commission for Children and Young People and Child Guardian, Queensland – Bronze membership
- Territory Insurance Office, NT – Bronze membership.

More information about the levels and benefits of corporate membership can be found at [www.acrs.org.au/membership/corporate-membership/](http://www.acrs.org.au/membership/corporate-membership/).

## AGM 2012

The Annual General Meeting of the ACRS was held via teleconference on 15 May 2012. A Special Resolution was passed to ratify a number of changes to the ACRS Constitution and members of the Executive Committee were elected/re-elected. Mr Lauchlan McIntosh continues as President, with Professor Barry Watson and Mr David Healy continuing as Co-Vice Presidents.

The Committee acknowledges and conveys special thanks and appreciation to **Mr Jeff McDougall**, outgoing member and Treasurer, who is retiring from the Committee after 15 years of dedicated service to the College. Ms Liz de Rome replaces Jeff in the Treasurer's role, while Dr Jeremy Woolley replaces Dr Stephen Jiggins as Secretary. Welcome to new member Ms Jess Truong who replaces David Healy as Chapter Representative for the Victorian Chapter.

## Decade of Action and NRSS 1st anniversary

Friday, May 11 marked the end of the first year of the UN Decade of Action for Road Safety, the global initiative which aims to reduce the number of people killed and injured on the world's roads. It was also the first anniversary of Australia's National Road Safety Strategy (NRSS). The College marked the occasion with a round-table forum at Old Parliament House

in Canberra, organised jointly with the Australian Road Research Board (ARRB) and bringing together many of the individuals and organisations whose work is key to achieving success.

The Hon. Catherine King, Parliamentary Secretary for Infrastructure and Transport, was among the speakers who addressed the forum. Ms King referred to the immense scale of the worldwide problem of road trauma and the imperative to reverse the global trend, noting that Australia has both the capacity and the responsibility to make an important contribution to the solution. Ms King provided information about the current national and global situation, reiterating her commitment to promote and implement road safety initiatives which will help reduce deaths and injuries on the roads.

## 3M-ACRS Diamond Award winner 2011 – Visit to Florida and Project RAPTAR update

Sergeant Michael Musumeci of Ravenshoe Police in Queensland, who reported on his community's award-winning RAPTAR project in the last issue of the journal, travelled to Tampa, Florida, in February to attend the 42nd American Traffic Services Association Annual Convention and Traffic Expo. Sergeant Musumeci wrote to the College, expressing his appreciation for the opportunity to experience this event and the valuable knowledge he gained in many aspects of traffic enhancement and road safety technology.

Since his trip, Michael has been invited to speak at a number of forums in Queensland to spread the word about RAPTAR and help others to address similar road safety concerns. Michael also reports that the RAPTAR team have extended their project to investigate and apply their successful '3E' formula to neighbouring areas in the southern tablelands, including one 'blackspot' where a number of fatalities have occurred on a remote section of highway. The RAPTAR team have also joined other community representatives in a campaign designed to focus attention on the dangers of texting while driving, targeting young drivers in particular. They have obtained the support of a number of local schools to promote their message and have distributed 40 signs with the slogan *Stay alive, Don't text and drive*. Michael reports that RAPTAR members are committed to keep working with the community on projects like these to improve road safety awareness and ultimately save lives.

## Chapter Reports

### New South Wales

In the last Chapter report, I reported that we were planning a *Media and Morality* seminar, run in partnership with the St James Ethics Centre. This event took place in March and proved to be a stimulating seminar that attracted much interest.

The seminar was filmed in its entirety by UNSW TV and now features as an iTunes Luminary Speakers podcast (<http://itunes.apple.com/WebObjects/MZStore.woa/wa/viewPodcast?id=423492512>) and also on YouTube (<http://youtu.be/UUFREW-ttbM>). It has also been shortlisted for screening on the ABC Big Ideas program. I reiterate my thanks to the seminar panellists: Dr Simon Longstaff, Executive Director, St James Ethics Centre; Dr Soames Job, Executive Director, National Road Safety Council; Jonathan Holmes, Host of *Media Watch*; and Jacob Saulwick, Transport Reporter, *Sydney Morning Herald*. Many thanks also to Lori Mooren, the key force behind this successful seminar, and to Ruth Lillian for her organisational assistance.

Following this, the Chapter's AGM was held on April 24, including election and re-election of Chapter Executive positions. Outgoing were three longstanding members to whom, on behalf of the Chapter, I extend sincere thanks for the many years of rotating positions on the Executive. These outgoing members are **Lori Mooren**, who is especially acknowledged as establishing our Chapter, **Peter Croft**, and **Professor Raphael Grzebieta** (who currently retains a position on the National Executive). Thank you for your years of service and commitment to road safety.

Incoming, we warmly welcome **Dr Julie Brown**, Research Fellow, Neuroscience Research Australia, **Anne Deans**, Chief Executive, Youthsafe, and **Arnold McLean**, Senior Partner, McLean Technical Services. I look forward to the new perspectives this will bring to the Executive.

Finally, we are now in the throes of reviewing and selecting papers for presentation at our 2012 ACRS National Conference to be held in Sydney, August 9-10. I therefore also extend thanks to members from around Australia and New Zealand for engaging in this process. We hope to finalise initial reviews and post a preliminary program on the conference website (<http://acrs.org.au/events/2012-acrs-conference/>) by the end of May. We trust this will prove to be a stimulating program and hope that you will be able to attend.

*A/Prof Teresa Senserrick, NSW (Sydney) Chapter Chair and Representative on the National ACRS Executive Committee*

## Victoria

The Victorian Chapter has enjoyed a successful year with the conduct of the national conference and the staging of three seminars - fewer than normal in light of the resources devoted to the staging of the conference.

Two seminars covered the issues of alcohol and road trauma, and the influence of parents on the safety of young people. A third is planned on the incidence of unlicensed driving – prevalence and countermeasure options. Presenters have hailed from a range of backgrounds including academia and government, with a special focus on gaining perspectives from outside the road safety field. To this end, we are grateful for

presentations from the Australian Drug Foundation and the Parenting Research Centre. The Chapter is very grateful to all presenters who so freely gave of their time to prepare and present on a range of safety issues of special interest to our members, and to VicRoads for its sponsorship of the parenting seminar.

The Chapter is very interested in building its active membership and, to this end, is developing a plan to further recruit interested members from both the public and private sectors to help develop a future program of dynamic and attractive events for the Victorian membership. We recognise that we need to encourage young and enthusiastic people to become members of the Victorian chapter to bring fresh ideas and ensure the College and the services it provides to its members continue to grow and be relevant.

*David Healy, ACRS Co-Vice President and outgoing Victorian Chapter Representative*

*Editor: Since submitting this report, David Healy has resigned from the role of Chair of the Victorian Chapter. We thank David for his wonderful work on behalf of the Chapter and welcome Jessica Truong to the position.*

## Queensland

The Queensland Chapter held its March quarterly seminar and Chapter meeting on Tuesday, 13 March 2012. The seminar *Younger and older drivers: What contributes to their risk?* was presented by Dr Mark King and Ms Bridie Scott-Parker, CARRS-Q. The presentation focused on the crash involvement and risk factors of both younger and older drivers. The presenters discussed how both older drivers and younger drivers tend to be at fault in their crashes, but for different reasons. Young drivers exhibit risk-taking behaviours, while older drivers are dealing with impaired physical and cognitive abilities. For example, they exhibit less ability to deal with information and make decisions such as detecting hazards and reacting appropriately.

The Queensland Chapter has continued to play a key role in the UN Decade of Action for Road Safety. This year, to mark the first anniversary of the launch, a special breakfast was held at Conrad Treasury Casino. The seminar featured a presentation by Professor Fred Wegman, Director SWOV entitled Dutch approach to sustainable road safety and resource management. Professor Wegman also gave a special ACRS seminar presentation entitled International Priorities in Road Safety Research.

I look forward to continuing to provide members with opportunities to meet and discuss current and emerging issues of importance to road safety.

*Dr Kerry Armstrong, Queensland Chapter Chair and Representative on the ACRS Executive Committee*

## South Australia

The South Australian Chapter has been active over the past year with its main activity being Lunchtime Dialogues, which continue to be the foundation events for the SA Chapter. A total of six dialogues have been held on various topics including:

- *Road Safety Education: directions for the future* - Simon Raftery (CASR)
- *Mobile phones and driving* - Dr Lisa Wundersitz(CASR) and Michael McGlashan, (Telstra)
- *Decade of Action in Road Safety RAA in Asia Pacific* - Nana Soetantri (RAA)
- *Motorcycle safety campaigns* - Richard Blackwell (Motor Accident Commission) and Neville Gray (OAM)(Motorcycle Riders' Association)
- *Royal Institution of Australia* (RiAus) - Stephan Kern and Ben Lewis (RiAus)
- *SAPOL Road Safety Strategy (2011-2014)* - Superintendent Linda Fellows (Traffic Support Branch, SAPOL)
- *The National Road Safety Council* - Dr Soames Job, and Measurement of on-road exposure - Chika Sakashita

The Chapter has also associated itself with the joint promotion of other road safety related seminars including an upcoming *Motorcycle Safety* seminar by the Institution of Engineers Australia (IEAust) in May and a joint CASR/MUARC seminar also in May. With the IEAust event, a deal was made for ACRS members to register at the same rate as IEAust members. I have also been negotiating the coordination of event calendars between ACRS and the Australian Institute of Traffic Planning and Management so that there are no unnecessary overlaps or clashes with seminars.

There have been a few changes to the committee and I would like to thank outgoing members Nana Soetantri and Linda Fellows for their contributions. I would also like to thank Ross McColl for his great work behind the scenes, Emily Cornes as treasurer and DPTI for the use of their facilities.

Finally a big thank you to the Motor Accident Commission who provide us with sponsorship and allow the dialogues to be provided to the road safety community free of charge.

*Dr Jeremy Woolley, SA Chapter Representative*

## Other news

### New driver medical standards

Amended medical standards for assessing drivers were introduced in March. The new standards were developed to ensure that all drivers are medically fit to drive safely. The standards were revised after consultation with medical professionals, industry bodies and drivers. They provide guidance to health professionals and driver licensing bodies on

the health assessment of private and commercial drivers of heavy vehicles, light vehicles and motorbikes. The National Transport Commission (NTC) reported that the amendments result in a system that focuses on how a person's medical condition affects their driving and their ability to drive safely, rather than the diagnosis of that condition. Other notable changes include improved guidance for health professionals regarding multiple medical conditions and age-related change.

A new publication produced by the NTC and Austroads, *Assessing Fitness to Drive*, can be downloaded from the Austroads website: <https://www.onlinepublications.austroads.com.au/items/AP-G56-12>.

### Retirement of Joe Motha

Joe Motha, a longstanding and dedicated advocate for road safety, has retired from the Department of Infrastructure and Transport. Joe joined the (then) Department of Transport in 1987, and in his time with the Department had a number of roles in areas such as Maritime Policy and the (then) Bureau of Transport Economics.

Joe authored a number of papers and reports on a range of issues including transport safety, road crash costing, valuation of human life in economic analysis, and transport-related environmental issues. He is best known for his untiring commitment to advancing road safety. In particular, he is acknowledged for his personal leadership and contribution to the development of the National Road Safety Strategy, thus helping to shape road safety policy for all Australians in the next ten years.

### Vale Jeremy Bowdler



Jeremy Bowdler, who died in March 2012

Jeremy Bowdler, long time motorcyclist and editor of *Two Wheels* and *Scooter* magazines, passed away on Tuesday 21 March. Aged just 52, his untimely death from a sudden illness has shocked his many friends and admirers.

Jeremy was the editor of *Two Wheels* for over 20 years, and foundation editor of *Scooter*, having recognised that scooter riders had different needs and interests to those of motorcyclists. He was also a classics scholar from University of Sydney, fluent in Latin and Classical Greek, reputedly a great cook and all round Renaissance man.

As editor, he broke new ground for motorcycle magazines in actively promoting rider safety. *Two Wheels* became the most widely read motorcycle magazine in Australia. From occasional safe riding tips, he progressed to detailed articles about different aspects of riding, understanding the risks and learning to manage them. Jeremy placed a high value on facts and wrote thoughtful articles combining evidence from road safety

research with his own substantial riding experience. The articles written for new riders were outstanding. Never patronising, he described the riding experience in ways that made it easier to absorb and apply his advice. The same articles also held resonance for more experienced riders, either reinforcing knowledge or challenging perspective. His last two articles, published posthumously, were about riding in the rain and merging in traffic.

Jeremy was generous in sharing his wealth of knowledge about motorcycles and riding. He was open-minded and patient in discussing issues affecting riders to those researchers fortunate enough to have found him. He was forensic in his search for evidence but, once convinced, had the courage of his convictions; he was not restrained by fear of retribution from readers or advertisers. He was influential in motorcycle circles because of this integrity.

I personally learned and gained a lot from knowing Jeremy. In particular, for reviewing and editing *The Good Gear Guide* with a deft touch, making my academic language more accessible for the audience that he knew so well. Some of those who work in motorcycle safety research and policy areas may be less aware of his contribution to this field. We all owe a debt to Jeremy Bowdler, who has reviewed and supported our efforts from the side. His contribution should be acknowledged, and now he will be greatly missed.

*Liz de Rome*

## Child safety news

### Changes to Australian Road Rules - seatbelts for children travelling in taxis and minibuses

The National Transport Commission (NTC) reports that drivers of taxis and public minibuses will be required to ensure that children are properly restrained while travelling in their vehicles. The Standing Council on Transport and Infrastructure, which comprises state, territory and federal transport ministers, approved a range of amendments to the Australian Road Rules late last year, including the required use of seatbelts for children who are covered by the existing exemptions to the use of child restraints in taxis and minibuses.

The NTC regards the changes as vital to ensure the Australian Road Rules (model rules on which the road rules for each state and territory are based) keep pace with best practice in road safety and continue to meet the needs of all road users. The amendments come into effect once they are implemented by state and territory governments. See more at [www.ntc.gov.au](http://www.ntc.gov.au).

### NSW driveway safety campaign

Child road safety is a key area of road safety in New South Wales. The NSW Government has a number of programs in place for children, including a road safety education program in schools. This has a large age-appropriate curriculum, along with

an extensive safety around schools program, including 40 km/h school zones, flashing lights and school crossing supervisors. Another key component is the Child Restraint Evaluation Program (CREP) which tests the occupant protection of child restraints and regularly publishes updated guides for buying the safest child restraints. The program also has a dedicated website [www.crep.com.au](http://www.crep.com.au).

Recently, NSW embarked on a new focus area - driveway safety. When we hear about a child being injured or killed in a driveway, it is heartbreaking - for the families and the broader community. A recent project undertaken by *The Daily Telegraph* with support from Transport for NSW is the *Driveway Safety* campaign. Creating awareness and having systems or rules around driveways can prevent a crash occurring. The *Daily Telegraph* campaign was successful in raising awareness and disseminating sound messages to help prevent these tragic crashes. The campaign was developed to raise awareness about how to better protect children from a driveway crash and included a sticker that can be placed in a vehicle as a reminder to drivers about being vigilant in looking out for children and driving safely at all times in and around driveways. Applying the sticker to the front and back of the car creates a conversation for parents, carers and families about the issue and also acts as a daily reminder to think about the safety of children.



Vehicle sticker used to promote awareness of driveway safety

The *Driveway Safety* campaign also reminded the community of the importance of taking steps to reduce the risk of a child being hit in a driveway. Parents are advised:

- Hold your child's hand, or hold them close, around driveways or other areas where a car is being moved.
- If you are in the car, make sure another adult is protecting young children close by.
- If you need to move a vehicle and there are no other adults at home, place your children securely in the vehicle with you.
- Separate play areas from the driveway and garage.
- If you have a reverse camera or sensor, don't just rely on it, as children move quickly.
- Always drive slowly and be on the lookout for kids around driveways.

The uptake of this sticker has been well received among the community. The NSW Centre for Road Safety will monitor the effects of this campaign.

*Troy Griffiths, Senior Project Officer, NSW Centre for Road Safety*

## Walk Safely to School Day

National Walk Safely to School Day (NWSTS), now in its 13th year, is an annual event held around Australia to encourage primary school-aged children to walk all (or part) of the way to school, combining walking with travel by public transport where necessary, instead of being driven by private car. The event is designed primarily to promote healthy lifestyle habits while at the same time teaching children critical road-crossing skills and raising community awareness of child pedestrian safety. It is also aimed at reducing car dependency and hazardous traffic congestion around schools. This year's event took place on Friday, May 18. More information about this annual event can be found at [www.walk.com.au](http://www.walk.com.au).

## New Zealand trial of safer speeds around rural schools

In June, the New Zealand Transport Agency (NZTA) will commence a trial of variable speed limits outside a number of New Zealand's rural schools. The trial has been prompted by concern that school drop-offs and pick-ups often take place in high speed traffic environments. Investigations have shown that children are most at risk during peak periods when vehicles are turning into, or coming out of, school grounds. The trial will investigate whether safer speeds are feasible and whether a safer environment can be created for children during these busy times.

The first step is the introduction of permanent 80 km/h speed limits outside four of the five schools participating in the trial. The next stage will be the installation of 'variable message' signs (VMS) outside the participating schools, similar to VMS operating in urban areas; these will display the variable speed

limits applicable during students' peak arrival and departure times. The trial is expected to continue for the next two years, during which traffic speeds and driver behaviour around the schools will be monitored to assess the effectiveness of these measures. The trial is part of the NZTA's commitment to the New Zealand Government's *Safer Journeys* road safety strategy which is based on the Safe System approach. More information can be found at [www.nzta.govt.nz/about/media/releases/1964/news.html](http://www.nzta.govt.nz/about/media/releases/1964/news.html).

## NRMA promotes safe cycling for kids through helmet artwork competition

Young artists from primary and high schools throughout NSW and the ACT have been invited to enter a competition to create artwork suitable for a bicycle helmet. Students will have the opportunity to create a helmet design that they would be happy to wear themselves, helping to dispel the idea that bicycle helmets are not 'cool'.

NRMA President, Wendy Machin, said the NRMA was working with Bicycle NSW to sponsor the competition. The winning design will be reproduced on a helmet to be sold as a limited edition. The NRMA hopes the competition will be used in schools as a classroom activity to stimulate discussions, to get children thinking about safety, and particularly to increase children's use of helmets when riding their bikes. The competition is supported by free road safety education resources created as part of the *Be Road Safe Ready* program for schools, featuring NRMA Road Safety Roadbots, Norman and Norma. More information can be found at [www.mynrma.com.au/helmetcomp](http://www.mynrma.com.au/helmetcomp).

# Letters to the Editor

### *Dangers for children travelling in Victorian and NSW Government contracted school buses*

Dear Editor,

I am writing to strongly emphasise the important issue of children's safety when travelling in rural school buses on regional roads and highways in Victoria and NSW. I have met with Victorian Transport Minister Mulder and senior police, and made submissions to coroners and numerous authorities on this issue. Specifically, I have expressed my concern regarding the failure of past and present Victorian and NSW Governments to demand ADR68 Bus Standards in rural and contract school buses.

Successful negotiations with other state governments gained full ADR68 safety, such as seatbelts, seat back heights and anchorages, rollover protection, emergency exits, etc.

Most rural school buses travel in speed zones ranging from 80 km/h to 110 km/h including many 'high risk' rural roads. Pupils travel without any real protection in the event of a crash. Their only protection is that no crash or sudden braking occurs.

In addition to the tragic impact of road trauma on families and communities, a single severe bus crash can and has resulted in costs of multi millions of dollars.

I am concerned specifically that

- Children are travelling in school buses without seatbelts.
- Buses have low-back seats and are fitted with non-compliant skull-cracking hand grips, inadequate seat anchorages and outdated flammability standards.
- Buses carry 3 for 2 seating in excess of the allowable adult passenger load, with children also travelling in crowded aisles in NSW (standing pupils are not permitted in seatbelted vehicles including buses).
- These school buses only need comply to 1986 ADR58 Standards, exempted only for urban route bus usage, as their structures need not withstand crashes or protect passengers in speed zones above 80 km/h as proven by many casualties.

The Victorian Chief Investigator's report into the Nullawarre school bus crash which occurred in November 2009 (in which a school bus carrying children from Nullawarre Primary School collided with a truck at an intersection near Warrnambool) indicated that this vehicle, like about 1600 Victorian Government contract school buses, had no specified minimum passenger safety standards then, and still do not now. Two children were severely injured in the 70 km/h crash, one receiving permanent brain and physical damage. The report said that had the bus interior been constructed in accordance with ADR 68, the lap sash seatbelts, required seat anchorage strength, seat back height and padding would have reduced the critical injuries and prevented pupils being hurled around or out of the bus.

The independent Chief Investigator confirmed this 1994 school bus had structure and fittings with Standards made about 30 years ago when all heavy vehicles were prohibited from travel at over 80 km/h, and buses restricted to 70 km/h maximum speed. Even about 1500 Victorian school buses, new since 1995, are not required or capable to protect passengers in crashes in already increased speed zones from 80 km/h up to 110 km/h with traffic including semitrailers, timber trucks, petrol tankers and buses.

Recently in May 2012 at Kyabram, Victoria, a seatbelted school bus collided head-on with a petrol tanker. There were no instant fatalities, but a young girl has severe head injuries. In other

Victorian rural school buses which have only suburban safety standards, a tragedy on a larger scale could easily occur.

Urgent remedial action is required to remove these inexcusable safety risks to our school children. I strongly urge governments to demand federal and state funding and insist on ADR68 seatbelted safety standards for school buses. Funding should be sufficient to ensure that adequate protections are built into new buses, and existing buses able to be retrofitted.

**Leon Hain** Life MPS MACRS

Doncaster VIC

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**Have your say.** The ACRS Journal provides a medium for the expression of views and the sharing of information on all aspects of road safety. Readers are welcome to submit letters for consideration for publication in the Letters to the Editor section of the journal. Letters may be on any road safety issue and should be no more than 600 words in length. Write to the Managing Editor at PO Box 198, Mawson, ACT 2607 or email [journaleditor@acrs.org.au](mailto:journaleditor@acrs.org.au).

*Views expressed on the Letters page are not necessarily those of the ACRS.*

# Literature review

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Recent reports reviewed by Road Safety Literature Editor, Andrew Scarce

## **Belgian study shows that traffic infrastructure influences parents' choice of travel mode to and from school**

A Belgian study has shown that the decline in the numbers of schoolchildren cycling and walking to and from school is linked to parental perceptions of how safe the environment is. The study investigated the reasons why, when compared to 20 years ago, more parents are opting to transport their children to school in cars. This trend is seen as negative because it implies more traffic on the roads and deprives children of the health benefits of walking or cycling to school. Autonomous travel by foot or bicycle has been shown to enhance children's motor system development, stimulate the development of their social identity and improve their physical condition.

The study follows previous research from a number of academics, including a 2006 study which highlighted several reasons for increased car dependency, such as higher levels of car ownership, greater complexity in lifestyle, increasing time pressure and parental concern about children's safety.

The study was concentrated on Flanders in northern Belgium, where 150 elementary schools were selected randomly and asked to distribute a questionnaire to the parents of pupils aged 6 to

12 years. The study found that, in this age group, travel mode is largely a parental decision and that parents' perception of the relative safety of the traffic environment is one of the most important factors in their decision-making. The study found that the presence of a bicycle or pedestrian lane – creating physical separation of the child and motor vehicles - is perceived to be a more effective safety measure than lowering speed limits.

The study findings also indicated that parents will, in the main, let their children cycle or walk to school only in what they perceive as well-known areas (ie. nearby and school areas). According to the study, parental perception of the traffic environment differs according to the age of the child, road type, travel mode (cycling or walking) and the perceived safety in 'nearby areas'. While the study concentrated only on cycling, pedestrian lanes and speed regimes, it showed that more infrastructural features will extend insight into which types of environment are perceived by parents to be high risk and low risk.

*Controlling factors of the parental safety perception on children's travel mode choice* by K Nevelsteen, T Steenberghen, A Van Rompaey and L Uyttersprot, *Accident Analysis & Prevention*, Vol 45, March 2012, is available at [www.sciencedirect.com/science/article/pii/S0001457511003101](http://www.sciencedirect.com/science/article/pii/S0001457511003101)

# Special issue: Child safety

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## Contributed articles

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### Bicycle safety for children and young people: An analysis of child deaths in Queensland

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#### Introduction

Bicycle riding can be a positive experience for children and young people that builds confidence, independence and promotes healthy recreation. However, these benefits are dependent upon safe bicycle-riding practices. Between 1 January 2004 and 31 December 2011, 12 children and young people under the age of 18 years died in bicycle incidents in Queensland [1]. An additional 1736 bicycle-related injuries requiring emergency department attendance are estimated to have occurred between 2008 and 2009 in Queensland for children and young people under the age of 18 years [2].

Of the twelve bicycle-related deaths between 2004 and 2011 in Queensland, two children were aged between 5 and 9 years, five young people were 10-14 years of age and five young people were between 15 and 17 years. The two children aged 5-9 years were riding their bikes for recreation. Children aged 10-14 years were most likely to have been killed in an incident while riding to school in the morning, with teenagers aged 15-17 years most likely to be killed in incidents occurring after school and in the evening [1].

Bicycle riders are vulnerable road users, particularly children and young people. This is due to several factors that can be grouped into (i) developmental characteristics such as body size and proportions, perceptual and attentional issues, road safety awareness and risk taking behaviours, and (ii) environmental factors such as supervision and shared road use with vehicles. This paper examines safety issues for children and young people who have died in bicycle-related incidents in Queensland, and outlines areas of focus for injury prevention practitioners.

#### Developmental characteristics

International evidence has found bicycle injuries and deaths disproportionately affect children and young people [3-4].

Children and young people may be at greater risk of bicycle-related injury and death compared to adults due to developmental characteristics unique to childhood and adolescence because the ability to negotiate the complexities of the road environment safely develops with their age and stage of development [2]. Nominating a specific age at which children can be objectively considered to be safe road users is challenging due to physical and cognitive skills developing at different rates and individual differences can be quite large. However, some broad conclusions on children's developmental abilities have been prepared on the basis of recent empirical studies.

#### Physical development

Children's motor skills and responses do not easily adapt to visual and auditory stimuli. Younger children have difficulty controlling their movements; for bicycling, they only fully master balance at ages 13 or 14 [2]. In addition, their smaller physical stature can pose safety challenges, because it limits their ability to see or be seen over certain heights. Cars and other environmental features such as shrubbery can mask a child and his/her view of oncoming traffic and present a safety hazard at crossings and intersections [2].

Will [5] stated that the small body size and disproportionate head to body ratio affects children's abilities to endure crashes and lends themselves to more head injuries when involved in a crash, with their small size also contributing to their poor visibility to motorists. These vulnerabilities are exacerbated when combined with the challenges of yet-to-be-developed skills in traffic perception and attention.

#### Perceptual and attentional development

According to the Organisation for Co-operation and Economic Development (OECD), children's acquired intellectual skills and knowledge in terms of understanding movement in space,

time and distance relationships, and physics and the law of mechanics continue developing through adolescence [2]. Until they reach an adult level of understanding, children do not understand and react to complex traffic situations in the same way as adults. Children's observational and reactive capabilities are different from those of adults, and their senses are not fully developed or well co-ordinated.

Will also found children's poorly developed perceptions of depth and hearing/kinaesthetic senses affect their speed and distance estimates, and their inattentiveness and preponderance to risk taking behaviour results in poor hazard perception [5]. Bakovic investigated risks for pedestrians and noted there are different safety considerations required for children of different ages, including ability to detect the presence of traffic, visual timing judgements, co-ordination of information from different directions, and co-ordination of perception and action [6].

### Rider characteristics by gender

According to the Queensland Child Death Register, all 12 bicycle-related deaths between 1 January 2004 and 31

December 2011 in Queensland were male children and young people [1]. This finding mirrors closely the New Zealand child fatality data where 11 males and 1 female child died as a result of a bicycle-related crash between 2003-2007, with the highest risk in males aged 10-14 years [7]. Furthermore, international research has also identified males (predominantly the 10-14 year age group) as substantially over-represented in child cyclist fatalities compared to females [8].

While research suggests a limited risk differential between males and females after adjusting for exposure rates [9, 10], Barton and Schwebel [11] suggest some gender-related behavioural explanations for higher rates of unintentional injuries in males in general including greater impulsivity, risk taking and lack of risk perception, and higher levels of activity.

### Risk-taking behaviour

Children and young people ride bicycles for varied reasons: for recreation and fitness, to travel to and from school, and to increase independence to participate in employment and social activities. The function of a bicycle changes as a child ages.

Therefore it is important to consider the developmental abilities of a child or young person and the intended use of a bicycle when developing road safety messages and initiatives. An OECD report examining international best practice approaches to road safety for children recommended that education and road safety messages should be developmentally appropriate and integrated into the national school curriculum throughout a child's schooling life [2].

The majority of Queensland fatal bicycle incidents involved the young cyclists being hit by motorists [1]. In a large number of cases, the young cyclists were engaging in intentional risk-taking behaviour while others were unintentionally increasing their risk due to lack of riding experience, such as unexpectedly

crossing roads without waiting for traffic to clear, riding at night in poorly lit areas or riding on the wrong side of the road. None of the twelve incidents featured a motorist who was considered criminally responsible for the death of the child or young person.

### The use of bicycle helmets

Wearing a bicycle helmet is one of the most effective safety measures a child can take to prevent injury [12]. In Australia, it is compulsory for people riding bicycles to wear bicycle helmets. The law adopted by each state and territory is laid out in Part 15 of the Australian Road Rules, approved by the Australian Transport Council [13]. As outlined in Table 1, only four of the 12 children who have died in bicycle incidents in Queensland since 2004 were known to be wearing helmets [1]. There is further evidence to suggest that in at least one of the four instances where helmets were worn, the helmet may not have been fastened and in another incident the helmet may not have been the correct size for the child.

Parkin and Howard concluded that bicycle helmets are effective in reducing injury, as is the promotion of bicycle helmets via the community and physicians and bicycle helmet legislation [14]. With only two of the 12 children who died from bicycle-related incidents correctly wearing a helmet, it is essential that young people and their parents understand the importance of correctly wearing an appropriately-sized helmet. Unfortunately, public attitudes towards wearing helmets do not seem very positive. A recent survey of 1000 Australians by the Cycling Promotion Fund and Heart Foundation of Australia found that 51% respondents were not interested in cycling for transport, with 15.7% citing 'don't like wearing a helmet' as one of their reasons. The use of a helmet has previously been cited as an inhibitor to bicycle riding [15]. Using examples of public role models, such as professional cyclists and BMX riders, where helmet wearing is standard within the sport, may assist in reducing the stigma of wearing helmets, particularly for teenagers.

**Table 1. Number of children and young people known to be wearing a helmet at time of fatal bicycle incident**

Bicycle Helmet	Age Category			Total
	5-9 years	10-14 years	15-17 years	
Worn	years	years	years	
Yes				
(Correct Use)	0	2	0	2
Yes				
(Incorrect Use)	0	2	0	2
No	1	1	5	7
Unknown	1	0	0	1
Total	2	5	5	12

## Alcohol and drug use

Of the five young people aged 15-17 who died in bicycle-related incidents in Queensland between 2004 and 2011, three were affected by drugs or alcohol at the time of their deaths [1]. Teenagers often use their bicycle to increase independence and enable them to participate in social and employment activities. However, young people need to be taught that the risks and consequences of drink driving are not just for motor vehicles, but for bicycles too.

## Environmental risk factors

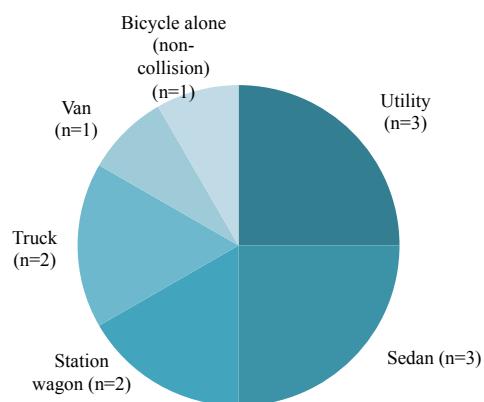
Keeping children safe whilst participating in the broader traffic environment requires an understanding of the developmental factors that can influence their safety and adequate safety messages put in place to minimise the impact of the environment in intensifying that risk.

## Child cyclists on major roads and highways

With high population growth in Queensland, particularly regional areas, there is an increased reliance on major roads and highways for private and commercial vehicles. Roads and highways previously used primarily for accessing residential areas are increasingly being used by commercial and heavy industry vehicles [2, 16]. Additionally, research indicates more parents are driving their children to and from school, with close to 60% reporting this is their primary method of transport [17]. High numbers of cars on residential and major roads during peak school starting and finishing times can also increase risks to child cyclists sharing the road.

For example, using evidence from the Queensland Child Death Register [1], three of the five young people aged 10-14 years who died between 2004 and 2011 were riding on roads with a speed limit of 80km/h or more. These children were all riding unaccompanied to school or school bus stops during a peak traffic period. In two of these three incidents, the roads did not have any designated bicycle lanes. This can potentially increase the risk for cyclists and also for motorists (if required to veer onto the incorrect side of the road to avoid cyclists).

Perceptions that some vehicles are safer than others due to high road visibility, braking features or other safety mechanisms were not supported in the Queensland data [1]. Figure 1 illustrates that all common forms of transportation used on residential and main roads as well as highways have been involved in transport fatalities. The impact of any vehicle making contact with a bicycle rider can lead to serious injury or death. As such, drivers of any model or size of vehicle on any type or speed of road need to be aware of the vulnerabilities of child cyclists.



**Figure 1. Type of motor vehicle in child bicycle fatalities in Queensland, 2004-2011**

Table 2 below shows that most child cyclist fatalities in Queensland occurred on residential streets with a maximum speed limit of 60km/h, closely followed by major roads with a speed limit between 60 and 90km/h [1]. The challenges for children and young people to navigate roads and highways using underdeveloped perceptual and attentional skills, as well as inexperience in bicycle riding or manoeuvring in different environments all play a factor in increasing the likelihood of injury or death. One of the most effective strategies to mitigate these risks is active supervision from an appropriate adult.

**Table 2. Number of bicycle-related deaths by place of incident**

Place of incident	Age category			
	5-9 years	10-14 years	15-17 years	Total
Highway (100-110km/h)	0	1	1	2
Major road (60-90km/h)	0	2	2	4
Residential street (up to 60 km/h)	1	2	2	5
Private property (no posted limit)	1	0	0	1
Total	2	5	5	12

## Unaccompanied child cyclists

Safety prevention experts, Kidsafe Queensland, advise that child cyclists should be accompanied by an adult until at least 10 years of age [18]. None of the four Queensland children aged 10 years or under who died whilst riding a bicycle were being supervised by an adult (as can be seen in Table 3). Further, two of these children were riding unaccompanied for some distance on major roads during a peak traffic period.

**Table 3. Number of child cyclists riding alone or with peers at time of fatal incident**

Age category	Riding alone	Riding with peers	Riding with an adult
5-9 years	1	1	0
10-14 years	5	0	0
15-17 years	3	2	0
Total	9	3	0

Three of the children and young people who died in bicycle incidents were travelling with peers at the time. Whilst parents may hold to the adage there is safety in numbers, the above evidence regarding developmental vulnerabilities of children and young people, including risk-taking behaviour, highlights that multiple riders travelling together is not a protective factor in and of itself. Road safety experts recommend that primary school-aged children should ride on major roads only when accompanied by an adult who is able to provide appropriate supervision and direction [2, 4, 17].

## Safety Messages

Understanding the complex interplay of vulnerability factors that may increase a child's risk of injury whilst bicycle riding can help to inform government and non-government safety campaigns, infrastructure and community planning and increase the enjoyment and participation of bicycle riding in our communities. Table 4 (Appendix A) provides a summary of developmental characteristics and environmental factors that require attention when considering safety messages for young cyclists.

Children's perceptions of speed, distance and time are not as developed as those of adults. Children under 10 years of age are recommended to ride only while supervised by a capable adult and should ride on the footpath rather than main roads. This corresponds with a recent survey of 1005 Australian parents with school-aged children [17]. The main concerns expressed by parents were centred on safety and the dangers posed by traffic and other users. Parents said they would be more likely to let their child ride a bicycle to and from school if personal safety, footpaths/cycle paths, safety of intersections/crossings, or speed/volume of traffic was changed or improved. Additionally, on average, parents stated that children should be 11 years old to ride a bike to and from school and over 10 years old to ride a bike for fun and recreation without supervision.

The authors support the development of infrastructure in our communities that enable safe bicycle riding. The establishment of designated off-road bike paths, separated bike lanes and community awareness campaigns can greatly assist in improving the safety of bike riding. However, designated bicycle lanes do not reduce the importance of appropriate adult supervision, obeying the road rules, correctly wearing a helmet and riding a bike that fits and is in good condition.

The data held by the Queensland Child Death Register demonstrates young riders can engage in intentional risk-taking behaviours while riding their bikes, including riding in and out of traffic, riding at night without lights or reflective clothing, as well as riding without a helmet. That only two of the twelve children and young people who died in Queensland from bicycle incidents were correctly wearing a helmet underscores the importance of basic safety messages being understood by these vulnerable riders.

## Conclusion

The main findings of the literature review and evidence from the Queensland Child Death Register were

- While the development of children and young people is individual, there are common vulnerabilities that occur at different stages. Younger children have difficulties perceiving and attending to factors such as speed and distance, as well as poor hazard perception. Even older children require time to develop physical skills in balancing and manoeuvring a bicycle.
- Risk-taking behaviours, whether intentional (such as riding whilst intoxicated) or unintentional (such as steering into traffic), can increase risk of injury. Non-compliance with helmet use is a common risk for children and young people across all ages.
- Bicycle fatalities can occur on any type of road, with any type of vehicle.
- Children and young people require active supervision and modelling of safety behaviours from appropriate adults.

Under Queensland state laws, a bicycle is a vehicle and therefore the rider, including a child of any age, is required to obey all road rules – the same as motorists. It is important that children learn the road rules and understand their responsibilities as riders. Parents can help children by modelling safe bicycle riding themselves and supporting children and young people to engage in safety programs.

Bicycle safety programs are available in schools and local communities. They offer training for children and young people at all age and skill levels. These programs help children improve their knowledge of road rules, improve riding skills and can build confidence on how to stay safe. The authors support initiatives to address road safety for children and young people.

Reducing the incidence of children and young people who die in bicycle incidents in Queensland requires commitment from parents, the community and organisations responsible for safe roads. It is important that injury prevention research drives effective partnerships that promote key education and prevention messages to improve the safety of children and young people riding bicycles in Queensland.

## Appendix A

**Table 4. Factors affecting bicycle safety of children and young people**

Developmental Characteristics	Age of Child	Cyclist characteristics	Environmental risk factors
Physical size and strength and co-ordination	5-9 years 10-14 years	Cyclist line of sight is reduced  Cyclist lacks strength to negotiate hazards such as wind gusts from passing heavy vehicles  Motorist visibility is reduced	Increasing number of motorists on roads, especially during peak periods when child cyclists are also using roads (travel to and from school)
Perception	5-9 years 10-14 years	Cyclist has limited depth perception significantly affecting their estimates of speed and distance  Cyclist has difficulty understanding direction of sounds	Rural roads are not designed for shared space between motorists and cyclists  Child cyclists riding on roads with high speed limits of 80km/h or more
Attention span, intelligence and experience	5-9 years 10-14 years 15-17 years	Cyclist has limited attention span  Cyclist unfamiliar with, and lacks understanding of routes, traffic, traffic patterns, signals, warnings and road rules  Cyclist lacks ability to assess environment for risks and hazards  Cyclist adopts attitude of invincibility and is over-confident  Cyclists riding more frequently as a means of travel	Supervision of child cyclists under the age of 12 is often inadequate (i.e. using a sibling or older peer to supervise)  Child cyclists riding unaccompanied by an adult
Risk-taking behaviour	5-9 years 10-14 years 15-17 years	Cyclist may act impulsively such as suddenly crossing roads and intersections  Cyclist may not wear helmet or wear helmet incorrectly (such as not fastened correctly) by choice  Cyclist may be affected by alcohol and/or drugs  Cyclist may be travelling at night time with no lights or reflective equipment	

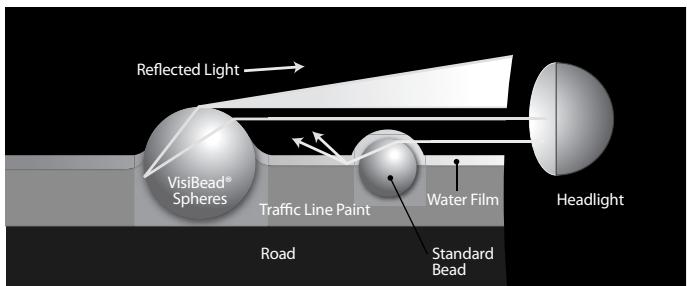
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# A review of evaluations of bicycle safety education as a countermeasure for child cyclist injury

by Julie Hatfield, Transport and Road Safety (TARS) Research Centre, University of NSW

## Introduction

Children should be encouraged to cycle for its health and psychological benefits [1] and because of the value of forming healthy habits early in life [2]. Children who cycle are more likely to become adults who cycle, and cycling has clear health benefits, even when injury risks are accounted for [3,4]. Cycling also has social benefits and, when it replaces motorised transport, environmental benefits [5].

Naturally, if children are encouraged to cycle there is an imperative to address cycling safety, both as a duty of care and by way of encouraging cycling. It can be assumed that people are most likely to allow and encourage their children to cycle if they perceive it to be safe – given that perceived cycling safety is one of the strongest predictors of whether they cycle themselves [6].

Although it is likely that cycling safety is best addressed by providing safe and amenable cycling infrastructure [7], public education programs may also have a role to play. Programs that aim to teach children safe cycling skills exist in many countries, including Australia (e.g. *Bike Ed*) and the United Kingdom (e.g. National Cycling Proficiency Scheme). It is important to evaluate such programs to determine how they might be best developed or how resources for improving child cycling safety could be best allocated.

A review of literature regarding education to improve cycling safety, particularly for children, was undertaken.

## Methods

Searches were conducted in Medline, Psychinfo, and Google Scholar combining the terms presented in Table 1, and

focussing on peer-reviewed publications since 1990. Search results were scanned to identify relevant articles, which were obtained and reviewed. Relevant articles cited in the obtained articles were also reviewed.

**Table 1. Outline of search strategy employed**

Bicycle, <i>or</i>	<i>and</i>	Injury, <i>or</i>	<i>and</i>	Education
Cycle, <i>or</i>		Injuries, <i>or</i>		Training
Bicyclist, <i>or</i>		Safety, <i>or</i>		Skills
Cyclist, <i>or</i>				

## Results

The literature search identified many reports and evaluations of ‘educational’ interventions that have sought to promote helmet wearing. Reviews of this literature are available (see [8]), so it will not be reviewed here. The literature search also highlighted that relatively few educational programs have sought to improve other behaviours or attitudes. The interventions that do exist mostly target child cyclists, and emphasise bicycle-handling skills. Evaluations are fairly limited, and mostly do not assess injury outcomes. The key studies available are summarised in Table 2.

### Crashes

Colwell and Culverwell [9] examined the cross-sectional relationship between cycle training under the UK’s National Cycling Proficiency Scheme (NCPS), cycling attitudes and self-reported behaviour, and cycle accidents, among children. The NCPS includes instruction on cycle rules and control skills.

**Table 2. Summary of studies evaluating cycle safety education for children**

Author	Year	Country	Outcome	Design	Finding
Carlin, Taylor and Nolan	1998	Australia	Hospitalised injury	Case-control	Negative effect
Colwell and Culverwell	2002	UK	Crashes Self-report behaviour Attitudes	Cross-sectional	Null effect
Kirsch and Pullen	2003	US	Self-report behaviour Knowledge	Cross-sectional	Positive effect
Macarthur, Parkin, Sidky and Wallace	1998	Canada	Observed behaviour	Randomised control trial	Null effect
McLaughlin and Glang	2010	US	Knowledge	Randomised control trial	Positive effect
Nagel, Hankenholz, Kimmel and Saxe	2003	US	Knowledge	Before-after	Positive effect
Stutts and Hunter	1990	US	Observed behaviour Knowledge	Cross-sectional	Positive effect

336 children were sampled from two schools, with 154 reporting having taken the NCPS. Training was not associated with crashes ( $n=64$ ). Training took place, on average, four years prior to the study. There may have been a self-selection bias in terms of completing the NCPS, although it is not clear how this would have influenced results.

### Hospitalised injury

Carlin et al [10] conducted a case-control evaluation of an Australian school-based bicycle safety education program, *Bike Ed*, which aims to cover safe riding skills, traffic knowledge and skills, and basic bike mechanics. 148 cases were recruited from the emergency department of two hospitals in Melbourne, and 130 controls were recruited by random telephone survey. All participants were aged 9-14 years. The Case and Control groups were compared in terms of rate of participation in *Bike Ed*. Results suggested a negative impact of the program (OR: 1.64, 95%CI: 0.98-2.75), which was unaffected by adjustment for sex, age, SES, and cycling exposure. There was no consideration of the time since completing *Bike Ed*.

### Observed behaviour

Macarthur et al. [11] conducted a randomised controlled trial of a bicycle skills training program for young children in Canada. Schools were randomly selected for playground-based bicycle-handling skills training to be given to their Grade 4 children, and compared to control schools. The schools did not differ significantly in terms of straight line riding (90% vs 88%,  $p=.78$ ), coming to a complete stop (90% vs 76%,  $p=.23$ ), or shoulder-checking before turning (0% vs 2%,  $p=1.00$ ), and authors concluded that the training was ‘not effective in improving safe cycling behaviour, knowledge, or attitudes’.

Stutts and Hunter [12] evaluated *Basics for bicycling*, an on-bike closed-course training program for elementary school age children in the United States. Curriculum schools demonstrated improvements in observed riding skills (as well as helmet use) compared to control schools. However, potential confounding differences between curriculum and control schools were not considered.

### Self-reported behaviour

Colwell and Culverwell [9] found no cross-sectional relationship between cycle training (under the NCPS) and self-reported ‘safe cycling’ behaviours (e.g. ‘give an arm signal before turning’, or ‘showing off’ behaviours (e.g. ‘ride through traffic lights if safe’). Training occurred, on average, four years prior to the study and there may have been a self-selection bias in terms of completing the NCPS.

Kirsch and Pullen [13] evaluated a school-based education program to promote bicycle safety, the *Safety Central* program. Among 284 students currently enrolled in 5th and 6th grades,

those who had completed the *Safety Central* program in the 4th Grade demonstrated improved knowledge of self-reported safety-related practices compared to those who had not. There may have been a self-selection bias in terms of completing the *Safety Central* program.

### Knowledge and attitudes

McLaughlin and Glang [14] conducted a randomised controlled trial of the *Bike Smart* program, an eHealth software program that teaches bicycle safety behaviours to young children. 206 students in grades Kindergarten to Grade 3 in the US were assigned to either the treatment condition (*Bike Smart*) or the control condition (a video on childhood safety). Regardless of gender, cohort and grade, the participants in the treatment group showed greater gains than control participants in the computer-presented knowledge items (as well as an observational helmet measure).

Colwell and Culverwell [9] found no cross-sectional relationship between cycle training (under the NCPS), and ‘safer attitudes’ (e.g. concentrating properly when riding). Training occurred, on average, four years prior to the study, and there may have been a self-selection bias in terms of completing the NCPS.

Kirsch and Pullen [13] found that 5th and 6th graders who had completed the *Safety Central* program in the 4th Grade demonstrated improved knowledge of safety-related behaviours compared to those who had not. There may have been a self-selection bias in terms of completing the *Safety Central* program.

Stutts and Hunter [12] found that schools with the *Basics for bicycling* curriculum demonstrated improvements in bicycle safety knowledge compared to control schools. However, potential confounding differences between curriculum and control schools were not considered.

Nagel et al. [15] evaluated a ‘structured bicycle safety program’ for grade school children in the US. Students viewed a video and listened to structured discussion of rules. The 251 students who underwent post-testing at one month demonstrated improved knowledge about riding with traffic, warning pedestrians, and stopping before riding onto the street (as well as helmet wearing) compared to pre-test. Although there was no control group, it is unlikely that any intervening events (including maturing) are likely to have wrought these changes.

### Conclusions

Existing research provides only inconsistent support for cycle safety education for children. The only study to consider crashes as an outcome showed no effect of cycle safety education (Colwell and Culverwell [9]), while the only study to consider injury outcomes showed a negative effect of training (Carlin et

al. [10]). A randomised control trial that considered observed behaviour showed no effect [11]. Although Stutts and Hunter [12] found a positive effect on observed behaviour, this may have been produced by self-selection bias. Although Kirsch and Pullen [13] reported a positive effect of a school-based education program on self-reported behaviours, Colwell and Culverwell found no cross-sectional relationship between cycle training (under the NCPS) and self-reported ‘safe cycling’ behaviours; both studies employed cross-sectional designs which may have involved self-selection biases. One randomised control trial reported a positive effect of a software program (*Bike Smart*) on knowledge [14]. Positive effects were also demonstrated in two cross-sectional studies ([12,13]; but see [9]), and one before-after trial [15]. On the whole, it appears that cycle safety programs for children may improve knowledge, but this is unlikely to translate into improved behaviour or crash outcomes.

Importantly, none of the papers give much detail about the contents of the cycling safety program – and some components may be more beneficial than others. Most of the programs considered appear to address bicycle-handling skills which are likely to be necessary but not sufficient for cycling safely. Moreover, young driver research suggests that training which addresses vehicle-handling skills is less useful than training which addresses risk awareness and styles of driving (including motives for risky driving), and may even be detrimental (see [16]). This is interesting in view of Carlin et al.’s [10] finding that young people who were hospitalised due to injuries from cycle crashes were more likely to have participated in *Bike Ed* than those who were not. Driving skills training is thought to be detrimental when it results in overconfidence – a belief that one can handle situations that are beyond one’s true skills – or increased driving exposure at an early age. Developers of cycle safety programs should also be wary of producing overconfidence or increased cycling exposure, because both are likely to increase injury risk.

A number of programs exist for adults, some of which include training on cycling style. Several of these are founded on the co-operative cycling approach (also known as vehicular cycling), which essentially advises cyclists to ride their bicycle like any other vehicle in traffic. For example, Franklin’s [17] related book, *Cyclecraft*, underpins the UK’s national standard for cycle training (*Bikeability*) which has, in turn, informed bicycle safety education in Australia. These programs are yet to be evaluated.

Although evidence for cycle safety education for children remains unconvincing, and there is cause for concern regarding training that focuses on cycle-handling skills, training that addresses cycling style (including co-operative cycling) and risk awareness may well be beneficial. Research is required to evaluate such training.

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# Peer-reviewed papers

## Understanding the challenges facing child pedestrian trauma in Victoria 2000-2010

by Jennifer Oxley, Effie Hoareau, Bruce Corben, David Logan and Anna Devlin

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### Abstract

Crashes involving pedestrians are severe in nature due to pedestrians' vulnerability, lack of protection and limited biomechanical tolerance to violent forces if hit by a vehicle. Children are thought to constitute a high-risk sub-group. This paper provides an analysis of serious casualty child pedestrians in Victoria and highlights some important features of these collisions. The findings show that young children (especially males) are at significant risk of serious injury, that the majority of collisions occur on urban roads with speed limits of 50-60km/h, and that (for older children) crossing the road at midblock sections without the aid of pedestrian crossings and (for younger children) emerging from parked vehicles are predominantly problematic. The implications of these findings are discussed, particularly with regard to developing targeted initiatives within the Safe System framework that may achieve significant reductions in child pedestrian injury crashes.

### Keywords

Child safety, Countermeasure, Injury, Pedestrian, Road safety

### Introduction

While there is a clear and continuing tendency for Australians and other western populations to rely on motor vehicles as a primary mode of transport, walking is another major mode of transport, and still forms a significant component of daily travel routines for most trips. Furthermore, walking has obvious health and wellbeing benefits for children and people of all ages, as well as environmental, social and economic benefits. Governments worldwide recognise this and there has been a major push to encourage increased walking and cycling [1,2].

If initiatives that promote walking and public transport use are successful, however, pedestrian safety concerns in Victoria (and Australia) are likely to grow unless there are concurrent improvements in road safety initiatives. Crashes involving vulnerable road users represent a major road safety problem worldwide and there is growing awareness within the road safety community that vulnerable road users may have their own particular needs and difficulties in using the road transport system.

Indeed, between the 1990s and early 2000s, Australia has enjoyed significant overall reductions in the number of pedestrian deaths and data from various Australian jurisdictions consistently indicate a downward trend in pedestrian deaths and casualties [3-5]. Victorian data, too, show a significant reduction in pedestrian deaths during this period – a reduction from approximately 160 deaths in the late 1980s to 40 deaths in 2003 (Figure 1).

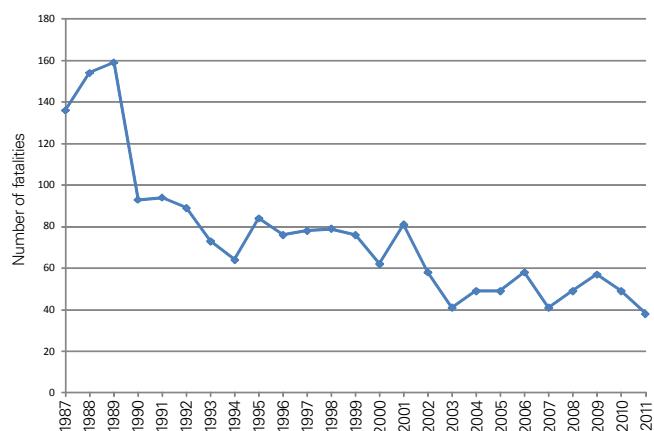


Figure 1. Number of pedestrian fatalities, Victoria 1987-2011

Within this period, two large-step reductions occurred in 1990 and 2003, following the introduction of two separate major speed initiatives in Victoria in 1989 and 2002. The first initiative involved the introduction of automated speed cameras and a boost in random breath testing in 1989. The second initiative was a reduction in the tolerance level of compliance with speed limits along with a range of improvements in speed enforcement in 2002. Despite these major gains, the general trend since 2003 has been for pedestrian deaths to increase in Victoria. In particular, pedestrian deaths have increased markedly from a total of 41 pedestrian fatalities in 2007 [6] to 59 in 2009, but have decreased in the last two years to 38 in 2011 [7]. Moreover, serious casualty data indicate that pedestrians constituted approximately 11% of all road injuries in Victoria in 2010 and 2011.

Traditionally, there are three noted high risk groups of pedestrians: children, the intoxicated, and the elderly. Young children's safety as pedestrians is of particular concern in view of their vulnerability in traffic situations and the special value society places on children. Their vulnerability stems from a number of factors including their smaller stature, cognitive development, unpredictability and lack of experience as road users. Indeed, young children are reported to be a high risk subgroup primarily due to a lack of experience in traffic situations and restricted development of those skills needed to become safe road users. Moreover, children between six and ten years of age appear to be at increased risk, and this is thought to reflect the fact that, at these ages, children are becoming independent and start walking unsupervised [8]. (Adults older than 60 years are at high risk because of changes in their mobility and deteriorating functional performance such as eyesight and hearing, as well as changes in cognitive abilities such as memory and information processing which makes it harder for them to judge distances and the speed of oncoming traffic [9,10]. Intoxicated pedestrians are at risk because of issues similar to intoxicated drivers: their judgement is impaired and reflexes are slowed after consuming alcohol or drugs [11,12]).

This traditional view attributing particular factors to the overall child pedestrian problem is based on data that are up to 15-20 years old, and while this view may still hold, there is a need to conduct current analyses of the contributing factors to child pedestrian injury collisions in Australia to provide a better understanding of current issues. Indeed, there may be significant behavioural changes (such as a decrease in walking activity associated with an increased trend of parents driving their children to school and other activities), or environmental changes (increased congestion, reduced speeds around school zones, changed vehicle mix, etc) that may account for changes in crash and injury profiles. This paper presents an analysis of an 11-year period of fatal and serious injury child pedestrian collisions from 2001 to 2010 in Victoria, as an example of an Australian jurisdiction. The findings are discussed in terms of impact on approaches to managing child pedestrian safety and recommendations for innovative ways to take the next major step forward to eliminating serious child pedestrian trauma.

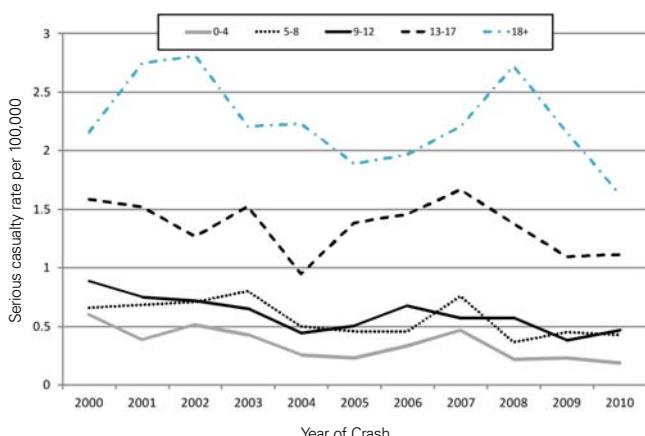


Figure 2. Incidence of all age pedestrian serious casualty rates per 100,000 population (age-adjusted)

## Method

Victorian Police-reported mass crash data covering the period January 2000 to December 2010 were used in this analysis. Pedestrians aged up to 17 years were extracted from these data and selected crash variables were analysed to highlight the patterns associated with child pedestrian serious casualties. Serious casualty pedestrians are defined as those pedestrians killed or taken to hospital as a result of involvement in a road crash. This subset was segregated into four age groups: 0-4 years, 5-8, 9-12 and 13-17 years. Variables identified for analysis included injury severity, road geometry, Definitions for Classification of Accidents (DCA), time of day and day of week, speed zone, and traffic control type. Aggregate analyses comprised cross-tabulations of these descriptor variables and are presented in graphical format. To enable comparisons between each of the child age groups, percentage contributions of each of the factors have been determined for each of the age groups separately.

## Results

Between 2000 and 2010, there were 8178 police-reported pedestrian serious casualties in Victoria, of which 1514 (19%) were children aged 17 years and under. Figure 2 presents age-adjusted pedestrian serious casualty rates per 100,000 population by age group. The Australian estimated residential population (persons) as at 30 June 2001 was used as the standard population in the calculation of these rates. These data show that children aged 13 to 17 years are at high risk, compared with younger age groups of children, but at lower risk than adults aged 18 years and over.

### Characteristics of child pedestrian serious injury collisions

The remainder of the analyses presented here examine child pedestrian serious casualties only. Given that the data are aggregated, and the main purpose is to examine differences between age groups, the remainder of the analyses are expressed in percentage terms, so that each of the age groups can be compared relative to each other.

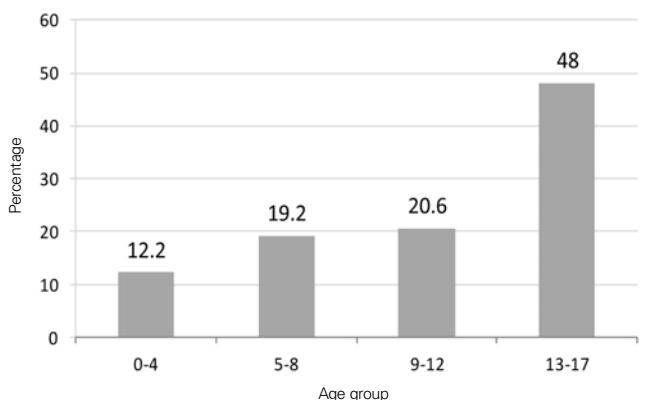


Figure 3. Percentage distribution of child pedestrian serious casualties by age group

First, the overall percentage distribution of serious casualties is shown by age group (Figure 3). Within these age groups, children aged between 13 and 17 years accounted for almost 50% of serious casualties, while the youngest age group (children 4 years and under) comprised only 12%.

Figure 4 shows the breakdown of child pedestrian serious casualties by severity and age group. The majority involved a serious injury, while fatalities comprised a low proportion across all age groups. Over 90% in each age bracket are seriously injured. Regarding fatalities, there was a higher proportion of deaths amongst the youngest children (6.5%), compared with older children.

Moreover, males were at higher risk of fatal or serious injury in

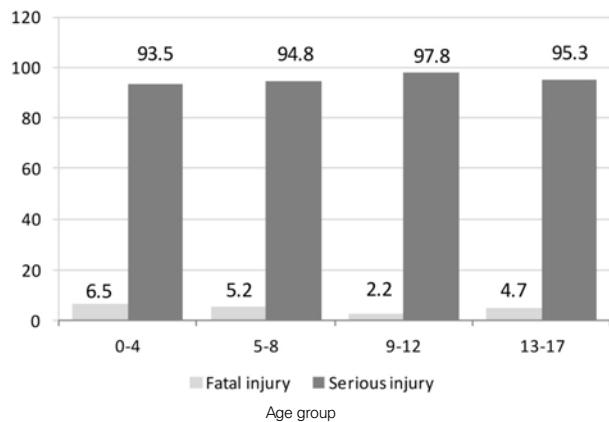


Figure 4. Percentage distribution of child pedestrian serious casualties by age group and injury severity

all age groups, compared with females, but particularly so for younger age groups up to 12 years of age, comprising approximately 65% of serious casualties (Figure 5). The gender difference was around 30% for each of the age groups but decreased to 10% for the oldest age group, where 55% were males and 45% were females.

The following analyses present information on crash types, location and other environmental characteristics. As above, all analyses examine child pedestrian serious casualties only.

The percentage distribution of pedestrian serious casualties by pedestrian movement type is shown in Figure 6 for each of the four age groups. Not surprisingly, crossing the road is the most problematic movement for pedestrians.

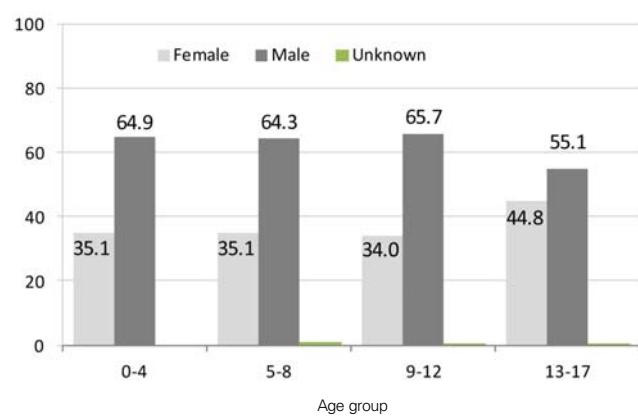


Figure 5. Percentage distribution of child pedestrian serious casualties by age group and gender

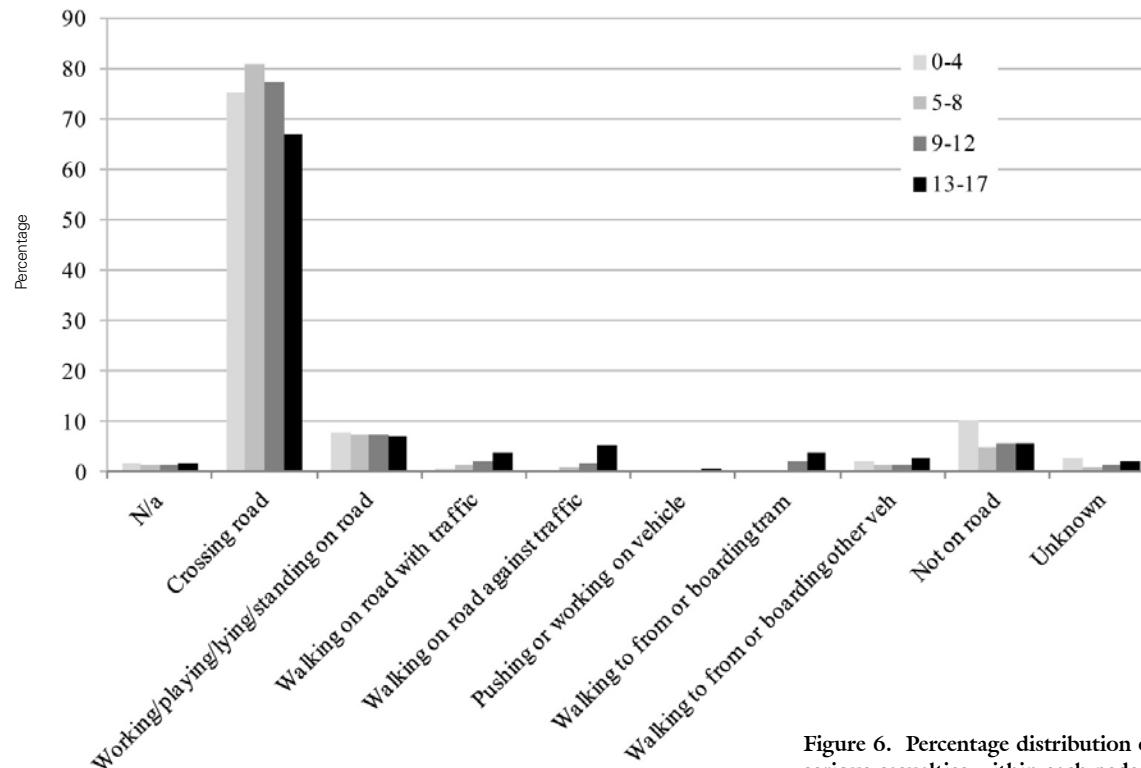


Figure 6. Percentage distribution of child pedestrian serious casualties within each pedestrian movement type

In addition, the Definitions for Classification of Accidents (DCA) chart was used to examine further the types of crashes children are involved in (Figure 7). As a reference, DCAs 100-109 classify pedestrian collisions and are as follows:

- 100: nearside – pedestrian emerging from roadside and colliding with nearside approaching vehicle
- 101: emerging – pedestrian emerging from behind parked vehicle and colliding with nearside approaching vehicle
- 102: farside - pedestrian on road and colliding with farside approaching vehicle
- 103: playing, working, lying or standing on carriageway
- 104: walking with traffic - pedestrian walking on carriageway in parallel (same direction) as vehicular traffic
- 105: facing traffic - pedestrian walking on carriageway in opposite direction to vehicular traffic
- 106: on footpath/median
- 107: driveway - pedestrian hit while on driveway
- 108: struck while boarding or alighting a vehicle
- 109: other pedestrian.

Figure 7 shows that the majority of child pedestrian serious casualties were struck by either a nearside or farside

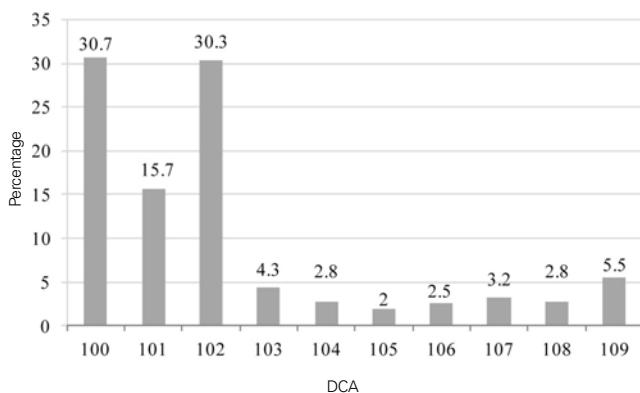


Figure 7. Percentage distribution of child pedestrian serious casualties by DCA

approaching vehicle (approximately 30%, respectively), while crossing the road. In addition, 16% were emerging from behind parked vehicles and were struck by a nearside vehicle. Approximately 4% of children were struck while playing or standing on the carriageway, while 3% were struck on a driveway.

These data are further broken down by age group. Figure 8 shows the three most frequent DCA types by age group.

The data show that older children account for approximately half of the serious casualties resulting from nearside and farside collisions, while much smaller proportions of young children were involved in these collision types. Interestingly, younger children were more likely to be involved in collisions when emerging from behind parked vehicles. These data confirm the issues of crossing from between parked vehicles identified in previous literature.

Figure 9 shows the proportion of collisions by time of day and shows that, for all age groups, the majority of collisions occurred during the afternoon between 2.00 and 4.00 pm. This was particularly so for children aged between 5 and 12 years, suggesting that many collisions occur while walking home from school, or playing in the street after school.

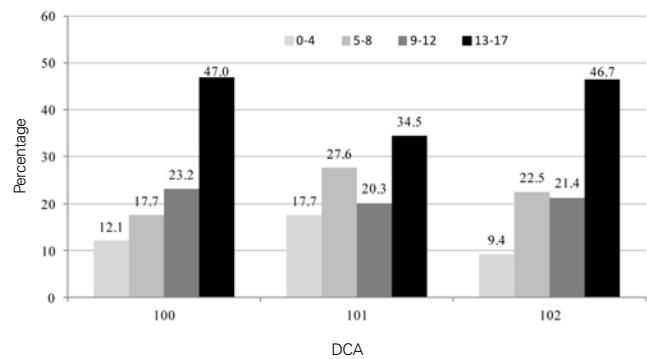


Figure 8. Percentage distribution by age group for three most common DCA types

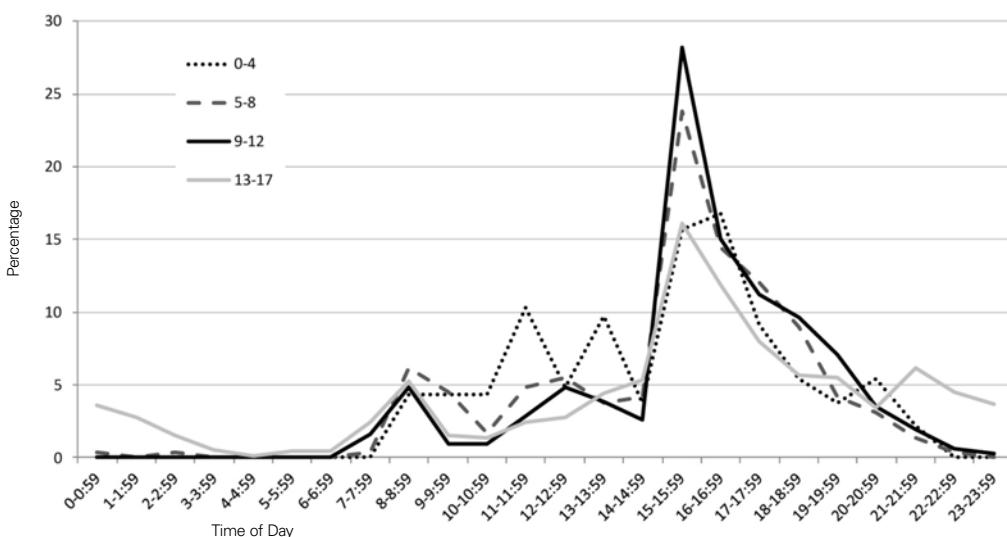


Figure 9. Percentage distribution of child pedestrian serious casualties by time of day

Regarding day of week, there was no clear pattern of when serious casualties occurred (Figure 10).

The remaining analyses examine road geometry and operation. Figure 11 shows the overall proportion of collisions by road geometry and shows that the majority of collisions (60%) occur at mid-block sections of the roadway, with the remaining 40% at intersections.

Further analyses revealed that, overall, children were struck while crossing the road with no traffic control<sup>1</sup> or no crossing facility (80%). Some age group differences were noted. A higher proportion of young children below 8 years of age were struck when crossing with no traffic control compared with older children (85% vs. 76%). In contrast, older children were more likely than younger children to be involved in collisions at stop-go lights (6% vs. 15%) (Figure 12).

Last, speed zone was examined. Figure 13 (next page) shows the distribution of collisions by speed zone. The majority of collisions occurred in 60 km/h and 50 km/h speed zones (44% and 32%, respectively). This was not a surprising finding, given that most walking and crossing of roads occur on urban roads.

## Discussion

Despite overall reductions in pedestrian deaths and serious injuries in Victoria over the last two decades, approximately 800 serious casualty collisions involving pedestrians still occur each year, representing approximately 11% of all road injuries in Victoria. Moreover, children under 17 years of age represent a significant proportion of child serious casualty crashes, accounting for almost 20% of all pedestrian casualties; however, little updated information is available regarding crash patterns and types and contributing factors to child pedestrian collisions.

This paper presented updated information on some of the characteristics of collisions involving this road user group. It has provided important information on which effective and innovative countermeasures can be developed within the Safe System approach to reduce the frequency and severity of pedestrian collisions.

There are some limitations in drawing comprehensive conclusions about trauma and collision risk from police-reported data, particularly when addressing vulnerable road users. For example, there is potential for biased reporting, given

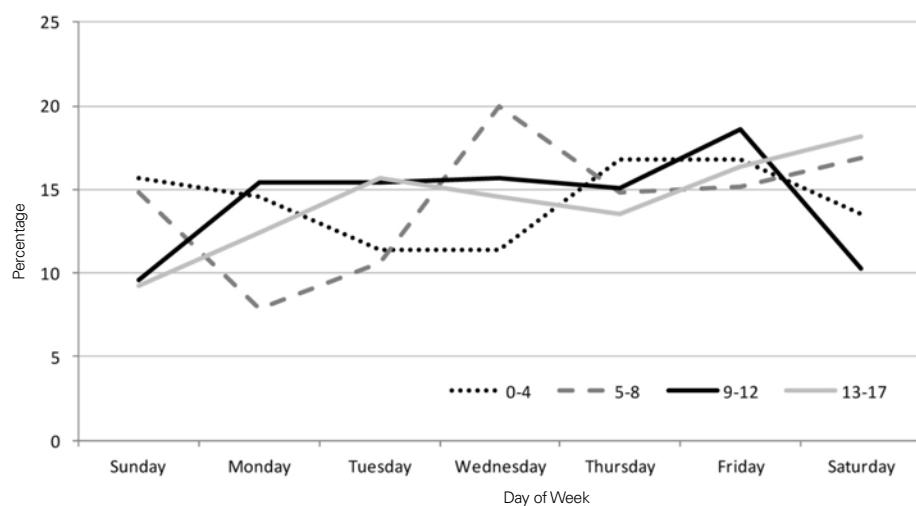


Figure 10. Percentage distribution of child pedestrian serious casualties by day of week

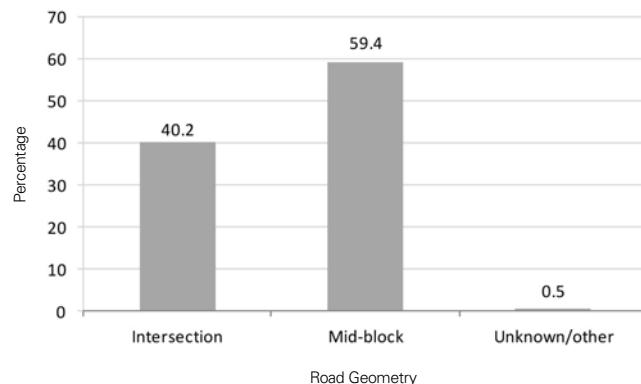


Figure 11. Percentage distribution of child pedestrian serious casualties by road geometry

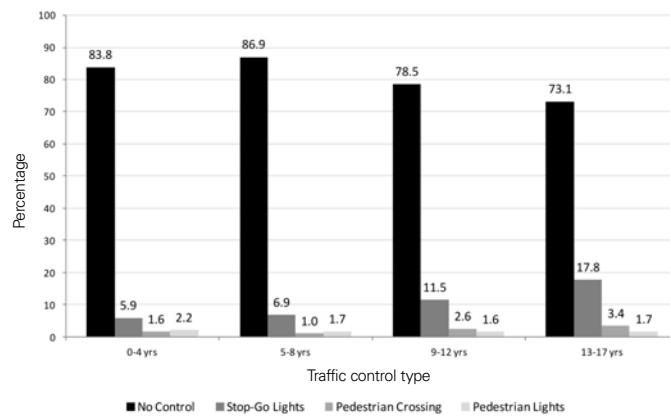
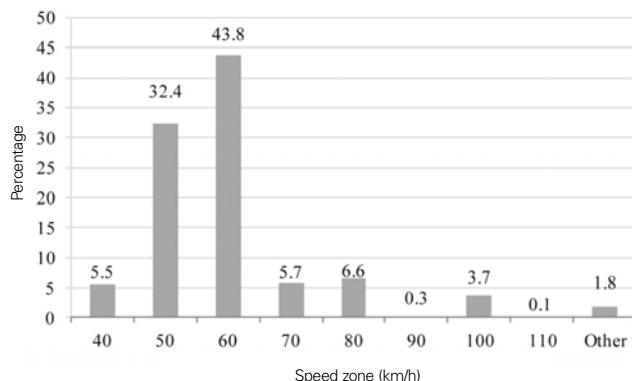


Figure 12. Percentage distribution of child pedestrian serious casualties by traffic control type



**Figure 13. Percentage distribution of child pedestrian serious casualties by speed zone**

the high likelihood of the pedestrian being injured (and not the driver). It should also be noted that, due to the way police-reported data are collected and collated, non injury and minor injury collision rates may be underestimated, and can be better understood by validating against hospital data (as discussed below). Furthermore, in-depth information regarding collision and injury causation is lacking in these data sources.

Nevertheless, it is important to analyse police-reported data sources to highlight important features of collisions.

The findings showed that males were over-represented in collisions, compared with females, and that approximately 60% of collisions occurred while crossing mid-block sections of road, with the remaining 40% occurring at intersections. With regard to crash type, the majority of collisions occurred on the carriageway, while children were attempting to cross, and most were struck by nearside or farside traffic. These findings were not surprising, given that the most dangerous part of being a pedestrian is crossing the road which involves interaction with vehicles. These findings also revealed that younger children were more likely to be struck while emerging from parked vehicles into the path of an oncoming vehicle. This confirms previous findings that this is a major problem for younger children. Young children have been shown to experience difficulty in choosing a safe location to cross and often cross between parked vehicles [13,14]. Because of their small stature, they have greater difficulty seeing over parked cars and other obstacles, and are in turn more easily hidden by them, making them more difficult for drivers to detect [15,16].

It was interesting to note that these analyses did not identify walking or playing on the road, or driveway collisions, as a major threat to young children, despite previous literature and media interest suggesting these collision types to be of high priority. It is worth noting, however, that other hospital-based data - such as the Victorian Emergency Minimum Dataset (VEMD), an injury surveillance database of injury presentations to emergency departments (ED) in major Victorian public hospitals - identify substantially higher numbers of driveway-related injuries, compared with those identified in the police-reported crash database. This discrepancy may be an artefact of

different coding systems, or under-reporting of these incidences to police. Nevertheless, it is worth noting here that between 2005 and 2010 there were at least 77 Victorian Emergency Department presentations for driveway run-over or back-over among children 14 years and under, an average of 13 cases per year. These presentations were evenly distributed across three age groups, 0-4 years, 5-9 years and 10-14 years, each group accounting for approximately 33% of presentations. Injuries to lower extremities were common, followed by multiple injuries, and 31% were admitted to hospital [17].

Another important finding was that the majority of collisions involving children occurred while crossing roads zoned at either 50 or 60 km/h. The evidence is clear that speed has a great impact on pedestrian safety and that pedestrian safety is highly compromised when interacting in traffic where speeds are higher than 30-40 km/h. Indeed, there have been many calls for moderating vehicle speeds in areas with high pedestrian activity and these findings support the critical need for moderating vehicle speed [18-20].

## Implications

The findings from this analysis provide some important insights into crash types and collision risk for children in Victoria which have implications for countermeasure development to address the problems within a Safe System framework. Three broad strategies are available for managing child pedestrian safety. These include improvements to road design and operation (especially vehicle speed reductions), improved education and training, and enhanced vehicle design.

### Safer roads and roadsides

The safety of pedestrians is compromised to a large extent by the design and operation of the road transport system and much of the literature has stressed the importance of separating pedestrians from motorised traffic either in time or in space. This is usually addressed through the use of well maintained footpaths, barrier fencing and provision of pedestrian crossings. The findings showed that the majority of serious casualties occur while crossing midblock road sections. Provision of appropriately placed crossing facilities with enhanced safety features such as raised crosswalks, highly visible crossings, kerb extensions and advanced warning signs could therefore be beneficial. In addition, given that a proportion of younger children are involved in crashes whilst emerging from parked vehicles, the placement of parking bays where there are children crossing could be reconsidered, in conjunction with barrier fencing to prevent children crossing in these locations.

### Safer speeds

As noted above, moderation of vehicle speeds - especially to speeds not exceeding 30 or 40 km/h - is critical for pedestrian safety. This can be achieved through adoption of low urban speed limits. Given that a high proportion of injuries occur on roads zoned at 50 km/h, we would argue that lower speeds in areas of high pedestrian activity, in the order of 30-40 km/h

could result in dramatic decreases in pedestrian casualty collisions. Additional measures to increase speed limit compliance and adoption of appropriate travel speeds include out-of-vehicle Intelligent Transport System (ITS) applications (e.g., dynamic messaging in the form of active speed warning signs and variable messaging signs) and introduction of traffic calming measures (e.g., pavement narrowing, refuge islands, alternations to the road surface, speed humps, roundabouts and gateway treatments). In ‘best-practice’ designs, these physical modifications to the roadway are part of an overall design concept giving vulnerable road users greater priority while discouraging high-speed through traffic.

### **Safe vehicles**

Current design of vehicle structures, particularly frontal structures and vehicle mass contribute significantly to the severity of pedestrian injuries. In previous years, there has been no mechanism for determining a vehicle’s performance in a pedestrian collision. However, the Australian New Car Assessment Program (ANCAP) has recently been extended to include a pedestrian test, consisting of dummy components projected at the vehicle’s front and bonnet to evaluate head, upper leg and knee injury risk [21,22]. It is expected that this process will have a positive impact on safer vehicle choices for both drivers and pedestrians. Moreover, given the evidence that driveway collisions may contribute significantly to child pedestrian injuries, it is worth considering the widespread introduction of forward and rear warning systems including sensors, mirrors and cameras.

### **Safer road users**

Given that much of the literature on child safety in traffic focuses on the behaviour of children in traffic, much emphasis has been on education, training and supervision. The evidence suggests that due to immature and less well-developed functional skills, young children are less competent in traffic, experience difficulty in dangerous locations, judging safe gaps in traffic, being distracted by irrelevant information and controlling impulsive reactions [23,24], and that children may not have the developed abilities to interact safely with traffic until at least 11 to 12 years of age. Recent evidence suggests that realistic and targeted training can result in improved gap selection skills and in coping with more complex situations [25,26]. Moreover, there is evidence that parents play a significant role in protecting their children in traffic and teaching adoption of safe road use and traffic skills [8,27]. There are opportunities to enhance parents’ knowledge and skills regarding child pedestrian safety.

## **Conclusions**

Although older adults make up the largest percentage of fatal pedestrian collisions, young children’s safety as pedestrians is of particular concern in view of their risk of serious injury, their vulnerability in traffic situations and the special value society

places on children. This paper examined police-reported crash data and identified crash patterns and associated factors to child pedestrian injury. The findings were discussed in terms of implications for countermeasure development within the Safe System. Some initiatives such as speed reduction measures, provision of enhanced road design and pedestrian facilities, and education/training/supervision programs that have the potential to significantly reduce child pedestrian injury collisions were highlighted.

### **Notes**

<sup>1</sup>A separate examination of this high percentage of child pedestrians being injured or killed at intersections with ‘no control’ found it was largely due to a definitional issue where it appears police are more likely to record an intersection crash as not having a traffic control if traffic lights are absent. At most intersections, however, where traffic lights are not present, it was found that there is almost always some form of traffic control, usually a ‘Stop’ or ‘Give way’ sign.

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## Analysis of child pedestrian deaths and serious injuries in Malaysia

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### Abstract

Vulnerable road users are at increased risk in many middle-income countries, largely due to rapid motorisation without associated road safety infrastructure initiatives and programs. Pedestrians are one of the most vulnerable road user groups, particularly young children. While crash patterns and causes of collisions amongst pedestrian are established in developing countries, less is known about crash patterns, types and contributing factors to pedestrian trauma in Malaysia. Analyses of fatal and serious injury child pedestrian crashes were undertaken by examining the police-reported crash database. The results identified high rates of pedestrian deaths overall, and high rates of serious injury amongst young children. Young children were at highest risk in rural areas, on major roads with relatively high speed limits and while they were playing on or attempting to cross the road without the aid of crossing facilities. Passenger vehicles and motorcycles were the most frequent striking vehicle. These findings have significant implications for countermeasures to address priority child pedestrian trauma issues in Malaysia including improved road design and reduced speeds on rural roads, as well as supporting education and enforcement initiatives.

### Introduction

Each year an estimated 1.3 million people die on the world's roads [1]. Even more alarming is the injury rate associated with road trauma: each year up to 50 million people are injured or disabled worldwide in road traffic crashes [2]. The World Health Organization (WHO) also reports that a high proportion of these deaths and injuries (up to 90%) occur in low- and middle-income countries, and this proportion is increasing.

In many middle-income and developing countries, vulnerable road users are at increased risk and these groups include pedestrians, cyclists and motorcyclists, and the young and elderly. Pedestrians are one of the most vulnerable road user groups, largely due to their lack of protection and limited biomechanical tolerance to violent forces when impacted by a vehicle.

Malaysia is a rapidly developing country and the level of motorisation has increased dramatically in the last two decades. In Malaysia, the number of registered per 100,000 population has increased by 71.1% from 1994 (36,986) to 2007 (63,319) [3]. This rate ranks Malaysia as one of the highest motorised middle-income countries in the world, with a rate higher than many high-income countries (UK: 56,489; France: 6477;

Sweden: 6031 [1]). However, the vehicle mix is very different in Malaysia. While in high-income countries motorcycles comprise an average of 7% of the vehicle fleet, in Malaysia motorcycles comprise 47% of all registered vehicles [1].

In association with this increase in motorisation, Malaysia has experienced high levels of road trauma, in the order of approximately 24 deaths per 100,000 population. This rate is significantly higher than road fatality rates in many high-income countries; for example, in Australia the road fatality rate in 2010 was 6.12 per 100,000 population [4]. While motorcycle-related trauma comprised the great majority of death and serious injury in this country, other vulnerable groups account for a substantial proportion of trauma: pedestrian trauma represented approximately 10% of all road deaths [1]. In 2010 alone, over 2600 people were involved in a police-reported pedestrian crash, and over 600 of these involved a fatality. Moreover, one of the main pedestrian groups most at risk is young children. Children are highly vulnerable due to their small stature and physical vulnerability. In addition, children may be at increased risk due to the fact that they are still at a developmental stage of specific functional processes and key perceptual skills concerning traffic including choosing safe locations and gaps in the traffic to cross.

In Malaysia, children aged 5 to 9 years are more likely to be killed as a pedestrian (43.5%) than as any other road user group. For children aged 1 to 4 years, most deaths occur as a car occupant (36.7%), followed by pedestrian collision (30.1%) [5]. For children aged 6 to 8 years, the trend of pedestrian injury around school areas decreased from 1997 to 2004; however, there has been a dramatic increase in injuries from 2005[6]. While researchers report that there are inconsistencies in the provision of a safe environment for students as pedestrians around schools, they also acknowledge that there are limitations in the police data and potentially technical errors that may affect the data [6].

The causes of pedestrian crashes are undoubtedly complex and poorly understood. Internationally, several explanations have been offered to account for the over-representation of children in serious injury and fatal pedestrian crashes and these generally include vulnerability, behavioural aspects and road and vehicle design [7-9].

Children are highly vulnerable due to their small stature and physical vulnerability. Young children may have difficulty seeing over parked cars and other obstacles, and are in turn easily obscured by them and therefore difficult for drivers to detect [10-11]. International research suggests that, due still developing cognitive, attentional, perceptual and visual skills, young children are less competent in traffic than older children and adults; this consequently increases their unpredictability and overall risk as pedestrians [7-9]. For younger children (under 7 years old), difficulties are experienced in various situations including high traffic locations, choosing a safe location to cross, judging safe gaps in traffic, being distracted by irrelevant information, attending strategically to traffic in complex traffic situations and

controlling impulsive reactions. For children aged 7 years or older, the abilities necessary to interact safely in traffic improve markedly in a number of important aspects but, for many children, these abilities may not be fully developed until they are at least 11 to 12 years of age.

There may also be socio-economic differentials in child pedestrian casualty rates. Some argue that, in the UK, children from lower socio-economic status backgrounds are at an increased risk of pedestrian injury, perhaps up to five times greater than children from higher socio-economic backgrounds [12-13]. Similar findings are reported in Sweden [14]. Whether this is due to behavioural factors on the part of the pedestrian or driver, or other environmental factors, is yet to be determined.

The safety of pedestrians and cyclists is also compromised to a large extent by the design and operation of the road-transport system, which is generally designed for vehicles and, for the most part, seems to be unforgiving for the most vulnerable road users. Overly assertive attitudes by drivers, failure to acknowledge the rights of pedestrians and fast speeds of drivers in areas of high pedestrian activity greatly increase the potential for crashes and, more importantly, the injury consequences once a collision occurs [15-16].

While international research has identified some contributing risk factors, there is little known about the nature and extent of child pedestrian crashes and their contributing factors in the Malaysian context. This paper addresses child pedestrian trauma in Malaysia and is a first attempt at understanding the overall child pedestrian trends, crash experience and crash types and to identify some contributing factors to fatal and serious injury crashes. It is expected that this information will provide valuable input into prioritising road safety initiatives aimed at reducing trauma amongst child pedestrians in Malaysia.

## Method

An analysis was conducted of all police-reported pedestrian crashes that resulted in a pedestrian death or serious injury for the period from 2007 to 2010 inclusive.

### Data

The pedestrian crash data were obtained from the Malaysian Institute of Road Safety Research (MIROS) Road Accident Analysis and Database System (M-ROADS). In Malaysia, all police-reported crashes are entered into M-ROADS. The M-ROADS database is populated by collision information collected by the Royal Malaysian Police and the data is managed and maintained by the MIROS. All identified pedestrian fatal and serious injury crashes between 2007 and 2010 (inclusive) were extracted from the database and a range of data variables were selected for examination and included: driver and pedestrian variables, site and crash characteristics, and broad injury outcomes. Table 1 provides a list of the selected and available variables for examination.

**Table 1. Selected data variables**

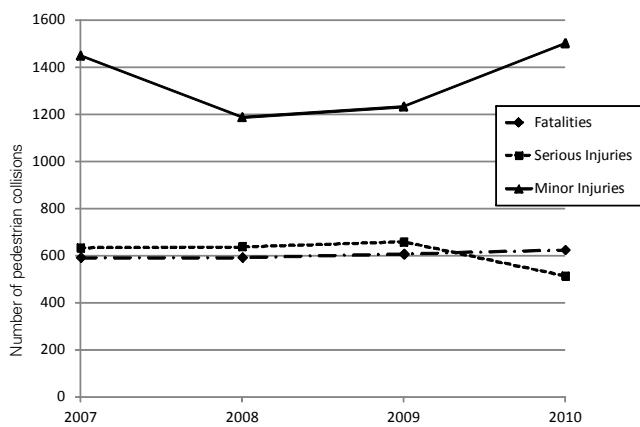
Variables	
Age of driver	Collision responsibility
Gender of driver	Seatbelt wearing/ helmet wearing
Types of road	Location of trauma on the victim/driver
Condition of the road	Age of pedestrian injured
Location of the road	Gender of pedestrian injured
Weather condition during collision	Severity of injuries on pedestrian
Speed limit of location	Body region injured
Time of collision	Behaviour of pedestrian before collision
Day of collision	Location of pedestrian before collision
Type of vehicle involved in the collision	Driver error

### Data analysis

Descriptive statistics are provided for all summary data of the variables as per Table 1. In addition, Chi-square tests were conducted to determine if there were any statistically significant differences between the data variables.

## Results

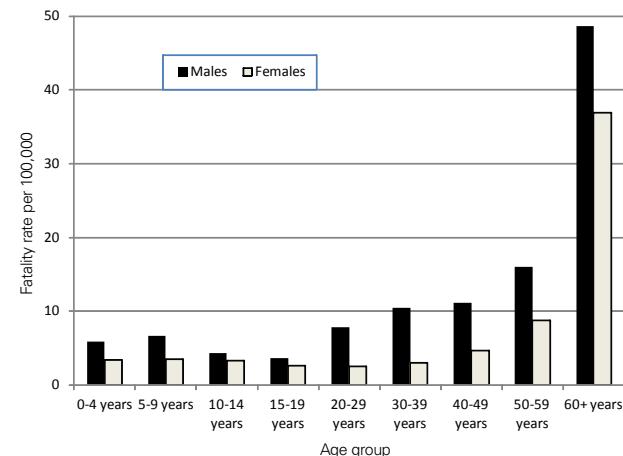
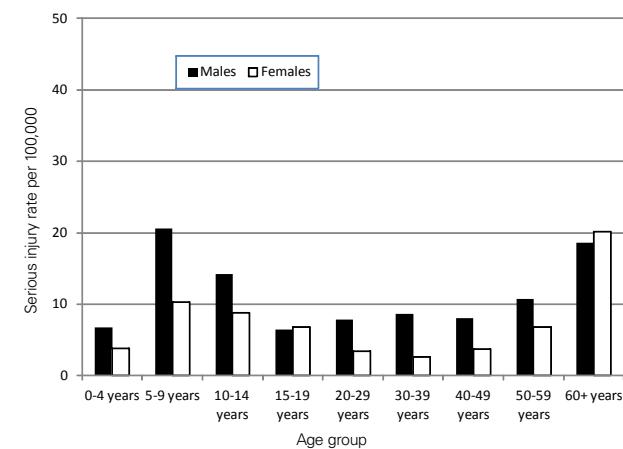
During the period 2007 to 2010, there were over 4640 pedestrian collisions. Figure 1 presents the number of collisions over this time period and shows that the numbers of fatalities and serious injuries have remained fairly stable during 2007 and 2010, while the number of minor injuries has increased since 2008.

**Figure 1. Number of pedestrian injury collisions (2007-2010)**

### Pedestrian characteristics

This section presents some of the characteristics of collisions, including vehicle and driver factors, crash types, and road/environmental characteristics. Figures 2 and 3 show the

rates of fatal and serious injury pedestrian collisions by age group and some clear injury outcome, age group and gender differences are noted.

**Figure 2. Rate of pedestrian fatalities by age group and gender (per 100,000 population) 2007-2010****Figure 3. Rate of pedestrian serious injuries by age group and gender (per 100,000 population) 2007-2010**

With regard to fatal pedestrian collisions (Figure 2), an effect of age group on fatality rate was found,  $\chi^2_{(8)}=26.92$ ,  $p<0.01$ . By far, older adults (aged 60 years and older) were at highest risk of a fatal outcome compared with younger age groups. Children under nine years of age were at slightly higher risk than older children. Moreover, in all age groups, males were more likely than females to be killed as a pedestrian.

With regard to serious injury collision rates (Figure 3), an effect of age group was also found,  $\chi^2_{(8)}=39.83$ ,  $p<0.001$ . However, the pattern was quite different to that of fatality rates. High risk age groups were children aged between 5 and 14 years, and older adults aged 60 years and over. Similar to fatality rates, males were more likely than females to sustain a serious injury as a result of a pedestrian collision amongst most age groups, except for those aged 60 years and older, and adolescents aged between 15 and 19 years.

All subsequent analyses presented here focus on child pedestrians aged 14 years and under. Pedestrian behaviour prior to the crash event was examined. Table 2 shows the pedestrian action, for child pedestrians aged 14 years and below only, by collision severity and age group.

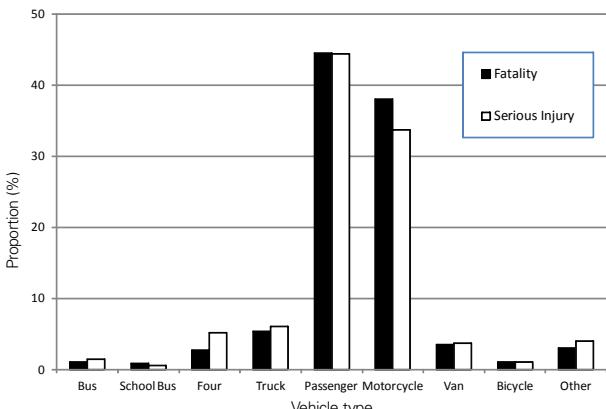
Almost two-thirds of children involved in a collision were recorded as showing negligence while crossing, while approximately one-third of children were walking or playing on the road when the collision occurred. There was no effect of collision severity; however, a significant effect of age group was found,  $\chi^2_{(12)}=66.08$ ,  $p<0.001$ . The most common pre-crash behaviour for all children was negligence related to road crossing, followed by walking or playing on the road.

**Table 2. Recorded pedestrian action by collision severity and age group**

	Collision Severity		Age Group		
	Fatality	Serious Injury	0-4 years	5-9 years	10-14 years
Negligence while crossing	62.0	67.1	50.0	71.7	66.4
Walking or playing on road	34.4	29.9	46.1	26.1	29.2
Did not use crossing facility	1.9	2.4	1.2	1.7	3.9
Medical disorder	1.1	0.3	1.9	0.3	0.0
Intoxicated	0.6	0.1	0.8	0.0	0.2
Doing sport	0.0	0.2	0.0	0.2	0.2

### Driver and vehicle characteristics

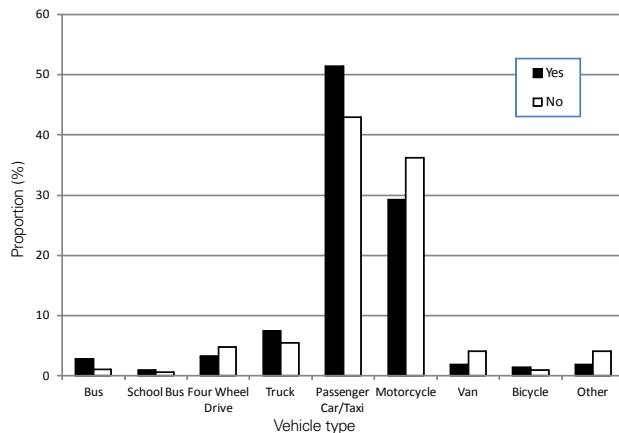
A number of vehicle and driver characteristic variables were extracted and examined. Figure 4 shows the type of vehicle involved in fatal and serious injury crashes amongst children 14 years and under.



**Figure 4. Type of vehicle involved in child pedestrian collisions by collision severity**

The majority of fatal and serious injury collisions occurred as a result of a collision with a passenger car or motorcycle. Trucks and four-wheel-drive vehicles accounted for approximately 8% of fatalities and 11% of serious injuries. Analyses also revealed that half of drivers/riders involved in collisions were experienced drivers/riders, having their licence for over five years, while 34% were less experienced, having their full licence for less than five years. 15% of drivers/riders were unlicensed.

The analyses also revealed that a relatively high proportion of collisions (16% of fatalities and 18% of serious injury outcomes) were 'hit-and-run' collisions, where the driver/rider left the scene of the collision. This variable was further analysed by vehicle type (Figure 5) and revealed that passenger car/taxi drivers were more likely to leave the scene of a collision than drivers of other vehicles.



**Figure 5. Proportion of hit-and-run collisions by vehicle type**

In terms of driver/rider errors, for those where information was available, drivers/riders were deemed 'not guilty' in the majority of cases (72% for fatalities and 76% for serious injury collisions). In a small number of police reports, specific driver behaviours were recorded: over passenger (over the legal number of passengers or pillion riders) (5.8%), driver/rider negligence (3.5%) and speeding (3%).

### Environmental characteristics

A number of road, location and timing characteristic variables were also extracted and examined by collision severity and age group. These are presented in Table 3.

The majority of collisions occurred in rural areas and in townships, and there was a significant effect of location by collision severity,  $\chi^2_{(4)}=17.00$ ,  $p<0.01$ . A high proportion also occurred on federal or state roads and where there was no traffic control. There was no clear pattern of collisions with regard to speed limit.

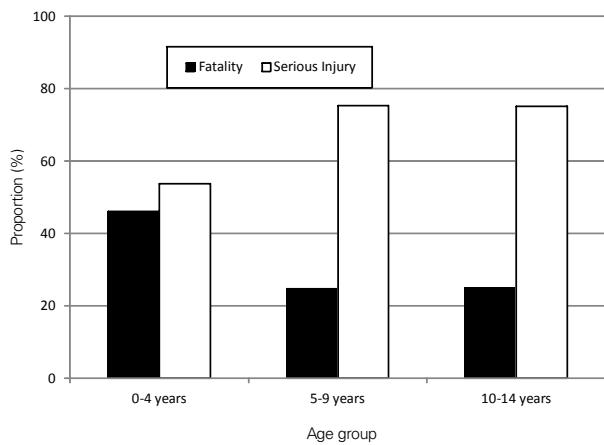
### Injury outcome

As noted above, young children were over-involved in serious injury crashes. Figure 6 shows proportions of fatalities and serious injuries by age group for children 14 years and below.

**Table 3. Road, location and environmental characteristics of child pedestrian crashes by collision severity and age group**

	Collision Severity		Age Group		
	Fatality	Serious Injury	0-4 years	5-9 years	10-14 years
<b>Speed Limit</b>					
50km/h	22.9	21.2	24.9	21.3	20.2
70km/h	22.3	25.1	23.1	24.5	25.4
80km/h	9.1	10.1	8.2	9.2	11.9
90km/h	11.7	12.8	12.1	12.8	12.4
110km/h	2.3	2.2	2.8	1.6	2.6
Other	31.7	28.6	28.8	31.1	27.6
<b>Control Type</b>					
Zebra Crossing	0.5	0.4	0.0	0.0	0.5
Railway Crossing	0.3	0.1	0.4	0.2	0.0
Yellow crossing line or box	5.0	2.8	3.9	3.1	3.3
No traffic control	90.5	92.6	91.5	89.8	88.8
Police or other	3.7	3.9			
<b>Location Type</b>					
Major City	7.1	9.5	16.3	15.9	16.2
Small City	16.4	16.0	18.5	20.3	20.8
Town	26.6	17.3	54.3	55.4	54.9
Rural	49.9	57.2			
<b>Road Type</b>					
Highway	3.1	4.0	34.0	33.8	37.0
Federal Road	35.2	34.5	20.6	25.1	23.9
State Road	19.4	25.4	33.3	25.1	27.9
Urban Road	32.4	28.1	7.8	8.4	8.1
Other	9.8	8.1			
<b>Area Type</b>					
Housing Area	23.1	22.7	24.1	21.9	23.2
Office Area	8.6	8.4	6.7	10.0	7.3
Shopping Area	6.8	6.7	5.6	4.6	6.6
Industrial/building Area	5.7	4.4	3.2	4.4	6.4
Bridge	1.6	1.5	1.8	1.1	1.9
School	4.7	6.0	6.7	6.1	4.3
Other	49.6	50.3	51.8	50.2	50.2

Significant age group differences were found,  $\chi^2_{(2)}=48.69$ ,  $p<0.001$ . The youngest children (aged 4 years and below) were more likely than older children to be killed as a result of a pedestrian collision.



**Figure 6. Pedestrian injury severity by age group**

Overall, the most frequent body region injured was the head and neck region, followed closely by lower extremities (as shown in Table 4). Younger children were more likely than older children to sustain head/neck injuries, while older children were more likely than younger children to sustain lower extremity injuries,  $\chi^2_{(16)}=38.31$ ,  $p<0.01$ . Not surprisingly, children who were killed were more likely to have sustained a head/neck injury or multiple injuries compared with children who sustained a serious injury, while children sustaining a serious injury were more likely to have sustained lower extremity injuries,  $\chi^2_{(16)}=38.31$ ,  $p<0.01$ .

**Table 4. Body region injured by injury severity and age group**

	Collision Severity		Age Group		
	Fatality	Serious Injury	0-4 years	5-9 years	10-14 years
Head/Neck	77.1	27.7	49.6	40.0	39.1
Chest/Thorax	4.1	3.4	4.7	2.5	3.4
Upper Extremities	1.1	7.9	4.3	4.7	8.7
Lower Extremities	1.1	51.7	26.4	41.6	37.2
Multiple	16.6	9.3	14.0	10.7	10.6

## Discussion

Children worldwide are at substantial risk of death and serious injury as a result of a pedestrian collision [1]. Pedestrians, and especially children, are at high risk of injury, largely due to their vulnerability, lack of protection and limited biomechanical tolerance to violent forces if hit by a vehicle. In low and middle income countries, especially, vulnerable road users constitute a high proportion of road trauma [2].

This paper presents the findings from an examination of the pedestrian fatal and serious injury crash data in Malaysia. The study aim was to better understand the nature and extent of child pedestrian collisions by identifying contributing factors to injury collision involvement and injury outcomes. The findings of this study highlighted both expected and unexpected findings which may have implications for the development of effective measures to reduce pedestrian-related trauma in Malaysia.

The overall finding was that the high level of death amongst pedestrians who are involved in a collision did not reduce significantly between 2007 and 2010. The overall numbers of pedestrian deaths during this period was high and comparable to numbers of serious injury pedestrian collisions. This was an unexpected finding, and contrary to the general trend in many developed countries, where fatality rates are generally significantly lower than injury rates. Furthermore, the findings revealed that, while older pedestrians were at high risk of death, children under 14 years of age, particularly males, were at high risk of serious injury.

Although comparable pedestrian fatality data was reported for the year 2007 by both M-ROADS (600) and the WHO report (628) [1], road user crashes are likely to be under-reported as found in international crash data analyses [17-18].

Generally, the causes of crashes are complex and multi-factorial, and this analysis confirms this. However, there were some significant findings. Overall, the findings suggested that young children were at risk of collision while they were walking or playing on the road, while, for older children, the main factor was negligent crossing. Moreover, the majority of pedestrian collisions occurred in rural areas, on major roads with relatively high speed limits and where there was no traffic control. This contrasts greatly to findings of pedestrian trauma in developed countries, where most collisions occur in large cities, in urban areas and on roads with relatively low speed zones [19-20].

In comparison with developed countries, but not surprising given the high use of motorcycles in Malaysia, the findings revealed that a high proportion of pedestrian collisions, both fatalities and serious injuries (38% and 35%, respectively), resulted from a collision with a motorcycle. Interestingly, however, the majority of drivers/riders were reported to be 'not at fault'. However, there was a substantial proportion of 'hit-and-run' collisions (approximately 16%), where responsibility cannot be determined. Passenger vehicle/taxi drivers were more likely to leave the scene of a collision than other vehicle operators. Moreover, approximately two-thirds of children were reported as being 'negligent while crossing', and this was more likely amongst older children. These findings raise important issues related to reporting. In any collision involving a vulnerable road user, they are more likely to be injured than the driver/rider and often unable to provide information to attending police about pre-collision behaviours or collision responsibility. This appears to be the case here, and especially among older children who may be unaccompanied by an adult.

Attribution of blame to young children was not as common as for older children, suggesting that an accompanying adult or older child may have been able to provide information on behalf of the injured pedestrian. In any case, these findings may overstate the responsibility of the child.

The findings regarding injury patterns revealed effects of injury severity and age group. It was not surprising to find that head/neck was the most frequently injured body region amongst fatalities, while lower extremity injuries comprised the majority serious injury collisions, given the severe outcomes of head injury. It was also interesting to note that younger children were more likely to sustain a head/neck injury compared with older children; this may be attributed, in part, to their smaller stature. Given height differences, it may be more difficult for drivers/riders to see younger children and therefore they may not take actions to slow down to avoid a collision, thereby colliding at relatively high speed. It may be that shorter children may be at increased risk of head impact compared with taller children [20].

The findings from this analysis raise a number of potential opportunities for countermeasures to address the high rate of pedestrian trauma and especially death and injury to children in Malaysia. The key issues that should be addressed to reduce child pedestrian deaths and serious injuries are rural collisions on major high speed roads, and collisions between pedestrians and passenger vehicles as well as motorcycles.

Rural roads and roads in small towns in Malaysia rarely provide footpaths for pedestrians, or crossing facilities. Moreover, speeds are relatively high on many of these roads. Engineering countermeasures have the potential to quickly and effectively create a safer and more ‘crashworthy’ travel environment for vulnerable road users. The improvements that appear to provide the most benefit for pedestrians in general, and for children, include: i) measures to reduce travel speeds where pedestrians are present (lower speed zones and traffic-calming measures), and ii) provision of infrastructure that gives higher priority to pedestrians in critical locations (through separation of travel modes, e.g., school crossings, provision of footpaths, signing to warn of children crossing) [19-20].

Pedestrians are only safe when vehicle speeds are low, in the order of 30 to 40 km/h [21-22]. At these speeds, most potential collision situations can be recognised and avoided, and, if a collision does occur, damage and injury should be light to severe, but rarely fatal. Research shows unequivocally that crash incidence and crash severity decline whenever speed limits are reduced and increase when speed limits are raised [23-24]. Most OECD countries have adopted general urban speed limits of 50 km/h and some permit zoning at lower speeds in residential areas and school zones. Reduced speed limits around schools are not common in Malaysia; however, there are increasing numbers of areas introducing 30 km/h speed limits near schools. An analysis of speeding in school zones revealed that there is poor compliance [25] with speed zoning in

Malaysia, therefore targeted speed reduction enforcement measures should be a priority in Malaysia. These include lowering of speed limits in high pedestrian activity areas as well as introduction of traffic calming measures. Traffic calming measures aim to reduce the number and speed of vehicles in local streets and in areas where there is high pedestrian activity. They act to make drivers more attentive to their surroundings and drive more slowly or appropriately for the environment. The ‘woonerf’ concept encourages drivers to drive slowly by physical modifications to the roadway (such as pavement narrowing, refuge islands, alterations to the road surface, speed humps, roundabouts and gateway treatments). These are now common in Europe, with many reports of success, particularly in terms of speed reduction, crash reduction, increased walking activity, and changes in driver behaviour [20].

These measures should be introduced in association with effective enforcement and educational strategies. Given that unsafe pedestrian behaviour often increases their crash risk, educational and training measures that aim to correct or modify these behaviours should be developed and implemented, particularly in rural areas. It is also considered important to educate both pedestrians and drivers/riders about the rights and responsibilities of all road users.

## Conclusions

Pedestrian safety is a concern worldwide, and in Malaysia. These concerns are likely to continue to increase unless effective initiatives are implemented. More importantly, the safety of our children as pedestrians is of great concern, given that a sizeable proportion of pedestrians killed and seriously injured involve children and the special value society places on its youth.

The findings from this study confirm previous studies and add some new information on fatal and serious injury collision risk amongst young children in Malaysia. Young children in Malaysia appear to be at highest risk in rural areas, on major roads with a mix of vehicles and relatively high speed limits, and while they are playing or attempting to cross the road without the aid of crossing facilities. The implications for countermeasure development are presented to address these priority issues including improved road design and reduced speeds on rural roads, as well as supporting education and enforcement initiatives.

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## Child occupant protection in Australia

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### Abstract

Child occupants require special consideration in the motor vehicle, where the environment is largely engineered for adults. This paper reviews the issues that place child occupants in a special category and how these have been dealt with in Australia, as well as the history of legislation covering children in cars and its effectiveness in enhancing crash protection. Recent research highlighting current problem areas for Australian child occupants is also reviewed.

This review illustrates that the general principles of occupant protection can be applied to children but that this application also requires knowledge of the developmental stages of children. Legislation has been effective in getting children into restraints when travelling in cars, and recent changes to

Australian law mandating the types of restraint used appears to have improved restraint choice in the short term. The history of legislation effectiveness suggests that it is likely that ongoing educational and enforcement activities will be required to sustain and maximise the effect of the new laws.

Ensuring that restraints are used correctly is as important as getting children into the right type of restraint. Increasing correct use among child occupants requires additional strategies. To date, the only strategies shown to be associated with increased levels of correct restraint use are hands-on demonstration and the use of services like the New South Wales Authorised Restraint Fitting Station network. There is a need for continued focus on reducing the complexity of child restraint systems to enable correct use. Other issues of current importance for child occupants include the need to ensure

interventions targeting optimal child restraint practices are made available to all members of the Australian community and that messages used in these interventions are consistent. Finally, there is currently a gap in protection for children too big for boosters but too small to be optimally protected by the adult seatbelt. This gap highlights the need for booster seats that can accommodate children beyond their 7th birthday and more focused attention to the safety performance of the rear seat of modern vehicles.

## Introduction

Trauma is the leading cause of death and one of the main causes of hospitalisation in Australian children. Transport-related incidents are responsible for the greatest burden of this disease. [1] The rate of deaths among children due to transport-related causes in Australia compares poorly to other industrialised nations. In 2001, UNICEF ranked Australia 17th out of 26. [2]

Within New South Wales (NSW), an average of approximately 1130 child occupants are injured and a further 17 killed each year in motor vehicle accidents (MVAs), based on data from 2005–2009. [3] Nationally, the number of children killed each year approaches 70 (5 year average for 2005–2009 is 68 [4]) and the number seriously injured is in the vicinity of 3000 per year.

While these casualty figures are a vast improvement on the number of deaths and injuries seen in child occupants in the 1970s where approximately 3000 children were killed and injured on NSW roads alone (RTA 10 year average), there has been little improvement over the last two decades, with total casualty figures remaining static.

Motor vehicles have historically been seen as a product designed for the adult population, hence the design of safety systems have also tended to prioritise the protection of adult occupants. There have been a number of extremely successful vehicle safety interventions, such as better designed vehicle structure, with engineered ‘crush zones’, seatbelts and airbags, which have led to the reduced frequency and severity of injuries to adult occupants.

Child occupants are a unique class of road user. This paper reviews how Australia has dealt with providing crash protection to children in the motor vehicle, where the environment has been, and continues to be, largely engineered for adults. It also examines the current areas of greatest need for enhancing crash protection for child occupants.

## Method

A non-systematic review of literature covering crash protection for child occupants and their special needs, and how this has been dealt with in Australia was conducted. This was achieved by targeted searches of published literature using Medline and the Australian Transportation Index, as well as the contents of published conference proceedings from relevant high profile international conferences, and following the citation trees of

relevant publications. The catalogue of the then NSW RTA library was also used to identify relevant historical reports not widely available in the published literature but documenting important historical information. Recent research (in which the authors have been involved) that provides insight into the current problems for child occupants was also reviewed.

## Results and Discussion

### Principles of occupant protection

Occupant protection is based on a set of principles, largely founded on Newtonian physics, and the objective of controlling the force transferred to an occupant during a crash.

The primary principle involves maximising the distance over which an occupant decelerates during an impact so as to lower the forces felt by the occupant. This is often referred to as maximising the occupant’s ‘ride down’. In modern vehicles this is generally achieved by engineering ‘crush zones’ into the vehicle design. This allows the passenger compartment to come to a stop over the greatest possible distance, while energy is absorbed by the crushing vehicle. To gain the full benefits of the available ‘ride down’ distance the occupant must be coupled as tightly as possible to the vehicle. Secondly, it is important to control the forces generated when the occupant is coupled to the vehicle (restrained). It is important that any loads developed by the restraint system and applied to the occupant are applied to the parts of the occupant’s body that can best withstand them.

Once the occupant is held within, and tightly coupled to, the passenger compartment, and loads are distributed in a controlled way, other principles of occupant protection become important. These include minimising the possibility of serious injury caused by the occupant contacting structures within the vehicle; the reasons behind this are similar to the key principle above, since contact with a rigid vehicle structure means the impacted body will decelerate over a very short distance and time. This is achieved by preventing the contact or, if this is not possible, ensuring any structures that are likely to be impacted control this deceleration as much as possible using energy absorption or compliant materials. Lastly, relative motion between adjacent body parts needs to be kept within physiologically tolerable ranges of motion.

These principles can easily be seen at work in the case of adult safety restraint systems. For seatbelts, the better the fit in terms of how tightly the occupant is tied to the vehicle, the closer the occupant’s deceleration matches the rate of deceleration of the vehicle. Three point seatbelts are designed to make contact with the stronger bony parts of an adult occupant’s body - the iliac crests of the pelvis, clavicle and sternum. Airbags also act to control the deceleration of an adult occupant’s head, minimise contact between the occupant and the steering wheel or dashboard, and minimise relative motion between an occupant’s head and neck. Head restraints, or headrests, also reduce relative motion between an occupant’s head and neck in rear impacts.

## Children are not scaled down adults

The same principles govern the protection of child occupants in crashes. However, there are significant differences in size, and the proportional size of different regions of the body in the child and in the adult, and these proportions change as a child grows from birth to adolescence. Body segment lengths and weight rapidly change in the first year of life, and growth slows incrementally until full adult size is attained. At 5 months the birth weight is doubled, at 5 years the birth weight has increased by a factor of 6 and by age 10 the body weight is 10 times that of the newborn. [5] At birth a child's head accounts for one quarter of the child's height and represents more than half of the total body weight. The size of the newborn brain is approximately 25% of the adult brain but the weight of an infant is only about 5% of an adult. In the infant, the torso and arms are proportionally longer than the legs. The relative difference in these proportions, compared to the adult, decreases as the child grows, resulting in distinct differences between children of different ages. At birth the mid-point of the body is slightly above the umbilicus, at 2 years it is slightly below the umbilicus and at 16 years it is near the pubic symphysis. [5]

These differences in body segment proportions have a marked effect on seated height. At birth, seated height represents about 70% of the total body length; at 3 years it is approximately 57% of overall height; at about 13 years it is about 50% and reaches the same proportion as an adult from about 15 or 16 years. [5]

Body segment differences also influence the centre of gravity, with the centre of gravity being much higher in children than in adults. The centre of gravity depends on size and weight distribution (as well as seated posture) and therefore also varies within age groups. Variations in seated height and the location of the body's centre of gravity, depending on age, underlie the need for variation in the approach to effective restraint to meet the principles of occupant protection.

There are also a number of other changes related to the structure and characteristics of bones, muscles and ligaments. These result in differences in structural and mechanical properties that are likely to result in differences in response to loading and are also likely to influence variations in injury patterns between children of different ages and between children and adults. For example the softer ligaments, weaker muscles, and less angled facet joints of the spine in young children predispose children to spinal cord injury in the absence of bony injury. This type of injury, known as SCIWORA (spinal cord injury without radiographic abnormality) is rare, but is a phenomenon seen most commonly among paediatric patients. [6] The reported incidence of SCIWORA in paediatric spinal injury patients ranges from 3% to 32% depending on the sample, definition used in the diagnosis, and method of diagnosis. [7] In adults, the upper range of reported incidence is about 12%. [8] Spinal injury and SCIWORA is rare, but the most common mechanism of spinal injury in children is motor

vehicle accidents. [9] In a medical record review of child occupants aged 0-16 years with injury to the spinal region at two major childrens' hospitals in Sydney throughout 1999 to 2004, two of the 80 children identified were diagnosed with SCIWORA. [10]

One area of anatomical difference between children of different stages of development is of particular relevance to child occupant protection - the morphology of the pelvis. These differences have particular significance for differences in seated posture. In adults, the components of the hip bones are completely fused together to form a single bone; however, in infants and children they are not. The most anterior edges of the hip bones are known as the iliac wings and on these, in adults, are two pairs of bony prominences known as the anterior superior iliac spine (ASIS) and the anterior inferior iliac spine (AIIS). The ASIS is a well-known anatomical landmark used as an anchor point for the lap part of seatbelts. These bony prominences are absent in young children and the iliac wing is round and smooth until at least 8 to 10 years. [5, 11, 12] This probably limits the effectiveness of seatbelts in restraining the pelvis in younger children, and contributes to 'seatbelt syndrome' injuries observed in the field.

Another important difference is the proportional size of the abdomen, and the relative size and position of abdominal organs. There is less bony protection of abdominal organs in children. For example, at birth the liver occupies two fifths of the entire abdominal cavity and accounts for more than 5% of the total body weight. In an adult, the liver lies completely behind the ribcage and accounts for less than 3% of the total body weight. As the child's skeleton grows, more of the liver becomes covered by the ribs, but parts of the liver remain at least 1cm below the ribs up until about 6 years of age. Further to the skeletal size issues, the ribs of infants and children are more elastic than in adults. The thoracic wall is also thinner and, like the contents of the abdominal cavity, there are differences in the relative size and location of the heart and lungs in children and adults. [5, 11, 12]

Understanding the unique features of child occupants is critical to understanding how injury to children in crashes can be prevented. Specific attention to differences in anthropometry and physiology between children and adults like those described above has led to the evolution of restraint systems designed for children of different age and size ranges, as described below.

## Child restraint types

Different types of restraint are available for children of different size ranges. In Australia, the design (and performance) of child restraints is regulated by Standards Australia. All child restraints sold in Australia must be approved to the current Australian Standard. This Standard designates five types of child restraints, which can roughly be grouped into restraints for infants (rearward facing restraints), restraints for toddlers/pre-schoolers (forward facing restraints) and restraints for young children (booster seats).

Type designations taken from Australian Standard (AS) 1754 are as follows:

- Type A1: Rearward-facing restraint with a harness or other means of retaining the occupant of supine length up to 70 cm, and approximately 6 months of age
- Type A2: Rearward-facing restraint with a harness or other means of retaining the occupant of supine length up to 80 cm, and approximately 12 months of age
- Type A3: Transversely installed restraint with a harness or other means of retaining the occupant of supine length up to 70 cm and approximately 6 months of age
- Type B: Forward-facing chair with harness, suitable for children approximately 6 months to 4 years of age
- Type C: Forward-facing harness without chair, to be used in conjunction with a booster seat suitable for children approximately 4 to 7 years of age and without a booster seat for children approximately from 8 to 10 years of age
- Type D: Rearward-facing chair with harness, suitable for children approximately 6 months to 4 years of age
- Type E: A booster seat used in conjunction with a Type C child restraint and a seatbelt, or with a lap-sash seatbelt, suitable for children approximately 4 to 8 years of age whose height is less than 128 cm
- Type F: A restraint consisting of either
  - (i) a booster seat used in conjunction with a Type C child restraint and a seatbelt, or with a lap-sash seatbelt suitable for children approximately 4 to 10 years of age whose height is less than 138 cm, or
  - (ii) a converter used in conjunction with a seatbelt, suitable for children approximately 8 to 10 years of age.

The current standard, AS1754:2010, is currently under review and a new version is expected to be released in late 2012. There may be some changes to these type designations in that version.

### Child Restraint anchorage systems

The current method of attaching rearward and forward facing restraint systems in Australia uses an adult seatbelt and a top tether strap. The adult belt is used as the means of tying the lower portion of a restraint system to the vehicle. Upper anchorage of the child restraint system is achieved through the use of the top tether strap. Top tethers provide much more secure attachment of child restraints compared to being attached by the seatbelt only. In particular, they provide secure attachment at the top part of the child restraint, so that it can ‘ride down’ the crash whilst the vehicle is crushing, and also considerably reduce excursion of the child’s head relative to the vehicle interior in both frontal and side impacts. [13, 14]

Alternative forms of anchoring rearward facing and forward facing restraints are used in other countries. In Europe, the use of top tether straps is not universal, and some rearward facing restraints use a floor mounted tether as an alternative. Recently, in Europe and North America other forms of anchorage have begun to become commonplace. These fall under the category

of dedicated child restraint anchorage systems. The intention of this concept was to develop a universal form of child restraint anchorage to overcome incompatibility problems between different designs of child restraint, vehicle seatbelt geometry and vehicle seat characteristics. An International Standard defining such a system was completed in 1999. [15] However, this international standard has not been universally adopted, and a number of different forms of this concept of anchorage are now being used in North America and Europe, including the European ISOFIX systems and North American LATCH systems. Numerous laboratory studies have demonstrated that a system incorporating two lower rigid anchorages and a top tether would enhance the protection currently being offered by Australian child restraint systems. [16- 19] However, implementation problems associated with harmonisation of Australian vehicle standards with international vehicle standards, and maintaining the same level of performance throughout a transition period where both the conventional and new forms of anchorage would be used, has slowed the adoption of such systems into Australia. [20]

The use of dedicated child restraint lower anchorages are being considered within the latest revision of AS1754 and it is likely that the next version of the Australian Standard will contain requirements for anchorage systems that will allow coupling of rearward and forward facing restraints with ISOFIX attachments provided in cars. The design and performance of the ISOFIX attachments within vehicles sold in Australia is covered by Australian Design Rules (ADRs). ADR 34/02 which includes requirements for ISOFIX anchorages in cars was recently published by the Federal government. The provision of ISOFIX anchorages by vehicle manufacturers is, however, optional.

Boosters are not generally tied to the vehicle, instead they are placed onto the vehicle seat and the adult seatbelt restrains both the child and the seat. Under AS/NZS 1754, combination forward-facing/booster restraints and booster seats over 2kg must use a top tether to limit the potential for the child to be excessively loaded between the restraint and the belt. In the past alternative (ISOFIX type) anchorage systems have not been used in combination with booster seats. More recently, a small number of booster seats designed for use with alternative forms of anchorage have come onto the North American market. However, there are potential problems with using booster seats with these anchorages, as they may overload the ISOFIX anchorages, which has resulted in some confusion in North American markets.

### Child occupant legislation and restraint use

Children under 8 years of age were initially exempt from laws requiring the compulsory use of seatbelts introduced into Australia in the early 1970s. Mandatory use of restraints by Australian children began in Victoria in 1976 and was extended to NSW in March 1977, and it became compulsory for all children under 8 years to use an appropriate restraint where one was available. By 1982, this legislation had extended to all

Australian states and territories. [21] The law at that time required all children to be restrained by an appropriate restraint when travelling in a vehicle. However, the legislation defined 'an appropriate' restraint differently for children under and over 12 months of age. For children under 12 months, an appropriate restraint was defined as an Australian Standards approved child restraint. However, for children over 12 months, an appropriate restraint was defined as being either an approved child restraint or an adult seatbelt. [22]

Until recently, there have been few observational studies conducted in Australia examining the types of restraint being used by children of different ages. In NSW, a telephone survey exploring the restraint use by children aged 0-10 found that the majority of children aged 6 or older were using adult belts only. Among younger children, 40% of 5 year olds were using adult belts and 50% were using booster seats; more than half of 3 and 4 year olds were using either booster seats or adult belts and more than 20% of two year olds were using boosters. The predominant restraint used by children less than 2 years of age was a forward facing or rearward facing child restraint. [18] Similarly, in Victoria, self-reported appropriate use was low in children in this age range [23]. An observational survey conducted in South Australia found that booster seat use became common among children from age 2 onwards, and by 6 years adult seatbelts became the most common form of restraint being used. [24] Low child restraint use by children under age 4 was later confirmed in South Australia in an on-road observational study. [25]

In 2008, Brown et al. [26] conducted a cross-sectional population referenced observational survey of child restraint practices across NSW which confirmed the high rates of inappropriate restraint use in children from about 2 years.

Studies conducted in Australia [27] and internationally [28-30] demonstrated that the use of inappropriate restraints increased the risk of injury in crashes. Laboratory work demonstrated that the increased risk of injury among inappropriately restrained children was largely due to poor belt fit that occurs when young children are prematurely graduated to booster seats and/or adult belts. Poor belt fit allows loading of vulnerable parts of the body, particularly if the child is not in a 'good' posture at the time of impact. This work also found that appropriate restraint use better controls occupant motion, directs the restraint forces to regions of the body better able to withstand them, and thus reduces the risk of serious injury. [9] Du et al. [31] used the population-level observational data of Brown et al. [26] to estimate the population attributable risk fraction for different forms of sub-optimal restraint and estimated that casualties and fatalities among Australian children aged 1-7 could be reduced by up to 13% and 34% respectively by moving more children into appropriate restraints.

In 2007, the National Transport Commission (the body governing the Australian Road Rules) published a review of

legislation pertaining to the restraint of children in cars. [32] This document recommended extending legislation requiring the use of child restraint and booster seats to children up to age 7 in the near future and up to age 9 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 have now been implemented as new laws in all Australian states, except the Northern Territory.

The introduction of mandatory restraint laws for children in Australia in the 1970's had an immediate effect on the rates of restraint usage among child occupants. Prior to the introduction of the legislation, only about 30% of children travelling in cars used some form of restraint; this increased to almost 60% after the introduction of the legislation in NSW. [33] However, according to Freedman et al. [34], these immediate increases in usage were shortlived and usage rates dropped to around 40% eight months after the introduction of the legislation. Further increases were gained through targeted educational campaigns. Ongoing efforts in this area resulted in usage rates in NSW in 1994 being between 80% and 90% depending on where the child was seated, with slightly higher usage rates in front seat positions. Currently, children in NSW have restraint usage rates beyond 98%. [35] Similar current usage rates have been reported in other states. [36] However, as noted above, prior to implementation of mandatory appropriate use laws, many of these restrained children were using restraints designed for older children or adults.

Data from direct observations of child restraint practices in NSW in 2008, prior to introduction of the new legislation in 2010, were compared with direct observations of child restraint practices among children aged 2-5 years within low socioeconomic areas in 2010 (in the immediate post legislation period). Logistic regression was used to adjust for any variations in demographic distributions between the samples. Age-appropriate restraint use increased from 41% to 73%. After controlling for the child's age, parental education, income and language spoken at home, children in the post-legislation sample were more likely to be appropriately restrained (OR 2.2; 95%CI 1.4-3.6). [37]

Keay et al. [38] demonstrated that a multifaceted intervention that included education, hands-on instruction and restraint subsidies was able to significantly increase optimal child restraint practices beyond the effect of legislation.

## Current problem areas for Australian child occupants

### Incorrect use

The real world benefit of a passive occupant crash protection system is determined by both its inherent design and how it is used in the real world. Getting children into the right design of restraint for their age is only half of the solution. Optimal crash protection requires correct use of size-appropriate restraints. Errors in how a child restraint is used increases risk of injury in

a crash because they loosen the link with the vehicle and allow greater motion of the child and/or alter the way crash forces are distributed over the body. A number of Australian studies have reported observed errors in child restraint use in convenience samples. [39-40] We recently estimated that half of all child passengers aged 0-12 years in NSW [26] had at least one error in how they were using restraints when travelling in cars, and have calculated that removing these errors in use among appropriately restrained children could prevent 42% of fatalities and 55% of non-fatal injury among children aged 1-6 years. [31] It is important to understand that prior to the new legislation, incorrect use was occurring as frequently as inappropriate restraint selection [26] and it potentially carries a higher risk of injury in crashes than simply using the wrong sort of restraint for the size of the child. [41, 31]

Brown et al. [26] examined the types of misuse and the frequency with which they occurred. Errors are more common in convertible restraints, and when errors occur they usually occur in combinations. From this work it appears that addressing harness misuse is the highest priority for rearward and forward facing restraints, followed by installation problems involving the seatbelt and the top tether. The highest priority areas for booster seats involve misuse of the seatbelt, and belt guide features. Similarly for seatbelt users, the priority is correcting errors associated with positioning of the belt. The most common harness and seatbelt errors, are excessive (>25mm) slack and non-use or partial use of the internal harness or belt.

In NSW, an Authorised Restraint Fitting Station (ARFS) network has been operating since the 1980s and is overseen by the State government road safety department. The fitting station network was established to assist parents and carers to correctly install and use child restraint systems. Restraint fitting stations also operate in other Australian states but do not all operate under the same governance system used in NSW, where operators must be accredited, and the services are audited regularly. Use of the NSW ARFS network is associated with less incorrect use, as shown in a recent analysis. [42] The results demonstrated that the odds of children of respondents who did not use restraint fitting stations being incorrectly restrained were 1.8 times higher (95% CI 1.1–2.8) than for children of users, based on parental report of the use of a fitting station. Regardless of whether or not a restraint fitting station had been used, there was a trend towards greater odds of incorrect restraint use as the length of restraint ownership increased (OR 1.3, 95% CI 1.0–1.7), suggesting that the improvements in restraint use arising from use of the fitting stations ‘wear off’ over time. [42]

While the above results relate to NSW fitting stations, it is likely that the hands-on instruction many parents receive at similar services are helpful regardless of how this is delivered, provided that they receive accurate and appropriate instruction. Hands-on demonstration of correct use outside of a formal

fitting station network has also been shown to be effective in reducing errors in restraint use. [43]

Not all parents use services like the fitting station networks and/or free restraint checking days held by different organisations. In the NSW study, only about 30% of parents reported using these services and greater understanding of the barriers to use of these services is needed. [42]

Other strategies in place in Australia to counter errors in use are directed at the design of child restraints. Child restraint systems can be more complex to use than adult seatbelts because these restraints must be installed in the vehicle and there are usually more steps necessary to properly secure the child in these restraints than in an adult seatbelt. Few restraints incorporate automatic adjusters, while these are almost universal for seatbelts. In many cases, the inherent designs of the restraint systems do not assist the process. Correct installation can be difficult to achieve because of confusing belt paths in rearward and forward facing restraints and difficulties in being able to completely remove slack from the belt and tether. Securing the child correctly can also be difficult to achieve and it is not always intuitively easy to understand which features need to be used, and when and how these features are supposed to be used. Further, there are no restraints currently on the Australian market that provide any feedback to the user as to whether or not the restraint is being used correctly. The Australian Child Restraint Evaluation Program (CREP) assesses the ease of use of child restraint systems on the Australian market and communicates this to consumers using a rating program. As part of its aims, CREP tries to encourage manufacturers to provide restraint systems that are not only easy to use but are also difficult to use incorrectly. This issue has also been picked up by Standards Australia with greater attention beginning to be placed on requirements centred around assisting users to achieve correct use, including enhanced labelling and warnings, and a new method of determining whether a child is using the most appropriate restraint for their size, based on seated shoulder height markers. [44]

#### **Children from culturally and linguistically diverse (CALD) communities**

The dominant language in Australia is English, but approximately 20% of the population speaks a different language at home. [45] Children from such families are more likely to incorrectly and inappropriately use restraints. [46, 47] This study identified that the increased risk of sub-optimal restraint use is associated with inadequate knowledge [46, 47], the determinants of intent and types of knowledge deficit in CALD communities in Australia are similar to those reported in mainstream populations [48], and there is a specific need to ensure access to detailed information through appropriate delivery strategies and languages. In a recent randomised controlled trial of a program delivered through early childhood education centres, the authors found an education program (including language specific material and free restraint checks)

was equally successful in improving restraint practices of children from CALD families as children from English speaking families. [38]

There is a clear need to ensure that any strategies implemented to enhance the effectiveness of legislation in promoting optimal restraint of children are implemented in appropriate languages and through appropriate delivery points to reach CALD community members, including the most recently arrived immigrants.

### Gap in protection

For child passengers there is also a gap in availability of suitable restraints between the time they become too big for available 'child' restraints and the size required to achieve good protection from adult belts. Current Australian law mandates the use of size-appropriate restraints up to age 7, and 'add-on' restraints are available that would accommodate most children up to about 9 years. A new category of booster seats (Type F) introduced in the 2010 edition of the Australian Standard (AS/NZS 1754) aimed to close this gap to some extent, but these restraints are designed to accommodate children up to 8-10 years of age, so there will still be a 'gap' for some children. This also reflects the situation internationally. However, adult restraint systems in many cars are unlikely to provide optimal protection for many children even up to the age of 16. [49] This highlights the importance of the inherent safety of the rear seat for optimising protection of older child occupants.

Almost 30% of passengers aged 9 years and older who were admitted to hospital in NSW following a motor vehicle crash during the three years 2005-2007, were rear seat occupants. Compared to drivers and front seat passenger positions, the rear seat had a greater proportion of fatalities (11% compared to 3% of drivers and 7% of front passengers). Among this sample, child occupants occupied rear seat positions relatively more often than adults, and while the proportion of fatalities among the rear seated older child occupants was similar to that for adult rear seat occupants, injury severity, in terms of length of stay in hospital, was greatest among the older child rear seat occupants with 2% requiring a hospital stay of longer than one week compared to only 0.5% of adults aged 17-55 years and 1% of the oldest adults. [37]

In Australia, there is currently no regulatory or other routine assessment of the rear seat and its safety systems. Recently, performance requirements have been introduced for rear seat crash tests in some New Car Assessment Programs (NCAPs) in other countries e.g. Japan, China and Europe. However, as shown by Brown et al. [50] these assessments do not adequately assess the rear seat for older child occupants. Brown et al. [50] suggest data from crash studies indicate a need to assess abdominal and lumbar/thoracic spinal injury risk in addition to assessments of head and chest injury risk like that currently included in NCAP protocols. Moreover, a lack of sensitivity to pelvic rotation in current generation Hybrid dummies makes assessment of abdominal and spinal injury risk difficult. [50, 51]

### Interventions beyond legislation

The success of the multifaceted intervention as demonstrated by Keay et al. [38] was based on a consistent message. Studies prior to the introduction of the new legislation illustrated the confusion felt by parents as to how best to protect their children in cars. The age-based nature of the new legislation, together with changes made in the 2010 version of the Australian Standard to support the age-based legislation, will address some of the confusion felt by parents. However, it is imperative that messages and answers to questions frequently asked by parents and the community give consistent advice in line with best protection principles. There are numerous agencies across Australia that provide guidance and advice to parents on how best to protect children in cars. However, there is currently no overriding co-ordination of these agencies or the advice given. Added to this is the growing number of informal parenting social internet networks where parents provide each other with advice, some of which might be correct advice but some which may not. There is a need for a single set of 'best practice' guidelines that can provide definitive and consistent advice for parents, carers and restraint professionals alike. The development of such a set of guidelines is currently underway. This co-ordination of messages is key to ensuring optimal restraint practices and the effect of the new legislation is maintained and improved on over time.

### Conclusion

Child occupant protection has come a long way in Australia since the 1970s when restraint use for children first became mandatory. Australia now mandates age appropriate restraint use up to age 7. Dedicated child restraint systems are available that will provide good protection up to about 9 years. However, there are still a number of areas where focused attention is required to ensure optimal crash protection for all child occupants. In particular there is a need to (i) actively encourage correct use of restraints, (ii) ensure information and interventions targeting optimal child restraint reach all members of the Australian community, (iii) actively pursue ways to ensure children too big for booster seats are offered high levels of crash protection in the rear seat, and (iv) ensure the effectiveness of the age appropriate restraint use legislation is sustained, and improved upon, by ongoing education and enforcement campaigns.

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## A cross sectional observational study of child restraint use in Queensland following changes in legislation

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### Abstract

As part of an evaluation of the 2010 legislation for child vehicle occupants in Queensland, roadside observations of private passenger vehicles were used to estimate the proportions of children aged under 7 years travelling in each of the five different restraint types (eg. forward-facing child restraint). Data was collected in four major population centres: Brisbane, Sunshine Coast, Mackay and Townsville. Almost all children were restrained (95.1%, 95% CI 94.3-95.9%), with only 3.3% (95% CI 2.6-4.0%) clearly unrestrained and 44 (1.6%, 95% CI 1.1-2.1%) for whom restraint status could not be determined ('unknown'). However, around 24% (95 CI 21.8-26.2%) of the target-aged children were deemed inappropriately restrained, primarily comprised of 3-6 year olds in seatbelts (18.7% of the 0-6 year olds, 95% CI 16.3-21.1%) or unrestrained (3.7% of the 0-6 year olds, 95% CI 2.5-4.9%) instead of booster seats. In addition, compliance appeared significantly lower for some regional locations where the proportion of children observed as completely unrestrained was relatively high and of concern.

### Introduction

Surveys of restraint use in Australia have shown consistently high levels of compliance over the past three decades, with recent figures indicating that compliance is in the order of 95-99% for all occupants. However, prior to 2010, legislation for children's restraints only specified the type of restraint that should be worn for infants under 12 months of age: these children were required to use an Australian Standards approved (AS/NZS1754) restraint [1]. For children of this age, approved restraints incorporate a 6-point internal harness and are secured to the vehicle by both an adult seatbelt passed

through the frame of the restraint and a top tether attached to an anchor point, generally located in the rear of the vehicle (Australian Design Rules govern where these anchor points may be located). For newborn babies, restraints face rearwards until the child outgrows the specification for the restraint (approximately corresponding to 6-12 months old depending on the restraint). Once this occurs, and the baby can support his or her head reliably, a forward-facing restraint can be used.

Before amendments to the pre-2010 legislation, it was perfectly legal for a child of 12 months old or more to be restrained in an adult seatbelt. However, research has consistently demonstrated that restraints specifically designed for children are very effective in reducing injury and death [1-7] and that children are better protected when they wear these restraints rather than adult seatbelts [8-11]. Fortunately, even though not mandated at the time, it was common practice in Australia for children aged 3 years and under to be restrained in child restraints [12-14]. Once past this age, studies in NSW, South Australia, Victoria and Queensland suggested that a large proportion of children were restrained in adult belts rather than dedicated restraints [12-17].

In recognition of this gap between the legislation and optimal protection, the National Transport Commission (NTC) amended the Australian Road Rules in 2009 to specify that child restraints should be used until children are at least 7 years old. Moreover, the type of restraint required and the seating row was also specified according to age in these new rules. From late 2009 to the end of 2010 all states and territories in Australia, with the exception of the Northern Territory, enacted legislation that incorporated these new child restraint requirements. For Queensland all child passengers have been required to use a dedicated child restraint until at least age 7

**Table 1. Rules for persons travelling in or on vehicles (as specified in Transport Operations (Road Use Management-Road Rules) Regulation 2009 Part 16: Rule No. 266: Wearing of seatbelts by passengers under 16 years old) [18]**

Age of child	Rules for the types of restraints to be worn (according to the child's age)
< 6 months	child must be restrained in a suitable and properly fastened and adjusted rearward facing approved child restraint
6 months – < 4 years	child must be restrained in a suitable and properly fastened and adjusted: rearward facing approved child restraint; or forward-facing approved child restraint that has an inbuilt harness
4 years – < 7 years	child must be: restrained in a suitable and properly fastened and adjusted forward-facing approved child restraint that has an inbuilt harness; or be placed on a properly positioned approved booster seat and be restrained by a seatbelt that is properly adjusted and fastened
	<u>Seating positions rules</u>
< 4 years	child must not be in the front row of a motor vehicle that has two or more rows of seats
4 years – < 7 years	child must not be in the front row of a motor vehicle that has two or more rows of seats unless all of the other seats in the row or rows behind the front row are occupied by passengers who are also under 7 years old

since March 2010. Table 1 sets out the types of restraints required for each age group. As can be seen, after children outgrow the rear-facing infant restraint, the next type of restraint is a forward facing child seat. Children must use these until at least 4 years old, at which time booster seats become the age-appropriate restraint. Booster seats are required until children are at least 7 years old, when seatbelts can then be used. Rear seating is also required until children are aged 7 years, although in situations where the rear seats are all occupied by other children under 7 years, a child can travel in the front seat if aged at least 4 years old. The legislation recognises that a very small proportion of children may be too big for the age-appropriate restraint and in these circumstances, a child can be restrained in the next-sized restraint.

In order to assess the extent to which parents were complying with the new legislation as well as to gauge the level of parental understanding of the purpose of the changes and support for these, an outcome evaluation was conducted approximately 18 months after the new laws were in place. The evaluation consisted of three studies, including the observational study to determine the level of compliance with the new legislation. This paper focuses primarily on the results from this observational study. Results of a second study using parent intercept interviews is reported in [19] and the interested reader is referred to this.

## Method

Roadside observations of vehicles carrying child passengers were carried out in four major population centres of Queensland. These were Brisbane, the Sunshine Coast, Mackay and Townsville. Brisbane was divided into north and south for

the purposes of ensuring that observations included a wider spread of the city. Suitable suburbs within each population centre were identified based on Australian Bureau of Statistics (2006) census data relating to two criteria: couple family income  $\leq$  AUD\$1400 per week; and at least 15% of residents aged under 15 years old. As the design of the evaluation included parent intercept interviews, and it was desirable for these to be conducted in the same suburbs as those for the observations, a third criterion was whether medium-large shopping centres in these suburbs were willing to grant permission for the researchers to approach parents within their precincts. Hence, while a fairly large pool of potential suburbs was generated for Brisbane North, Brisbane South, and the Sunshine Coast, in practice, consent to the study was only granted by a few shopping centre managers, thus limiting which suburbs were eventually included in the study. Table 2 details those suburbs where observations were carried out.

Observation sites were chosen close to primary schools and medium-large shopping centres as these were deemed likely to have high volumes of child-related travel and thus be cost-effective for data collection. Specific schools within or close to the selected suburbs were chosen on the basis of enrolments levels ( $\geq 200$  students) as indicated by the Queensland Schools Directory on the website for Education Queensland. For the Sunshine Coast and Mackay, due to there being fewer schools with sufficient enrolments, some of the schools chosen were located 10-15 minutes drive from the shopping areas where the interviews were conducted. In addition, for Mackay, a single data collection session was conducted in Sarina, a town of approximately 3200 people, located about 35 kilometres south of Mackay. This was because the demographic information

**Table 2. Cities and suburbs selected for collection of the observations (children's restraints and seating positions)**

City	Suburbs	Number of vehicles observed (number of child passengers observed)
<b>Brisbane North</b>	Aspley	
	Bald Hills	
	Bracken Ridge	
	Brookside	
	Keperra	
	Mitchelton	293 (419)
<b>Brisbane South</b>	Acacia Ridge	
	Algester	
	Calamvale	
	Inala	
	Forest Lake	512 (713)
<b>Sunshine Coast</b>	Maroochydore	
	Mudjimba	
	Mooloolaba	462 (668)
<b>Mackay</b>	West Mackay	
	Sarina	354 (526)
<b>Townsville</b>	Heatley	
	Vincent	294 (458)
	<b>Total</b>	<b>1915 (2784)</b>

from parents participating in the interview study in Mackay revealed that a proportion were residents of Sarina who regularly travel to Mackay to shop.

Trained observers worked in pairs and stationed themselves on the footpath at places where traffic was forced to slow down (e.g. corners) or stop (e.g. traffic lights) and where they could clearly see into the vehicles. In order to reduce the possibility of counting vehicles more than once around schools, an assumption was made that parents would use the same pick-up/drop-off point for their children each day and thus data was collected for each school entrance only once. Sessions were conducted around schools at the typical school day commencement and closing times, 8.15–9.00 am and 2.30–3.30 pm. Around shopping areas, sessions were carried out between 9.00 am and 10.30 am when child passenger traffic is highest. Observers were instructed to include only private passenger vehicles (i.e. no taxis, buses, mini-buses or vans) with a rear seat (not utilities/pick-up trucks) and carrying child passengers. In order to ensure that drivers were free to choose where the child was seated, only vehicles with no adult front seat passenger were included. For sites where vehicles were moving, both observers collected data on each vehicle and verbally verified the details with each other for each observation. Where vehicles had more than one row of rear seats, one observer collected the data for the front and middle row, while the other collected data for the subsequent row(s). Where the observers disagreed about what they had observed,

the vehicle was excluded from the collection. For situations where traffic was forced to stop, observers were able to collect data on separate vehicles (e.g. standing on opposite sides of the road and observing traffic in opposing directions of travel) by walking up and down past the stationary vehicles. In practice, due to the high prevalence of vehicles with very darkly tinted windows or window 'socks', and the difficulty of making accurate observations when these vehicles were moving, the majority of observations were taken where traffic was forced to stop. Thus observers could spend more time on each observation and be reasonably certain that the data captured was accurate.

Data was recorded for each child passenger's seating position (front, rear), estimated age (based on baby length or child's seated height, ≤ 6 mths, 7 mths-2 years, 3-6 years, 7-12 years), and the type of restraint worn. Restraint types were categorised as rear-facing infant restraint, forward-facing child seat, high-backed booster seat, seatbelt, 'unknown', or unrestrained. Children were only categorised as 'unrestrained' where the observer could clearly see that the child was not wearing a restraint (e.g. the child was standing up, sitting on an adult's lap, sitting in the middle of the two front bucket seats). Where the observer could not see the restraint (e.g. a child sitting in the middle rear position in a lap-only belt), but could not clearly see that the child was unrestrained, the category 'unknown' was used to denote this. As the legislation specifies that 3 year old children should be restrained in a forward-facing

child seat until they are at least 4 years old, it would have been ideal for the age groupings match these requirements. However, though in practice it was fairly easy to distinguish between a child under 2 years and those 3 years and over, it was too difficult for observers to distinguish between a 3 year old and a 4 year old child with a high degree of confidence. Accordingly, they were instructed to use the 3-6 year age grouping instead of 4-6 years.

## Results

Across the four cities, a total of 1915 vehicles carrying 2783 child passengers were observed. Almost two thirds (62.7%) of the vehicles carried only one child passenger, with 30.8% carrying two children and 6.5% carrying three or more. About half the sample of children were estimated as aged 6 years and under (1419, 51%) and the remaining children as aged 7-12 years (1364, 49%). Around one third (611, 31.9%) of the observed vehicles had a child passenger in the front seat. The majority of these were estimated as aged 7-12 years (542, 88.1%), though there were 69 children estimated as aged 3-6 years, and three children estimated as aged under 2 years, seated in the front seat.

Almost all children were restrained (2644, 95.1%, 95% CI 94.3-95.9%), with only 93 (3.3%, 95% CI 2.6-4.0%) children clearly unrestrained and 44 (1.6%, 95% CI 1.1-2.1%) for whom restraint status could not be determined ('unknown'). Consistent with similar studies, the most common type of restraint used was an adult seatbelt, with more than half of the 0-12 year old children (1470, 52.8%) restrained in these regardless of seating position.

Overall, 22.0% (615/2783) of the children were seated in the front seat, with 543 of these aged 7-12 years (39.8% of the children in this age group, 95% CI 37.2-42.4%), and 72 aged 0-6 years (5.1% of this age group, 95% CI 4.0-6.2%). As might be expected, almost all of the children seated in the front seat were restrained in seatbelts, though there were 13 children observed using dedicated child restraints. For children seated in the rear seat, more than half wore dedicated child restraints (1161, 53.6%) with the most common being forward-facing child seats (639, 29.5%) followed by booster seats (470, 21.7%) and rear-facing infant restraints (41, 1.9%), with a few children (11, 0.5%) restrained in a child H harness (4-point restraint). For 42 (1.9%) children, the type of restraint could not be determined and a larger proportion (82, 3.8%) were clearly unrestrained. Table 3 summarises these results.

## Children under 7 years

As the legislation applies to the types of restraints for children under 7 years, the remainder of the analyses will refer only to the children in this age group. For these children, most were seated in the rear seat (1347, 94.9%, 95% CI 93.5-95.9%). A primary interest was whether children were restrained in the type of restraint specified for age under the legislation, and seated in the rear seat as required. Accordingly, each observed child estimated as aged 0-6 years ( $n = 1419$ ) was given a code of 'appropriate' or 'inappropriate' based on the combination of observed restraint type and seating position. Thus infants estimated as aged 0-6 months were deemed appropriately restrained if they were in the rear seat and using a rear-facing infant restraint or capsule. Children estimated as aged 7

**Table 3. Types of restraints worn and seating positions by estimated age group of child**

<b>Restraint type</b>	Child's estimated age					<b>Totals</b>
	<b>0-6 mths</b>	<b>7 mths-2 yrs</b>	<b>3-6 yrs</b>	<b>7-12 yrs</b>		
<b>Front seat</b>						
Rear-facing infant restraint	1	-	-	-	-	1
Forward facing child seat	-	-	2	-	-	2
Booster seat	-	-	7	3	-	10
Seatbelt	-	1	55	531	-	587
Unknown	-	-	3	1	-	4
Unrestrained	1	-	2	8	-	11
					<b>Total 615</b>	
<b>Rear seat</b>						
Rear-facing infant restraint	38	3	-	-	-	41
Forward facing child seat	8	367	263	1	639	
Booster seat	1	5	356	108	-	470
H harness	-	-	7	4	-	11
Seatbelt	-	1	211	671	-	883
Unknown	-	3	32	7	-	42
Unrestrained		1	51	30	-	82
					<b>Total 2168</b>	
<b>Totals</b>	<b>49</b>	<b>381</b>	<b>989</b>	<b>1364</b>	<b>2783</b>	

months to 2 years were deemed appropriately restrained if they were in the rear seat and using a forward-facing child seat, or a rear-facing child restraint. Children estimated as aged 3-6 years were deemed appropriately restrained if they were sitting in the rear seat and using either a forward-facing child seat, a booster seat or an H harness. The legislation allows for children aged 4-7 years to occupy front seats if all rear seats are already occupied by other children aged under 7 years. Only seven vehicles in this study carried four or more child passengers, and thus may have necessitated a child seated in the front seat. However, all had more than two rows of seats and none were observed with a child seated in the front row.

Overall, 1041 (73.3%, 95% CI 71.0-75.6%) of the under 7 year old children were categorised as 'appropriately' restrained, while 340 (24.0%, 95 CI 21.8-26.2%) were deemed 'inappropriately' restrained and for 35 (2.7%, 95% CI 1.9-3.5%) children restraint status could not be determined. Chi square analyses revealed that the number of children in the vehicle (1-2 children versus 3 or more children) did not appear to affect whether a 0-6 year old child was seated in the front seat  $\chi^2 (1) = 1.52$ ,  $p = .218$  (data not shown). Similarly, no statistically significant differences were found between the

different locations for whether a child aged 0-6 years was seated in the front seat ( $\chi^2 (4) = 7.12$ ,  $p = .130$ ), with over 90% of vehicles in each location not carrying a child of this age in the front seat (data not shown). The mean proportion of vehicles with a child aged 0-6 in the front seat was 5.6% (range 3.6% in Townsville, to 8.5% in Mackay).

However, differences were found for location in terms of the number of child passengers in the vehicle. Children aged 0-6 years that were observed in Mackay were more likely to be travelling in a vehicle carrying three or more children, while children observed in Brisbane South were less likely to be travelling in vehicles with three or more children (see Table 4).

Due to the very small numbers of children using a dedicated child restraint in the front seat, as well as the relatively small numbers of children aged 0-6 occupying front seats, only the data for children in the rear seat was included in more detailed analyses on restraint type and appropriateness. In addition, for these analyses, H harnesses were combined with booster seats, and the 'unknown' restraint category (35 children) was excluded.

As can be seen in Table 5, the most popular type of restraint for children 0-6 years was a forward-facing child seat (48.7%

**Table 4. Number of vehicles (%) carrying either one or two children, or three or more children (0-6 years only) by location**

Location	1 or 2 child passengers n vehicles (%)	3 or more child passengers n vehicles (%)	
Brisbane North	204 (90.3)	22 (9.7)	
Brisbane South	381 (91.1)	37 (8.9) <sup>a</sup>	
Sunshine Coast	302 (84.4)	56 (15.6)	
Townsville	193 (86.2)	31 (13.8)	
Mackay	159 (80.7)	38 (19.3) <sup>a</sup>	$\chi^2 (4) = 7.12^b$ , $p = .002$ , $\varphi_c = .11^c$

a These cells had a major contribution to the chi-square result (standardised residuals +/- 1.96)

b Significant > .05

c  $\varphi_c$  = Cramer's V for effect size (Small = .1; Medium = .3; Large > .5)

**Table 5. Number of child passengers in the vehicle by restraint type (0-6 year olds, rear seat only)a**

Restraint type	Number of child passengers in the vehicle		
	1 or 2 children n (%)	3 or more children n (%)	Totals
Rear-facing infant restraint	40 (3.5)	1 (0.6)	41
Forward facing child seat	573 (50.1)	65 (38.5)	638
Booster seat	329 (28.8)	39 (23.1)	368
Seatbelt	153 (13.4) <sup>b</sup>	59 (34.9) <sup>b</sup>	212
Unrestrained	48 (4.3)	4 (3.0)	52
<b>Totals</b>	<b>1143</b>	<b>168</b>	<b>1311</b>

a For number of child passengers in the vehicle, the figures in the table refer only to the 0-6 year olds but the vehicles may have had one or more child passengers aged 7-12 making up the total count of children in the vehicle. 'Unknown' restraint type was excluded; H harnesses combined with booster seats

b These cells had a major contribution to the chi-square result (standardised residuals +/- 1.96)

c  $\varphi_c$  = Cramer's V for effect size (Small = .1; Medium = .3; Large > .5)

**Table 6. Number of child passengers in the vehicle by appropriateness of the type of restraint worn (0-6 year olds, rear seat only)**

Number of child passengers in the vehicle	Restraint status		$\chi^2$ (1) = 34.75, p < .001, $\varphi_c$ = .16 <sup>b</sup>
	Inappropriate n children (%)	Appropriate n children (%)	
1 or 2 children	208 (18.2)	936 (81.8)	
3 or more children	64 (37.9) <sup>a</sup>	105 (62.1) <sup>a</sup>	

<sup>a</sup> These cells had a major contribution to the chi-square result (standardised residuals +/- 1.96)<sup>b</sup>  $\varphi_c$  = Cramer's V for effect size (Small = .1; Medium = .3; Large > .5)**Table 7. Number of children restrained in each type of restraint by location (0-6 year olds, rear seat only)**

Location	Restraint type				
	Rear facing n (%)	Forward-facing child seat n (%)	Booster seat n (%)	Seatbelt n (%)	None n (%)
Brisbane North	6 (3.0)	107 (53.8)	47 (23.6)	37 (18.6)	2 (1.0) <sup>a</sup>
Brisbane South	14 (3.6)	194 (50.0)	96 (24.7)	69 (17.8)	15 (3.9)
Sunshine Coast	15 (4.5)	160 (47.9)	108 (32.3)	39 (11.7)	12 (3.6)
Townsville	4 (1.9)	106 (49.8)	73 (34.3)	19 (8.9) <sup>a</sup>	11 (5.2)
Mackay	2 (1.1)	71 (39.7)	44 (24.6)	48 (26.8) <sup>a</sup>	14 (7.8) <sup>a</sup>

<sup>a</sup>These cells had a major contribution to the chi-square result (standardised residuals +/- 1.96)

overall), followed by booster seats (28.1% overall) and seatbelts (16.2% overall). However, the number of children in the vehicle appeared to influence the type of restraint worn, with children in vehicles with three or more child passengers more likely to be wearing a seatbelt than children in the vehicles with only one or two child passengers (see Table 5). Consistent with this result, children in vehicles with greater numbers of children were also more likely to be deemed to be inappropriately restrained (37.9%) than children in vehicles with fewer child passengers (18.2%) as displayed in Table 6.

Results of comparisons of restraint type and appropriateness for location revealed that children observed in Mackay were more likely to be restrained in a seatbelt (26.8%, 95% CI 20.2-33.2%) or to be unrestrained (7.8%, 95% CI 3.9-11.7%) compared to children who were observed in the other locations  $\chi^2$  (16) = 55.29, p < .001,  $\varphi_c$  = .21 ( $\varphi_c$  = Cramer's V for effect size (Small = .1; Medium = .3; Large > .5, see Table 7). Results for appropriateness of the restraint type for age were similar, with children observed in Mackay (34.6%, 95% CI 27.6-41.6%) more likely to be deemed inappropriately restrained than children observed in the other locations (see Table 8).

Figures are available from an earlier observational study conducted in Brisbane by the author [14] in 2005. Methods for this earlier study were similar, being roadside observations (made by trained observers) of children's seating positions and types of restraints. Types of vehicles included were the same,

and estimates of children's ages were also based on seated height. Categories of restraint were slightly different in the earlier study. In the 2005 study, the observed vehicles were not always stationary, and hence distinctions between a forward facing child seat and a high-backed booster seat could not always be made reliably. As a result, these restraint types were collapsed into a single category. Thus it is not possible to make a direct comparison between the two studies in the proportions of children in appropriate restraints. Moreover, the previous study was confined to Brisbane rather than including other cities. However, the extent to which children 0-6 years were seated in the front seat, and the proportions of these children restrained in dedicated child restraints, may be compared. Accordingly, the data for Brisbane children aged 0-6 years were extracted and compared with the figures from 2005.

For the current study, 5.5% (95% CI 3.8-7.2%) of children observed in Brisbane and estimated as aged 0-6 years were observed occupying front seats. In the earlier study, this figure was 8.4% (95% CI 6.3-10.5%). Recategorising restraint type for both front and rear-seated children into 'dedicated restraint' versus 'not dedicated restraint' for each study yielded 74.8% (95% CI 71.5-78.3%) of the 0-6 year old children observed in Brisbane in the current study wearing dedicated restraints; for the 2005 study, this figure was 69.7% (95% CI 63.0-73.4%). As can be seen, these results suggest a movement in the desired direction in the current study for both front seating and dedicated restraint use in this age group. However, this difference is not statistically significant.

**Table 8. Appropriateness of children's restraints for age by location and number of children in the vehicle (0-6 year olds, rear seat only)**

	Appropriateness of restraint for age		
	Overall <sup>b</sup>	1 or 2 child passenger vehicles <sup>c</sup>	3 or more child passenger vehicles <sup>d</sup>
	Appropriate n (%)	Appropriate n (%)	Appropriate n (%)
Brisbane North	158 (79.4)	143 (79.9)	15 (75.0)
Brisbane South	303 (78.1)	287 (80.4)	16 (51.6)
Sunshine Coast	281 (84.1)	240 (86.0)	41 (75.0)
Townsville	182 (85.4)	163 (88.1)	19 (67.9)
Mackay	117 (65.4) <sup>a</sup>	103 (71.5)	14 (40.0) <sup>a</sup>

<sup>a</sup> These cells had a major contribution to the chi-square result (standardised residuals +/- 1.96)

<sup>b</sup> $\chi^2$  (4) = 31.16, p < .001,  $\varphi_c$  = .15

<sup>c</sup> $\chi^2$  (1) = 19.42, p=.001,  $\varphi_c$ =.13

<sup>d</sup> $\chi^2$  (1) = 14.14, p=.007,  $\varphi_c$ =.29

where  $\varphi_c$  = Cramer's V for effect size (Small = .1; Medium = .3; Large > .5)

## Discussion

Most of the children (aged 0-12 years) observed in this study were deemed to be wearing the restraint required under the legislation for children of their age (84.7%, 95% CI 83.4-86.0%), based on seated height as a proxy for child age, suggesting high levels of compliance with the legislation overall. Consistent with other Australian studies on children's restraint use, [4, 9, 12-14] restraint use for this sample of children was high (95.1%, 95% CI 94.3-95.9%), with only 93 (3.3%, 95% CI 2.7-4.0%) children clearly unrestrained and 46 (1.6%) for whom restraint status could not be determined. Only 22.1% of the 2783 children observed were travelling in the front seat, and most of these (88%) were estimated as aged 7-12 years.

Considering only those children in the age range targeted by the legislation (under 7 years), the results were somewhat less encouraging. Only 73.3% (95% CI 71.0-75.6%) of children estimated as aged 0-6 years were deemed appropriately restrained according to the requirements of the legislation, with 24.0% (95 CI 21.8-26.2%) deemed inappropriately restrained, and 2.7% (95% CI 1.9-3.5%) for whom this could not be determined. While almost all of these children were seated in the rear seat (94.7%, 95% CI 93.5-95.9%), there was a large proportion of 3-6 year olds wearing seatbelts (18.7% of the 0-6 year olds, 95% CI 16.3-21.1%) or unrestrained (3.7% of the 0-6 year olds, 95% CI 2.5-4.9%) instead of using an age-appropriate restraint.

This study does not provide any information about parental reasons for non-compliance with the changes in the legislation more generally. It may be that parents are unaware that changes have been put in place, or they may be misinformed about what the requirements are for children of their own child(ren)'s age(s). It may also be that parents do not regard

the changes as applicable to them, or are unconvinced that there is any additional benefit from using a particular type of restraint rather than another type. One explanation for the higher proportion of children aged 3-6 years using adult belts is that parents may believe the child has outgrown the booster seat and can legitimately be moved into a seatbelt. Indeed, an additional possibility is that parents are basing their decisions about the appropriateness of booster seats and transition times on the weight limits specified for this type of restraint under the previous Australian Standard (AS/NZS1754:2004). These specify a weight range of 14-26 kg for booster seats, which would lead parents to believe that they must progress a child from the booster once he/she reaches 26 kg. As this weight is based on the 50th percentile weight for boys of 7 years given in the Centres for Disease Control US growth charts of 2001 [26], it is likely that, with increasing body mass and the prevalence of obesity, many Australian children may exceed this weight earlier than 7 years old. The age basis of the requirements under the new legislation and Standard (AS/NZS1754:2010) targeted this issue. However, if this reason underlies parental behaviour, then the problem is likely to persist until the complete phasing out of restraints that comply with the previous Standard (AS/NZS1754:2004).

## Conclusions

Taken as a whole, these results suggest that the legislation may have improved both the extent to which children aged 0-6 years travel in the rear seat and the extent to which they are restrained appropriately for their ages when in the rear seat (though as highlighted previously, in the current study the observations may have overestimated the extent to which 3 year olds were using age-appropriate restraints due to the way that

age was estimated for these children). However, in relation to the use of dedicated restraints, these improvements might be regarded as modest, amounting to safer travel for an estimated 7-10% of children in the 0-6 years age range targeted by the legislation: one in four children of this age still appears to be inappropriately restrained while travelling in a passenger car.

One concern from these results is that there may be differences in the level of safe travel for younger children depending on the number of children in the car and where children live. Though it affected only a small proportion of the children in this study, the benefits of the legislation appear to be diminished where there are three or more child passengers, with 0-6 year olds much more likely to be restrained in a seatbelt under these circumstances than children who were sole passengers or had only one other child in the car. The proportions of 0-6 year olds deemed to be inappropriately restrained were significantly higher for Mackay compared to the other cities in this study, and this was particularly marked for children observed as completely unrestrained. This non-use of restraints in children may be reflective of the tendency towards lower rates of restraint use among rural populations (compared with urban ones) that has been reported previously [20-21]. The level of children completely unrestrained is of particular concern since previous research in South Australia, Western Australia and Queensland consistently demonstrates that rural and remote crashes are characterised by lower rates of seatbelt use [20-24]. Thus the current results suggest that children in these locations would seem especially at risk. Moreover, in international studies, the driver's use of a restraint has been found to be predictive of whether children are restrained and this pattern is likely to be relevant in Queensland [25]. Accordingly, interventions to improve the rates at which children are restrained may be more effective if they address adult use as well, particularly if the underlying reasons for non-use are identified and targeted. Though it is not possible from observation alone to determine the reasons for the observed differences in patterns of restraint use, the results suggest that further exploration of the factors influencing the restraint of child passengers in Mackay and other more rural locations is urgently needed in order to inform such interventions.

## Limitations

Several factors may need to be considered in relation to determining the representativeness of the results reported here. As described above, selection of sites for the observations was dependent to some extent on the availability of shopping centres willing to allow conduct of the interviews for the second study. We cannot be sure what level of bias this may have introduced, as it may be that shopping centres servicing predominantly more disadvantaged families, or with higher proportions of families with larger numbers of children in the target age range, were more cooperative than those in more advantaged areas. The type of travel represented by the sites chosen for the observations (schools and shopping precincts)

may also not be representative of other types of travel for children. An additional limitation was the physical difficulty in being able to see the restraints children were wearing. A more careful and expert inspection of children's restraints and their actual use would have been desirable, though clearly much more expensive and difficult to undertake. More careful inspection would also allow conclusions about whether restraints are being used in a safe manner, an issue that has been highlighted as critical in other studies [27-28].

The calculation of proportions of appropriately restrained children in each age group depended heavily on the estimations of age made by observers. As already noted in relation to 3 and 4 year olds, such estimations can be difficult, though observers undertook several practice sessions prior to collecting data. The level of error introduced by use of this method is also not able to be determined without a more objective measure of age, such as parental report for each child.

Lastly, the figures used for comparative purposes in determining the effectiveness of the legislation were based on observations carried out in Brisbane only. There are no available figures that can act as a baseline for the other population centres used for data collection. Thus for population centres such as Mackay, where compliance levels may be significantly lower than for other locations, it is difficult to tell what the precise effect of the legislation has been since there is no way of determining what the pre-legislation levels of restraint use were. Moreover, the changes may have resulted from other influences rather than form the amendments to the legislation. These points need to be borne in mind when interpreting the findings and their meaning.

## Acknowledgements

The author wishes to acknowledge the Queensland Injury Prevention Council and Transport and Main Roads, Queensland for providing funding to undertake the project. Thanks are due to Angela Watson for assistance with statistical analyses and to Millie Darvell and Lauren Shaw for data collection.

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## Age-based selection of child restraints

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### Abstract

**Background.** Advice to parents about child restraints is sometimes based on the child's weight, and can be complicated and confusing. Children tend to want to progress to the next restraint earlier rather than later, and the lack of clarity in advice to parents means that parents are more likely to move children up into the next type of restraint prematurely. Moreover, many parents do not know the weight of their child. This paper explores what might be the consequences of very simple advice, such as advising parents to change the type of restraint when children reach 6 months of age, 4 years, and 8 years. **Method.** The distribution of children's weights at different ages is used, along with the range of weights for which each restraint is

appropriate, to work out the number of children who would be in an inappropriate restraint if progression were at particular ages. **Results.** If 6 months is the age of transition from an infant capsule to a forward-facing child restraint, the number of children misclassified is approximately two one-month cohorts. If 48 months is the age of transition from a forward-facing child restraint to a booster seat, the number of children misclassified is again approximately two one-month cohorts. **Conclusion.** These numbers of misclassifications are low (relative to what has been reported in surveys when weight-based advice was the norm). It has not been proven that there would indeed be good compliance with sharp ages of transition, but the simplicity and salience of age make it attractive as a criterion.

## Keywords

Advice to parents, Age-based advice, Anthropometry of children, Child restraints, Weight-based advice

## Introduction

Published surveys of in-vehicle child restraint use demonstrate that many children are in an inappropriate type of restraint [1-18]. In particular, children progress from a forward-facing child restraint to a booster seat at too small a size, and from a booster seat to an adult belt at too small a size. It seems likely that child restraints have been designed to be suitable for children within a certain weight range, not an age range, and until recently the standards were written that way. Thus it might seem natural for advice to parents to emphasise the child's weight as the criterion for selecting a type of restraint, but unfortunately there is a tendency for this to lead to advice becoming complicated and confusing. National child restraint laws that give greater prominence to age than to weight or height were introduced in Australia in 2010, and advice easily available to parents now reflects this. (The authors hope that the advice is perceived as being insistent that age is almost always a sufficient guide to the appropriate restraint, but at present it is not known if that is the case.)

In the United States, the American Academy of Pediatrics has a webpage that emphasises age [19], but the formal policy [20] is complicated and, for the broad age range 2 to 8 years, relies on weight and height. Since March 2011, National Highway Traffic Safety Administration (NHTSA) advice is age-focused, with an aim of preventing too-early progression [21]. Children tend to progress to the next restraint earlier rather than later, and the fact that this happens so frequently may be because of lack of clarity. Moreover, many parents do not know the weight of their child. This has also been found in child restraint surveys and in other contexts [3, 22, 23]. Very likely, there are some places where parents do know the heights and weights of their children, e.g., Japan, where there is thrice-yearly measurement by school nurses [24].

In Australia, the main types of in-vehicle child restraint are

- Infant capsule (rearward-facing infant restraint), known as type A1
- Forward-facing child restraint (FFCR), which has an integral harness - type B
- Booster seat (or booster cushion), which positions the child so that an adult seatbelt can be used safely. (Some booster seats have a back.) This is known as type E.

The 2004 edition of Australian Standard 1754 specified that these must respectively be suitable for children weighing 0-9 kg, 8-18 kg, and 14-26 kg. The 2010 edition [25] refers to 'the occupant of supine length up to 70 cm, and approximately 6 months of age', 'suitable for children approximately 6 months to 4 years of age', and 'suitable for children approximately 4 to 8 years of age whose height is less than 128cm'. Shoulder

height markers [26, 27] are incorporated in the restraints and are intended to be directive as to their use and unsuitability, taking precedence over a child's age.

Elsewhere in the world, standards have been written differently, and not necessarily in ways that are easily comparable to Australian practice. (However, roughly speaking, the European Union employs weight ranges of 0-10 kg, 9-18 kg, and 15-25 kg, and the US employs weight ranges of 5-22 lb, 20-40 lb, and 40+ lb.) Historically, standards for child restraints have not been well coordinated with standards for adult seatbelts. It is tacitly assumed that children will graduate to an adult belt at 7 or 8 years; however, at this age, children are appreciably smaller than a 5th percentile adult female, which is the smallest size for which adult belts have to be satisfactory. The 2010 Australian Standard makes provision for a larger booster seat - type F - suitable for children up to 10 years. In practice, adult belts are used for many children as young as 4 years.

This paper explores what might be the consequences of very simple advice, such as 'change the type of restraint at 6 months, 4 years, and 8 years'. Obviously, children differ in size but design can, in principle, ensure that the restraint is suitable both for a small-for-age child at the youngest age and a large-for-age child at the oldest age. Given the distribution of children's weights at different ages and the range of weights for which each restraint is appropriate, the number of children who would be in an inappropriate restraint if progression were at particular ages is derived. For details of some aspects, see [28-30].

## Method

### Formulation of the key question

If children changed from one restraint to another at a specific age, how many would be in the wrong restraint?

Notice this question refers to a sharp transition age, with no mention of an age range or a weight range. Once this question is formulated, the information needed becomes clear: how many of the children younger than the transition age are too big for the first restraint? how many of the children older than the transition age are too small for the second restraint?

It is assumed that a particular type of restraint, such as an FFCR, is suitable for a particular range of weights of children, and unsuitable for other weights. It is also assumed that the distribution of children's weights at different ages is known. Specifically, the data from the Centers for Disease Control and Prevention in the United States [31] will be used. In this dataset, children are disaggregated by sex and one-month cohorts of age.

*Notation concerning the restraint.* A child changes from restraint A to a larger restraint B at age  $y$ . Restraint A is satisfactory for children whose weight  $u$  is  $a$  or less. Restraint B is satisfactory for a child whose weight  $u$  is  $b$  or greater.

*Notation concerning the child.* In the  $i$ th month of life, the child is in one-month cohort  $i$ . For this cohort, the proportion of

children whose weight is less than  $u$  is  $F_i(u)$ . Change from restraint A to B occurs at the end of month  $y$ .

*The function F.* For fixed  $i$  and regarded as a function of  $u$ ,  $F$  describes the variability of children at a given age; statisticians would call it the cumulative distribution function of weight. For fixed  $u$ ,  $F$  decreases as a function of  $i$ : it reflects the growth of children with age by describing the falling proportion who are smaller than a given weight  $u$ .

### Obtaining the answer

First, consider children younger than  $y$ . These are in restraint A. The proportion of cohort  $i$  who are too big for restraint A is  $1-F_i(a)$ . The relevant one-month cohorts are those up to and including  $y$ . The total number of children (in units of the number in a single month cohort) is  $\sum_1 [1-F_i(a)]$ , where  $\sum_1$  denotes summation from  $i = 1$  (or the previous transition) up to  $i = y$ .

Second, consider children older than  $y$ . These are in restraint B. The proportion of cohort  $i$  who are too small for restraint B is  $F_i(b)$ . The total number of children is  $\sum_2 F_i(b)$ , where  $\sum_2$  denotes summation from  $i = y+1$  up to the next transition.

The total number of children who are either younger than  $y$  but too big for A, or older than  $y$  but too small for B, is the sum of these,  $\sum_1 [1-F_i(a)] + \sum_2 F_i(b)$ . This total is a function of  $y$ ,  $a$ , and  $b$ . Given these, and knowing the function  $F_i(u)$  from [31] or some other source, the total may easily be worked out.

### Choice of transition age

The quantities  $a$  and  $b$  are characteristic of the restraints available. Restraints can be redesigned, thus changing  $a$  and  $b$ . But the easier issue to tackle is what the age  $y$  should be.

As  $y$  increases, the number of children in restraint A who are actually too big for it increases, and the number in restraint B but actually too small for it decreases. Thus, there is a trade-off. It is possible to identify an age at which the sum is minimised.

## Results

### Transition from infant capsule to FFCR

The first step is to consider one particular choice of transition age. For the transition from infant capsule to FFCR, we took  $a$  to be 9 kg and  $b$  to be 8 kg (as in the 2004 version of Australian Standard 1754). Suppose that the transition age is  $y = 6$  months.

- Boys, cohorts 1 to 4. Very few of these are too big for an infant capsule (i.e., exceed 9 kg).
- Boys, cohort 5. Some 2% of these exceed 9 kg.
- Boys, cohort 6. Some 8% of these exceed 9 kg.
- Boys, cohort 7. Some 43% are too small for an FFCR (i.e., are less than 8 kg).
- Boys, cohort 8. Some 25% are less than 8 kg.
- Boys, cohort 9. Some 13% are less than 8 kg.
- Boys, cohort 10. Some 6% are less than 8 kg.

And so on. Total misclassification is 103% of a one-month cohort of boys, made up of 10% who were too big for the infant capsule in the month or two before the transition, and 93% who were too small for the FFCR in the months after transitioning. Thus the total misclassification is around 9% of boys in their first year of life. A similar calculation can be made for girls.

The second step is to repeat the calculations for different choices of the transition age  $y$  (5 months, 7 months, 8 months, and so on).

There are two forms of visual presentation of the results that are quite helpful:

- Having calculated the total number of children (in units of one-month cohorts) who are too large for restraint A and the total number who are too small for restraint B, these numbers can be plotted one against the other, the different data points corresponding to different ages of transition,  $y$ . As  $y$  increases, so the first of these numbers increases and the second decreases: there is a trade-off between them. One wants to select the point on the graph that is closest to the origin, i.e., where the sum of these proportions is minimised. (If it is considered plausible that one type of misclassification is more serious than the other, one could consider a generalized sum in which one misclassification is given more importance than the other.)
- The sum can be plotted against transition age  $y$ . Naturally, this presupposes that one is comfortable with the idea that the two types of misclassification are equally important.

It turns out that the sum is minimised at 7 months for boys and 9 months for girls. The improvement from 6 months is not great enough to suggest changing from this, however (see Table 1).

**Table 1. Numbers of children misclassified (in units of a one-month cohort), for various choices of the transition age from an infant capsule to an FFCR**

Age of transition, $y$ (months)	Number of children misclassified		
	Too big for the first restraint	Too small for the second restraint	Total
6	0.06	1.53	1.59
9	0.80	0.31	1.11
12	2.74	0.04	2.78

**Table 2. Numbers of children misclassified (in units of a one-month cohort), for various choices of the transition age from FFCR to booster seat**

Age of transition y (months)	Number of children misclassified			Total
	Too big for the first restraint	Too small for the second restraint		
36	0.11	4.09		4.20
48	1.22	0.70		1.92
60	5.45	0.04		5.49

### Transition from FFCR to booster seat

The method of calculation for the transition from a forward-facing child restraint to a booster seat is similar to that described in the previous section. The authors took  $a$  to be 18 kg and  $b$  to be 14 kg (as in the 2004 version of AS 1754). Some results are in Table 2.

### Transition from booster seat to adult belt

As mentioned earlier, there has been something of a disconnect between standards for child restraints and standards for adult seatbelts. This has become of concern to an increasing number of people in recent years, with it being suggested that an adult belt is only suitable once a child has reached 145 cm in height. Possible solutions include ensuring that adult belts are suitable for smaller people than the 5th percentile adult female (e.g., the average 7 year old), developing booster seats suitable for bigger children (e.g., the average 12 year old), or a compromise between these strategies.

To proceed with an analysis similar to those for earlier transitions, it would need to be known how unsatisfactory a standard booster seat is as a function of weight (over the range 26-40 kg, say), and also how unsatisfactory an adult belt is as a function of height (over the range 120-145 cm, say). However, this probably goes beyond what can be confidently supported.

## Discussion

### Effect of change to standards

The calculations above take  $a$  and  $b$  as known, and examine what effect  $y$  has. A complementary analysis would suppose that  $y$  has been fixed at some memorable and convenient age (such as 4 years) and determine how  $a$  and  $b$  affect the proportion of children misclassified. Comparison could be made of the present Australian, European, and US standards. Also, the effect of a change to  $a$  and/or  $b$  in the Australian context could be examined. See [29] for more on this.

If  $a$  exceeds  $b$ , there is overlap in the weight ranges for successive restraints. This is the case for some standards but not for others. Overlap will mean that a sharp age transition will lead to fewer misclassifications by weight. Thus having an FFCR suitable for up to 40 lb and a booster seat suitable only

from 40 lb upward, as in the United States, is not well-suited to a sharp age transition. (However, this is a simplification of what the US system is, and may be exaggerating the unsuitability.)

Children vary more when they are older and bigger than when they are younger and smaller. Consequently, a given amount of overlap (e.g., 1 kg) is more useful at a younger age and smaller size. For the FFCR-to-booster transition in Australia,  $a$  is 18 kg and  $b$  is 14 kg. If  $y = 48$  months were chosen as the transition age, the number of children misclassified would be about two one-month cohorts (Table 2). Keeping  $y$  the same, if  $a$  were 19 kg and  $b$  were 13 kg, the number of children misclassified would be reduced to about 0.8 one-month cohorts.

Once the calculation has been programmed, it is easy to compute the result for a grid of values of  $a$  and  $b$ . Then the results can be presented as, for example, a contour plot. The effect of specifying different  $a$  and  $b$  in the standard can then easily be seen.

### Overview of different methods of illustration

It may be useful to list a number of ways of illustrating the calculations and their results that have been mentioned in preceding sections of this report, either implicitly or explicitly [26-28].

- There is variability in the size of children at any given age. This is described by  $F_i$  regarded as a function of  $u$  for fixed  $i$ .
- Children grow. This is described by  $F_i$  regarded as a function of  $i$  for fixed  $u$ .
- As different transition ages are considered, so the proportions of children too big for restraint A and too small for restraint B vary in opposite directions. They can be plotted one against the other to demonstrate the trade-off.
- The two proportions of misclassifications can be added together and plotted against transition age.
- Greater overlap in the weight ranges for successive restraints (i.e.,  $b$  exceeding  $a$  to a greater extent) will mean fewer misclassifications. This can be shown by, for example, a contour plot, the axes being  $a$  and  $b$ .

### Alternative analyses

Earlier in this report, any type of restraint was said to be either unsuitable or suitable for a particular weight of child. The

analysis could be generalised by devising and utilising a ‘suitability function’. However, it is unlikely that anyone knows how the unsuitability of being (say) 2 kg too heavy for one restraint compares with the unsuitability of being 1 kg too light for another. Thus it has simply been assumed that if a restraint satisfies a standard, it is suitable for the weight range mentioned in the standard and unsuitable for other weights. (In effect, the analysis assumes that suitability is 1 for some range of weights, and 0 for other weights.)

Child weight has been assumed to be the important variable. Instead, the analysis could be adapted to height, or sitting height, or shoulder width, provided data on these measurements were available.

It might be said that the sizes of boys are different from those of girls, or that children from different ethnic backgrounds differ in size. However, differences are not sufficient for it to be worthwhile destroying the simplicity of advice in order to tailor it to a particular sex or ethnicity.

## Concluding remarks

The implication of the way the central question was worded at the start is that advice to parents can be very simple and directive. For example, the advice might be simply to switch the child from one restraint to the next at the ages of 6 months, 4 years and 8 years – with no mention of weights, no mention of ranges and no mention of big-for-age or small-for-age. (It would be appropriate to include information about where to find expert assistance if the child is very unusually sized or shaped, or if there are closely-spaced children in the family.)

The standards describing successive restraints would need to have overlapping weight ranges. Responsibility for exercising expertise - accommodating the range of different sizes and shapes of children - is thus being placed with the designer and manufacturer of the restraint, not with the parent. That seems entirely appropriate.

Two possible weaknesses in the argument here need to be addressed. First, there might be concern that designers and manufacturers would find it very difficult if standards prescribed an overlap of weights. This concern can be confidently dismissed. There are small overlaps in the Australian and European standards at present, and informal discussions indicate the overlaps could be made a little greater without difficulty. Indeed, the dummy specified in the Australian standard for dynamic testing of the FFCR weighs 22 kg, even though the specification otherwise requires suitability for an 18 kg child. Second, the calculations assume compliance with the directions to graduate the child from one restraint to the next at a particular age. It could be said that it is not fair to compare results from a theory that assumes compliance with results observed in the real world where many parents and children are not complying with the advice available. A complete answer to this cannot be given, in the sense of proving that there would

be compliance with firm directives. But it is plainly common sense that clear advice is easier to understand than complicated advice, that advice in terms of something that parents know (child's age) is better than advice in terms of something parents often do not know (child's weight), and that similar factors apply in respect of children's wishes and demands.

Should advice to parents be simplified and based on a child's age? The calculations have, at least, not demolished this strategy. Using weight as the criterion seems reasonable when the restraint itself is in one's mind. But if the problem lies with parents' and children's knowledge and their utilisation of that knowledge, the simplicity and salience of age increase its attraction as a criterion.

A strategy has been suggested here that puts the child's age - well known to adults and highly salient to children- at centre-stage. What has been done is

- demonstrate by reference to surveys that there is a problem at present
- formulate a question concerning what might happen if there were sharp ages of transition
- answer that question, finding that the proportion of misclassified children would be low with the present Australian Standards, and could be even lower if there were greater overlap in the weight ranges of different types of restraint
- informally check with experts on restraint design and manufacture that greater overlap is practicable.

What has not been done is to prove that there would indeed be good compliance with sharp ages of transition. Perhaps experts on the promotion of health advice to the general public are able to comment on the merits or otherwise of simple directives based on child age.

## Acknowledgements

The Centre for Automotive Safety Research (CASR), University of Adelaide, is supported by both the South Australian Department of Planning, Transport and Infrastructure and the South Australian Motor Accident Commission. The views expressed in this paper are those of the authors, and do not necessarily represent those of the University of Adelaide or the sponsoring organisations.

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## Prevalence of mobile phone vs. child-related driver distraction in a sample of families with young children

by CM Rudin-Brown, S Koppel, B Clark and J Charlton

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### Abstract

Motor vehicle crashes are the leading cause of accidental death in Australia, with substantial societal costs. Unlike crash test dummies, child vehicle passengers rarely sit still and their behaviour can often be unpredictable. Analysis of naturalistic driving video data from journeys undertaken by 12 families with

young children revealed that children accounted for 12% of all potentially distracting activities, with drivers in this study interacting with rear seat child occupants 12 times as often as they did with mobile phones. Educational interventions to reduce driver distraction are discussed and the use of the naturalistic driving methodology is proposed to investigate the

potential benefits of a novel, best practices-based road safety education program targeting child-related driver distraction. Outcomes of such an evaluation could be used to inform and refine future education strategies designed to minimise child-related driver distraction and crash risk, and to improve overall road safety in Australasia.<sup>1</sup>

## Keywords

Child restraint systems, CRS, Road safety, Road safety education

## Introduction

Driver distraction is the diversion of attention away from activities critical for safe driving towards a competing activity [8, 12]. A distraction can be either in-vehicle ('internal') or outside the vehicle ('external'). Generally, there are four potential sources of driver distraction: (i) visual (e.g. looking away from the road at a non driving-related object or person); (ii) cognitive (e.g. thinking about something other than the driving task); (iii) physical (e.g. dialling a mobile phone or tuning a radio); and (iv) auditory (e.g. responding to a passenger or a ringing mobile phone). There is ample evidence that driver distraction impairs driving performance, making it a significant cause of motor vehicle crashes [6, 12, 17]. The costs of distracted driving are undeniable. In New Zealand, for example, research suggests that distraction contributes to at least 10% of fatal crashes and 9% of injury crashes, with an estimated social cost of NZ\$413 million (in 2008) [18].

In recent years, interest in driver distraction as a source of crash causation has increased due to the increasing prevalence of mobile communications and 'infotainment' technology, such as mobile phones. The observed prevalence of mobile phone use while driving varies depending on the country or jurisdiction in which it is assessed. In Australia, where the use of handheld devices by drivers is prohibited in all states and territories, a recent roadside observational survey found 5% of drivers to be engaged in mobile phone use, including 3.4% of drivers who were using it in handheld mode, including text-messaging [14, 20] (hands-free phone use in that study was recorded in cases where a driver was wearing an earpiece or headset, or a speaker phone was visible, and the driver was talking in a conversational manner with no passengers in the vehicle). This use rate is similar to those observed in previous surveys of jurisdictions within the United States and Canada where handheld mobile phone use is also banned [3, 9, 10]. A recent internet survey of 287 Victorian drivers found that almost 60% reported using a mobile phone while driving, and over one-third of those drivers admitted using it in the illegal, handheld mode [19].

In 2006, approximately nine million Australians, or 51% of the adult population living in a family situation, had children aged 15 and under [2]. In the 12 months ending 31 October 2007, there were an estimated 14.8 million vehicles registered in Australia, most of which (78%) were passenger vehicles. Travel survey data from the Australian state of Victoria indicate that children under the age of 15 spend, on average, approximately

four and a half hours per week travelling as passengers in cars [5]. In New Zealand, where travel survey data is more comprehensive, yet the environment similar to Australia, 35% of passenger vehicle trips had passengers present, with children accounting for 26% of those passengers [11]. It is clear that the practice of transporting children as passengers in motor vehicles is common.

Anecdotally, the carriage of children as passengers is recognised by many as a significant, though unavoidable, source of driver distraction. Survey studies also implicate child passengers as a significant source of driver distraction. A United Kingdom survey revealed that children were far more likely to distract drivers from their task than anything else; 53% of over 500 people surveyed reported child passengers to be the biggest distraction while driving [15]. In Australia in 2011, 35% of over 3700 driver respondents to an internet survey [1] reported children in the car to be the most common source of driver distraction. Regrettably, there have been few systematic evaluations of the effect of child passengers on driver performance.

It is of benefit to quantify and describe the nature of driver distraction caused by children in order to develop and propose countermeasures that are effective while, at the same time, logical and feasible. An extensive literature review revealed few empirical studies that considered rear seat child occupants as a source of distraction. In an observational study conducted by Stutts and colleagues [16], the most common reported distractions in terms of overall event durations were eating and drinking, distractions inside the vehicle (reaching or looking for an object, manipulating vehicle controls), and distractions outside the vehicle (often unidentified). Children were found to be about four times, and infants almost eight times, more likely than adults to be a source of distraction to the driver, based on the number of distracting events per hour of driving.

The collection of naturalistic observational data during vehicle trips is an effective means to investigate child-driver interaction in vehicles and to more systematically quantify the relationship between rear seat child passengers and driver distraction.

Comparing the prevalence of potentially distracting child-driver interactions to the prevalence of another source of driver distraction—mobile telephone use—can also frame the issue in relative terms. If a problem is identified, it may be possible to limit child-related driver distraction through the development and implementation of effective educational countermeasures. The research and results described here represent a portion of a larger naturalistic observational pilot study that was designed to evaluate the positioning of child vehicle passengers within their Child Restraint Systems (CRS) and their interactions with drivers [3, 8, 16]. The focus of the present paper is on driver distraction associated with rear seat child passengers. In particular, the paper considers the prevalence of this type of distraction in the context of other more widely studied/recognised sources of distraction including mobile telephone use, with the aim of informing future targeted educational programs to limit driver distraction.

## Method

### Experimental Design

A naturalistic observational study design was used to investigate whether, and to what extent, child rear seat passengers are a source of driver distraction.

### Participants

Twelve families volunteered to participate in the study. The families included at least one licensed driver aged between 25 and 39 years, and at least one child aged between one and eight. All drivers were experienced (licensed for > 5 years), reported driving between five and ten kilometres per week with children as passengers, and at least 100 kilometres per week on average, and had not been involved in a crash in the previous two years. All participant drivers had normal or corrected-to-normal vision. Across all families, there were 25 child passenger participants. Families were recruited through word-of-mouth and through an existing participant database. Ethics approval for the study was obtained from the Monash University Human Research Ethics Committee. Participants were compensated \$100 for their time and as partial recompense for petrol costs.

### Equipment

The vehicle used in the study was a luxury model, large family sedan with automatic transmission. The study vehicle was fitted with a discrete camera and recording system which comprised four cameras, providing images of the driver and front seat passenger, the rear seat child passengers and the traffic ahead. The video recording system, which also recorded audio data, was strategically positioned to gain an overall view of the forward road scene and the interior of the cabin with minimal disruption to the driver's view and concealed so as not to be obvious to the vehicle passengers.

### Procedure

Participants were required to drive the instrumented study vehicle on their regular journeys for a period of three weeks. Vehicle handover took place at the participants' homes. A CRS fitting specialist attended each participant's home to make sure that all CRS were installed correctly. All children used their regular CRS, booster seats, or H-harness while travelling in the study vehicle. At the end of the three-week observational study period, the study vehicle was collected, and CRS were re-installed in the family's own vehicle.

### Video data coding

To aid in the analysis of the video data, each trip made by participants was divided into three sub-sections: pre-journey, journey, and post-journey. The 'journey' sub-section began when the vehicle began to move and ended when the vehicle was put into 'park', and is the trip section reported in this report. Key journey variables that were coded included: duration, time-of-day, driver ID, presence of front seat

passenger, and number of child passengers. Road and traffic conditions such as traffic density (low, medium, high) were also classified, as were child passenger activities and communication patterns (e.g., whether they were talking, crying, fighting, amusing themselves, eating or drinking, sitting quietly, watching DVD, or sleeping). All activities with the potential to divert attention away from activities critical for safe driving [8] were coded. All activities that involved the driver looking away from the forward roadway for more than two seconds were also coded. Glances away from the forward roadway of greater than two seconds are associated with approximately twice the near-crash/crash risk compared to normal, baseline driving [6]. Data coding was conducted using Snapper performance analysis software (Webbsoft Technologies, UK), which provided a viewing platform that facilitated the logging of events into a database. Inter-rater agreement for two data coders measured across 10% of trips was adequate at 87.8%.

### Statistical analyses

The study used a naturalistic methodology to study driver behaviour and the potential for driver distraction. Dependent measures included the driver's engagement (frequency and duration) in potentially distracting activities. Associations between driver characteristics (e.g., gender) and their engagement in potentially distracting activities were compared using *t*-tests. In all cases, a two-tailed  $\alpha$ -level of .05 was used to determine statistical significance. Prior to all analyses, data were checked for violations of statistical assumptions, outliers and missing data points. Parents' responses to the questionnaire were summarised using descriptive statistics. Univariate analyses were used to investigate sources of driver distraction and to examine the types of child-related activities that drivers engaged in while driving.

## Results

### Child passenger characteristics

A total of 25 children (56% male) participated in the study as passengers. The majority of children used either a forward-facing CRS (44%) or booster seat (40%) when travelling. Most families (7 of 12) had two children, two families had one child, and three families had three children.

### Observed 'potentially distracting activities'

To limit the video data analysis to a manageable size, analysis of only a select number of journeys per family was conducted, including data from the first four journeys for all families (48 total) plus four randomly selected journeys for 11 of the 12 families (44 total). For the 92 journeys analysed, 19 drivers and 25 children were observed for a total of 24 hours and 54 minutes.

Video analysis revealed the mean journey duration to be 16 minutes, 14 seconds (range 2 minutes to 3.5 hours). Most journeys (89%) were made during the day, and did not include a front seat passenger (65%). Almost all of the journeys

analysed took place in urban areas (97%), on suburban roads (94%), and under low complexity (91%) (defined as minimal traffic congestion). Use of the DVD player was observed in only 6% of trips.

Drivers were observed to engage in at least one potentially distracting activity in 98% of the journeys analysed. In total, across all of the journeys analysed, drivers were observed to be engaged in 2439 potentially distracting activities. Male drivers (fathers) were significantly more likely to engage in potentially distracting activities,  $t(32.147) = -3.094, p < .01$ , and were distracted for significantly longer periods of time,  $t(32.761) = -2.945, p < .05$ , than female drivers (mothers). The most common potentially distracting activities were grooming-related (37%), followed by those that involved some kind of in-vehicle adjustment (e.g., to the seat, seatbelt, or rearview mirror) (13%). Interactions with children accounted for 12% of the potentially distracting activities, while interactions with mobile phones accounted for 1% of all activities (Figure 1).

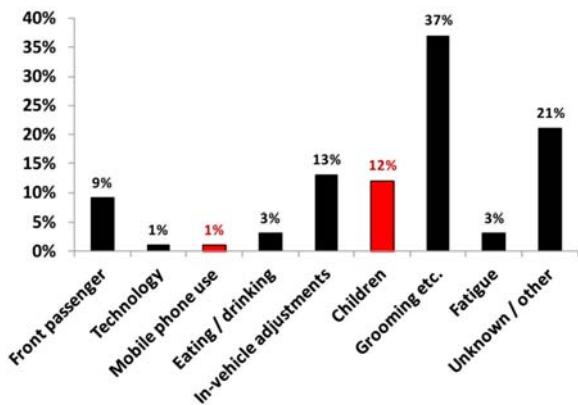


Figure 1. Relative frequency of the types of potentially distracting activities engaged in by drivers

### Interactions with rear seat child passengers

Examples of some of the interactions with rear seat child passengers observed are presented in Figure 2.

**Activity type.** The most frequently observed child passenger-related activities engaged in by drivers were checking on their children by either turning back to look at them or by viewing them through the rearview mirror (76%), engaging in

conversation with the children (16%), and assisting the children (8%; for example, passing food and drink—see Figure 2, below).

**Driver characteristics.** Interestingly, fathers (male drivers) were observed to be distracted by their children for significantly longer periods of time than were mothers (female drivers) (26 vs. 8 seconds),  $t(30.321) = -1.567, p < .05$ . Although not statistically significant, fathers also tended to be more likely to be observed engaging in child passenger-related activities than mothers,  $t(88) = -0.619, p > .05$ .

Activities where drivers' eyes were off the road for > 2 seconds and the vehicle was in motion

**Technology- vs. child-related activities.** Interacting with child passengers represented a significant proportion (12%) of the total number of potentially distracting activities engaged in by drivers in this study; this interaction appears to be a far more common activity than technology and mobile phone use while driving (see Figure 1). However, when a measure of driver distraction with a demonstrated increased crash risk was used, that is, the proportion of potentially distracting activities that are engaged in while the driver's eyes are off the road for more than two seconds *and* while the vehicle is in motion, a slightly different picture emerged: 40% of interactions with technology (which accounted for 2% of all distracting activities) were carried out with the driver's eyes off the road for longer than two seconds, making the relative proportion of this activity compared to all other potentially distracting activities 0.8%. On the other hand, only 10% of drivers' interactions with children (which accounted for 12% of all distracting activities) were associated with the driver's eyes off the road for more than 2 seconds and the vehicle in motion, making the relative proportion of that activity 1.2%.

**Driver characteristics.** Male drivers were significantly more likely to engage in potentially distracting child passenger-related activities while the vehicle was moving and their eyes were off the road for greater than 2 seconds than female drivers (41% vs. 20%),  $\chi^2(1) = 13.434, p < .001$ . As well, drivers were significantly more likely to engage in child passenger-related activities with their eyes off the road for greater than 2 seconds while the vehicle was in motion when there was a front seat passenger present (47% vs. 9%),  $\chi^2(1) = 25.347, p < .001$ .



Figure 2. Driver interactions with rear seat child passengers (left: passing drink; centre: adjusting DVD player; right: talking to child)

## Discussion

Collectively, results demonstrate that drivers' interaction with rear seat child passengers has the potential to result in driver distraction and, in instances where the driver's eyes are off the forward roadway for more than 2 seconds while the vehicle is in motion, may be associated with a crash risk of twice that of normal, non-distracted, driving [6]. Drivers were observed to be engaged in potentially distracting activities with children more often than interacting with mobile phones and other in-vehicle technology. However, interactions with technology were associated with a relatively greater proportion of instances where the driver's eyes were off the road for more than 2 seconds while the vehicle was in motion. Despite this relatively greater proportion of high risk interactions, the overall prevalence of drivers' activities with children was greater than the prevalence of technology and mobile phone use. This finding underscores the need for further study in the area of child passenger-related driver distraction, and the need for effective countermeasures.

The overall prevalence results are comparable to those from another, more extensive naturalistic study, the 100-car study [6], in terms of the prevalence of potentially distracting (what Klauer et al. refer to as 'inattentive activities') behaviour in which drivers were observed to engage. While task duration was not recorded in that study, the finding that 73% of all six-second video segments analysed contained at least one form of driving inattention indicated that drivers were engaging in secondary tasks, driving while drowsy, or looking away from the forward roadway very frequently. This high frequency was mirrored in the present study, where 98% of trips involved the driver engaging in at least one potentially distracting behaviour.

The rate of mobile phone use in this study is comparable to the rate observed in a recent observational survey of Melbourne-area drivers [14, 20, 21], where 5% of drivers were observed engaging in a variety of mobile phone activities, including talking on a hand held phone. Considering that drivers in the present study were aware that their behaviour was constantly being recorded, that rate can be deemed comparable to the 2% of drivers in the present study who were observed to be using a mobile phone.

It has been proposed that educational countermeasures can be developed to effectively reduce, or mitigate, the prevalence and effects of driver distraction generally, including distraction caused by mobile phone use as well as that which is child-related [4,13]. Education and public awareness campaigns have been identified by experts in road safety as a 'priority need' to minimise driver distraction [4]. Of particular relevance, recommendations regarding distraction-related educational countermeasures from the 2005 International Distracted Driving conference [4] include that awareness and educational activities should target specific behaviours and audiences (for example, parents with young children), and identified children (as so-called distraction 'influencers') as a specific target audience for distraction-related campaigns. These recommendations suggest that the development of an educational program targeting both parents *and* their children

would have the potential to effectively minimise child-related driver distraction.

Although distracted driving educational programs do exist, there are few empirical evaluations that have been conducted. One evaluation study that has been identified evaluated the effectiveness of a brief, internet- and video-based, educational program on driver distraction administered to over 1400 respondents [7]. Results revealed that, while exposure to the program was not associated with respondents' self-reported anticipated future distraction-related behaviours, it was associated with increased ratings of perceived danger of certain distracting activities. One of the distracting activities that was associated with increased perceived ratings of danger following exposure to the educational program was 'tending to child', indicating that it is possible to influence drivers' perceptions in this area. This finding also suggests that an educational program targeted more specifically on child-related driver distraction may have the ability to go further and influence drivers' actual in-vehicle behaviour, and to minimise the prevalence of this type of distraction. Unfortunately, the above evaluation study used only indirect measures of driving performance—self-reported anticipated frequency of distracted driving and perceived danger of distracting activities - and so we cannot know if the increases in danger perceptions were associated with any actual changes in respondents' driving behaviour.

The naturalistic driving method, described above, offers the unique opportunity to evaluate such a brief, child-related driver distraction educational program in a much more effective manner, by collecting and analysing objective measures of rear seat child passenger behaviour as well as measures of driver distraction and performance. In fact, the naturalistic methodology is particularly well-suited for this purpose, and to elucidate any correlative relationship(s) between the two behaviours. It is anticipated that future research by the authors will include such an evaluation. The aims of the research will be to not only quantify and describe the nature of child passengers' behaviour and interactions with the driver, but to quantify and describe the nature of the resultant driver distraction and performance.

## Limitations

During data analysis, some issues regarding data precision emerged that may limit some of the study findings; for example, it was difficult to distinguish whether drivers' glances in the rearview mirror were directed towards children or towards rear traffic. Rearview glances were coded as a potentially distracting activity only if drivers were also engaged in dialogue with the children while looking in the rearview mirror. An improved camera system could potentially alleviate this shortcoming in future studies.

The use of a dedicated test vehicle may be considered to be a further limitation of the study protocol, in that children and drivers may have both behaved differently because of the novel environment. This may, in fact, have been the case—not only were participants required to drive a luxury model study vehicle, but they were also instructed to drive safely and legally, and were

aware that their behaviour was being recorded by video cameras. As such, the observed results are quite probably an *underestimation* of the real world prevalence of potentially distracting child passenger-related activities in drivers carrying young children. Despite these study conditions, participants were observed to engage in a range of potentially distracting activities, some of which (hand held mobile phone use) were also illegal.

## Conclusions

Observation of naturalistic video data revealed that children accounted for 12% of all potentially distracting activities, with drivers in this study interacting with rear seat child passengers 12 times as often as they did with mobile phones. The findings demonstrate that child-related driver distraction represents a distinct road safety issue that is preventable. The feasibility of the naturalistic observational method for studying child behaviour in vehicles and the potentially distracting interactions that can take place between rear seat child passengers and drivers was demonstrated. Educational programs targeting driver distraction more generally have been put forth as feasible countermeasures to the issue, and represent a potential method by which to mitigate child-related driver distraction as well. Future research using the naturalistic driving methodology should focus on the evaluation of effective educational programs that target child-related driver distraction. In the meantime, drivers who travel with children as passengers should be reminded to be prepared, be patient, and focus on the road (and not the kids!).

## Acknowledgements

The authors gratefully acknowledge Ms Chelvi Kopinathan, Mr David Taranto, and Ms Samantha Bailey for their assistance with data collection, vehicle set-up, and video analysis. Many thanks also to study sponsors, GM Holden and the Australian AutoCRC (Cooperative Research Centre for Advanced Automotive Technology). This paper was supported through the Australian Research Council Linkage Grant LP110200334 Child safety in cars: an international collaboration.

## Notes

<sup>1</sup> This paper reports data that were previously presented at the 2nd International Conference on Driver Distraction and Inattention, held in Gothenburg, Sweden in 2011 (5-7 September).

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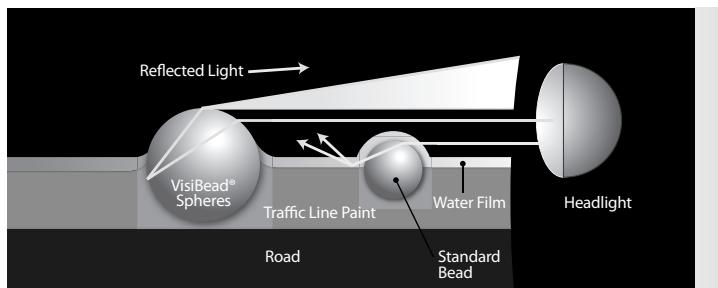


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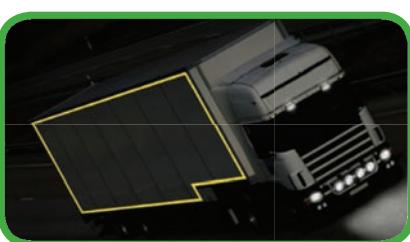
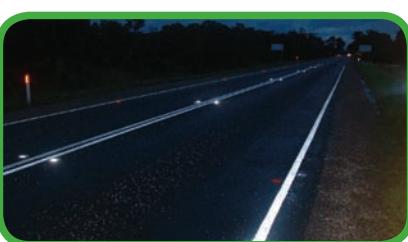
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