Road safety management needs to be strengthened with vision, direction, coordination, management, funding, interventions, advocacy, monitoring and evaluation. Many countries need to be strengthened with sustainable, cost effective and scientific policies. The five pillars of the Decade of Action on Road Safety 2011-2020 including safe roads, safe vehicles, people, post-crash care and efficient management need to be implemented in all Member States. Information through good research is an important building block for all these activities with strong, robust and quality data that can drive activities in future. The report provides an overview of the road safety information systems in the South-East Asia Region, the current knowledge scenario on road safety in the region, priorities for research, research methods and recommendations.
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Executive Summary

Motorcycles are relatively unsafe vehicles, the riders are considered as unprotected vehicle users. In developing countries, children riding on a motorcycle as a passenger or driver are very common in spite of prohibition by law for the driver. Motorcycle use continues to be marketed to young users through corporate advertising and other strategies.

To improve child survival, governments should play a stronger role in preventing deaths from motorcycle injuries. Efforts should be made to prevent the promotion of unhealthy behaviours or life-styles among children and adolescents by understanding their age-specific development. Keeping this in mind, the following recommendations are made related to motorcycle safety for children:

<table>
<thead>
<tr>
<th></th>
<th>Maximal safety</th>
<th>Possible option for minimally acceptable safety</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Infants:</strong> at birth to 1 years old</td>
<td>• Do not allow infants on motorcycles</td>
<td>• Design a motor-tricycle which has a protective passenger space and a restraint system which is compatible with a child seat.</td>
</tr>
<tr>
<td></td>
<td>• Do more bio-mechanical research for appropriate helmet, infant seat, and infant sling related to speed limitation for future safety recommendations</td>
<td>• A baby of nine months and older should wear an age-appropriate standardized helmet as additional safety equipment (a bicycle helmet is available for children of 9 months and older).</td>
</tr>
<tr>
<td><strong>Toddlers and preschoolers:</strong> 2 to 5 years</td>
<td>• Do not allow toddlers and preschoolers under 6 years on a motorcycle as a passenger</td>
<td>• Children 2 to 5 years old must use all available protective gear when being carried on a motorcycle:</td>
</tr>
<tr>
<td></td>
<td>• It should be prohibited by law</td>
<td>– Mounted seat: Children 2 to 5 years old whose feet cannot reach the footrest must be transported on a motorcycle with a well-designed child seat for motorcycle passenger.</td>
</tr>
<tr>
<td>Children 6 to 15 years old</td>
<td>Maximal safety</td>
<td>Possible option for minimally acceptable safety</td>
</tr>
<tr>
<td>----------------------------</td>
<td>----------------</td>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>Do not allow children under 15 years to drive a motorcycle.</td>
<td>• Do more bio-mechanic research for appropriate helmet, and child seat (comparing benefit and risk of increasing momentum) related to speed limitation for future safety recommendations</td>
<td>– Crash helmet: A child pillion passenger must wear his/her own standardized crash helmet which fits his/her head.</td>
</tr>
<tr>
<td>Children whose feet cannot reach the footrest of the motorcycle must not be transported on a motorcycle.</td>
<td>• Only motorcyclists who have passed an additional motorcycle test for carrying a child passenger can carry children under 12 years.</td>
<td>– Clothing: A pair of pants is necessary because it can protect his/her legs in case of a crash, that skirts or shorts would not do.</td>
</tr>
<tr>
<td>For maximal safety of pillion passenger, children must use all available protective gear when being carried on a motorcycle. (crash helmet, a pair of pants, footwear:</td>
<td>• For maximal safety of pillion passenger, children must use all available protective gear when being carried on a motorcycle.</td>
<td>– Footwear: Rubber or leather footwear would prevent foot injuries in case of a crash or foot entrapment.</td>
</tr>
<tr>
<td>• Only motorcyclists who have passed an additional motorcycle test for carrying a child passenger can carry children under 12 years.</td>
<td>• Only motorcyclists who have passed an additional motorcycle test for carrying a child passenger can carry children under 12 years.</td>
<td>• Use motor-tricycle as a safer mode of transport instead of a motorcycle. Child passengers aged 2 to 5 years or weight &lt; 20 kg could be transported in a protective passenger space with a child seat.</td>
</tr>
<tr>
<td>• Children whose feet cannot reach the footrest must be transported on a motorcycle with a well-designed child seat for motorcycle passenger.</td>
<td></td>
<td>• New driving education, and skill development training programmes should be designed to increase knowledge in safe driving, hazard perception and management of specific age groups (young drivers such as 13 to 15 years, and 16 to 18 years).</td>
</tr>
<tr>
<td>• Design new driving license permission system which will focus on novice young drivers to be:</td>
<td></td>
<td>• Limited for the high-risk situations (limited according to road types, no passenger, night-time curfew).</td>
</tr>
<tr>
<td>– supervised during the first highest risk period (especially in the first few months of driving)</td>
<td></td>
<td>• Decreased interest and delayed onset of driving of the child to have more maturity.</td>
</tr>
<tr>
<td>– limited for the high-risk situations (limited according to road types, no passenger, night-time curfew)</td>
<td></td>
<td>• The supervision and limitation criteria should be more stringent for younger age groups, such as more serious criteria in the age group of 15 to 17 years than 18 to 20 years.</td>
</tr>
</tbody>
</table>
Child development and motorcycle safety

Introduction

In Asian countries, children using motorcycles as a driver or a pillion passenger is the main cause of their injury, mortality and morbidity\textsuperscript{1-3}. The main reason for using motorcycles is due to it being an economical mode of transportation. Most families prefer using a light-weight motorcycle, one with an engine capacity below 125cc. Also, a study of motorcycle-related injuries in Thailand reveals that the great majority involved motorcycles in the engine range of 101-125 CC (Table 1)\textsuperscript{4}. Two groups of young riders use these motorcycles; one group uses them for daily activities, while the other uses them for recreation. There are a few upper class motorcycle riders who use a heavy-weight motorcycle (engine capacity >125cc) as a personal mode of transportation, both for daily activities and for recreation.

\textit{Table 1: Motorcycle engine displacement in the study of motorcycle crash causation in Thailand, 2001}

<table>
<thead>
<tr>
<th>Motorcycle engine displacement (cc)</th>
<th>Frequency</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 100</td>
<td>110</td>
<td>30.6</td>
</tr>
<tr>
<td>101 – 125</td>
<td>221</td>
<td>61.6</td>
</tr>
<tr>
<td>126 – 150</td>
<td>25</td>
<td>7.0</td>
</tr>
<tr>
<td>&gt; 150</td>
<td>2</td>
<td>0.6</td>
</tr>
<tr>
<td>Unknown</td>
<td>1</td>
<td>0.3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>359</strong></td>
<td>100.0</td>
</tr>
</tbody>
</table>

(Source: Kasantikul V, 2001)

The study in Thailand by Dr Vera Kasantikul identified the manufacturer of the motorcycles involved in the crashes in some provinces where the study was undertaken (Table 2)\textsuperscript{4}. Honda motorcycles accounted for nearly half of all crashes (46%) followed by Suzuki (27%), Yamaha (21%), Kawasaki (5%) and Piaggio motorcycles (0.6%). This data does not illustrate the risks because the denominators, the total motorcycle sales by each manufacturer, are not shown\textsuperscript{4}. 
Table 2: Motorcycle manufacturer, by province (in the study of motorcycle crash causation in Thailand, 2001)

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Phetchburi</th>
<th>Trang</th>
<th>Khon Kaen</th>
<th>Saraburi</th>
<th>Chiang Rai</th>
<th>All Provinces</th>
</tr>
</thead>
<tbody>
<tr>
<td>Honda</td>
<td>19</td>
<td>29</td>
<td>34</td>
<td>12</td>
<td>70</td>
<td>164</td>
</tr>
<tr>
<td></td>
<td>35%</td>
<td>57%</td>
<td>34%</td>
<td>24%</td>
<td>68%</td>
<td>46%</td>
</tr>
<tr>
<td>Kawasaki</td>
<td>2</td>
<td>2</td>
<td>9</td>
<td>6</td>
<td>0</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>4%</td>
<td>4%</td>
<td>9%</td>
<td>12%</td>
<td>0%</td>
<td>5%</td>
</tr>
<tr>
<td>Piaggio</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>2%</td>
<td>0%</td>
<td>1%</td>
<td>0%</td>
<td>0%</td>
<td>1%</td>
</tr>
<tr>
<td>Suzuki</td>
<td>14</td>
<td>16</td>
<td>26</td>
<td>20</td>
<td>21</td>
<td>97</td>
</tr>
<tr>
<td></td>
<td>26%</td>
<td>31%</td>
<td>26%</td>
<td>39%</td>
<td>20%</td>
<td>27%</td>
</tr>
<tr>
<td>Yamaha</td>
<td>19</td>
<td>4</td>
<td>29</td>
<td>13</td>
<td>12</td>
<td>77</td>
</tr>
<tr>
<td></td>
<td>35%</td>
<td>8%</td>
<td>29%</td>
<td>26%</td>
<td>12%</td>
<td>21%</td>
</tr>
<tr>
<td>Total</td>
<td>55</td>
<td>51</td>
<td>99</td>
<td>51</td>
<td>103</td>
<td>359</td>
</tr>
</tbody>
</table>

(Source: Kasantikul V, 2001)

The overwhelming majority of accident-involved motorcycles were the step-through frame type such as the Honda Dream or Kawasaki Leo (Table 3). Standard street motorcycles differ from those with a step-through frame because the rider must throw his leg over the seat to get on the motorcycle, and the riding position has the fuel tank located between the rider’s knees.

Table 3: Motorcycle type in the study of motorcycle crash causation in Thailand, 2001

<table>
<thead>
<tr>
<th>Motorcycle type</th>
<th>Frequency</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard street, no significant modification</td>
<td>14</td>
<td>3.9</td>
</tr>
<tr>
<td>Sport, race replica design</td>
<td>26</td>
<td>7.2</td>
</tr>
<tr>
<td>Cruiser design</td>
<td>2</td>
<td>0.6</td>
</tr>
<tr>
<td>Scooter</td>
<td>5</td>
<td>1.4</td>
</tr>
<tr>
<td>Step through</td>
<td>312</td>
<td>86.9</td>
</tr>
<tr>
<td>Total</td>
<td>359</td>
<td>100.0</td>
</tr>
</tbody>
</table>

(Source: Kasantikul V, 2001)

With an increase in the number of motorcycle riders and pillion riders, the incidence of motorcycle-associated injuries has also increased. This problem is not limited only to developing countries. In developed countries such as the U.S.A. and Australia, motorcycle-related injuries among children have also increased. A study in Australia showed that the incidence of motorcycle-related injuries requiring hospital emergency room treatment in children and adolescents in Victoria had increased by almost 10% per year.
Motorcycle riders must be considered as unprotected vehicle users. The injury risk of a motorcycle rider is 20 times more per kilometer than the drivers of other vehicles, even in developed countries where the mortality and the morbidity rates are low. Not only physical loss, these crashes mostly resulted in psychosocial deficits which may be deeply imposed.

Children as motorcycle passengers or riders are more vulnerable. They should be protected by their family and also by society. In most countries of South-East Asia, especially Thailand, motorcycles are the most widely used mode of transportation and the main source of road traffic injury risk. The annual number of motorcycles sold in Thailand has rapidly increased, from 254 949 in 1986 to 1.74 million in 2003. A 2004 report on injury surveillance data from 26 trauma centre hospitals in Thailand showed that 65.9% of traffic-related morbidity and 68.2% of traffic-related mortality among individuals younger than 15 years were related to motorcycles. Forty-eight percent of those fatal cases were drivers, while 52% were passengers. The youngest child motorcyclist was 7 years old, and the youngest drunken child driver was 11 years old. Ninety-five percent of children injured on a motorcycle were not wearing a helmet.

Traffic laws in Thailand prohibit children younger than 15 years from operating a motorcycle, and children 15 to 18 years old are only permitted to drive motorcycles with an engine smaller than 110 cc. In addition, traffic law requires drivers and passengers of all ages on motorcycles to wear a helmet. Since 2003, child protection laws in Thailand make it illegal to sell alcoholic beverages to children younger than 18 years. But those laws have not been widely respected by the public, nor have they been effectively enforced by the responsible businesses, officials and local authorities.

Despite the unacceptably high rate of motorcycle-related deaths among Thai children and adolescents, motorcycle use continues to be marketed to these young users through corporate advertising and other strategies. Young urban consumers are the first target, because cities are centres of consumption and promote consumption country-wide. To improve child survival, the government has to play a strong role in protecting the public. It should work to prevent the promotion of unhealthy behaviours or lifestyles among children and adolescents by understanding their age-specific development.

A set of important documents have been prepared to provide the governments of Member States and the road safety authorities and public health network in South-East Asia with evidence from different perspectives in relation to children and motorcycles e.g., child development, epidemiology of child motorcycle-related injuries, motorcycle rules and regulations for child drivers/passengers in developed countries that manufacture motorcycles. These will help support the governments of Member States for leadership in child safety transportation. The objective of this document is:

(1) To review the physical and mental child developmental stages and readiness to ride on a motorcycle.

(2) To provide appropriate recommendations to governments in SEA Region for policy and decision regarding safe transportation of children in relation to motorcycle use.
Infants: at birth to one year

2.1 Physical growth

In the first week a newborn’s weight may decrease by 10% below the birth weight which is regained by the second week. After that a newborn’s weight should increase approximately 30 g/day during the first and second month, 20 g/day between the third and fourth month. By four months, birth weight is doubled. By one year of age, the infant has tripled his birth weight. Height grows about 2.5 cm per month during the first year; length increases almost 50% from birth length.

The mean of head circumference is 35 cm at birth and increases by 10 cm at one year. Children at birth to two years of age have been identified as “a head-neck-injury-prone group”. A major difference in anatomy between young children and adults is the proportion of total head mass. At birth, the infant’s head is larger compared to an older child. An infant’s head comprises 30% of body weight while the adolescent’s head is only 6%; and infant’s head is 1/4 the total height, while an adolescent’s head is 1/7 the total height. Meanwhile, an infant’s neck muscles are not well developed so most infants cannot hold up their heads until about three months. The relatively large head may particularly affect neck loads, as a larger proportion of mass is being supported by a smaller structure\textsuperscript{14}. This may allow more cervical spine injuries if not properly supported. (Procter M 2002).

At birth, an infant’s skull is flexible and can deform easily under load. Skull fracture is not common. Until children are 18 months of age, the unfused sutures can widen and the various fontanels can bulge and accommodate the increased intracranial volume\textsuperscript{15}. However, the volume changes in the skull can lead to large motions of the brain relative to the skull, which is not possible in older children and adults.

At birth, the neck vertebrae consist of three different bones joined by cartilage. They typically grow together during the third year. However, the atlas (C1) and the axis (C2) do not complete their joining until age 4 to 6. By puberty, the vertebrae reach their adult size, but do not finish developing until age 25. During the first year, the facet joints in the upper neck are nearly horizontal, allowing partial dislocation...
under minimal forces. Under impact, a child’s flexible vertebrae can displace more without fracture, but allow the spinal cord to stretch. For this reason, children can have spinal cord injury without radiographic abnormality (SCIWORA), which is rarely found in adults. The retrospective analysis of 103 consecutive C-spine injuries in children by Brown revealed that SCIWORA occurred in 38% of the C-spine injuries in children (Brown RL, Brunn MA, Garcia VF, 2001). Another difference in neck injury between adults and children is the point where most cervical spine fractures occur. About 60-70% of paediatric cervical fractures occur at C1 or C2, compared to about 16% of adult cervical spine fractures[15,16]. This occurs because of the natural neck pivot of children is at C2 or C3, while in adults it occurs near C6.

### 2.2 Motor, cognitive and psychosocial development

The brain develops rapidly during the first two years of life. The brain’s areas do not mature uniformly, with the primary motor areas developing earlier than others. From birth to the end of the first year, major changes occur in the infant’s gross motor skills. As tone, strength, and coordination improve sequentially from head to heel, the infant attains head control, rolls, sits, crawls, pulls to stand, cruises, and may even walk by one year of age.

Infants can sit unsupported at 6-7 months and pivot while sitting around 9-10 months. Many infants begin crawling and pulling to stand around eight months. Some walk by one year. Motor achievements correlate with increasing myelinization and cerebellar growth. These gross motor skills expand an infants’ exploratory range and create new physical dangers as well as opportunities for learning.

Infants are most vulnerable to motorcycle injuries, most will need hospitalization because of their vulnerable characteristics. In hospitalized situations, infants can easily develop post-traumatic stress disorder (PTSD) just as older children, reported by Solter[17].

### 2.3 Implication for motorcycle safety

Because of infants’ immature neural development, parents, guardians or caretakers should assume full responsibility for children on a motorcycle. In most developing countries, infants are often carried on motorcycles. They are carried by the driver or another passenger. Some who are about one year old sit in front of the driver, but some sit or stand between the driver and the passenger.

**How young is too young to be a motorcycle pillion rider?**

Learning from bicycle safety recommendations in several developed countries, infants are not allowed to be carried on bicycles due to two main reasons; first, even bike seats for children have been developed and commonly used, but it is not recommended for infants because infants are just learning to sit unsupported at about nine months of age and they have not developed sufficient bone mass and
Child development and motorcycle safety

Muscle tone to enable them to sit unsupported with their backs straight. Second, even helmets have been proven to prevent or lessen the severity of brain injury during a bicycle crash and produced in soft shell-light-small sizes for correctly placing and securing on the infant’s head, but increasing head mass by helmet would increase risks for cervical spine fracture because of the relatively large heads and poorly developed neck and upper body musculature of infants, compounded by incomplete growth of their cervical vertebrae. For bicycle safety, the American Academy of Paediatrics has recommended that children below one year should not be passengers on a bicycle under any circumstances\(^{18}\). The U.S. Consumer Product Safety Commission agrees that children under one year of age should not be on bicycles\(^{19}\). The recommendations are\(^{20}\):

- Young children who ride as passengers must wear an appropriately sized helmet and be placed securely in a bicycle-mounted child seat or, preferably, a bicycle-towed child trailer.
- Children should never ride on the handlebars or crossbar.
- Passengers should be at least one year old, by which age most children have sufficient muscle strength to control head movement during a sudden stop, even with the additional weight of a helmet.

As per EU recommendations, children should not be carried unless they are within the weight range for the seat and they can sit up unaided for at least the length of the cycle journey. EU standard applies to seats for the transport of children, weighing from 9 up to 22 kg. This more or less corresponds to the age group of 9 months up to 5 years, provided that the child is capable of sitting unaided. They should no longer be carried in the seat when they are above the maximum weight\(^{21}\).

While laws in many states of USA strictly forbid children under one year to be transported on a bicycle, a few states allow it by using an infant sling or trailer as an optional equipment to carry infants. The examples can be seen in the differences between New York’s bicycle safety law and Georgia’s bicycle safety law (Box 1).

**Option for developing countries**

For motorcycles, there is a possible option for developing countries to allow infants to be transported with their parents. This is the new design for motor-tricycles which have a protective passenger room and a restraint system which includes a safety belt or harness which is compatible with a special child seat. Infants older than nine months can be protected by using an appropriate helmet for them. The traditional motorized tricycle which needs a new design and research to improve its safety level is shown in Figures 1 and 2.
Box 1: Bicycle safety laws in New York and Georgia

**New York’s bicycle safety law**

“1238. Passengers on bicycles under one year of age prohibited; passengers and operators under fourteen years of age to wear protective headgear

1. No person operating a bicycle shall allow a person who is under one year of age to ride as a passenger on a bicycle nor shall such person be carried in a pack fastened to the operator. A first violation of the provisions of this subdivision shall result in a fine. A second violation shall result in a civil fine not to exceed fifty dollars.”

**Georgia bicycle safety law**

“(c) No person shall transport a child under the age of one year as a passenger on a bicycle on a highway, roadway, bicycle path, or sidewalk; provided, however, that a child under the age of one year may be transported on a bicycle trailer or in an infant sling so long as such child is seated in the bicycle trailer or carried in an infant sling according to the bicycle trailer’s or infant sling’s manufacturer’s instructions, and the bicycle trailer is properly affixed to the bicycle according to the bicycle trailer’s manufacturer’s instructions or the infant sling is properly worn by the rider of the bicycle according to the infant sling’s manufacturer’s instructions and such child transported in a bicycle trailer or infant sling is wearing a bicycle helmet as required under paragraph (1) of subsection (a) of Code Section 40-6-296.”
Child development and motorcycle safety

Figure 1: The traditional motor-tricycle which needs a new design and research to improve its safety level

Figure 2: New motor-tricycles which are produced in China. This is promising for infant transportation with their families; however, its passenger room needs to be redesigned to make it safer with a stronger body and restraint system.

2.4 Recommendations

Maximal safety

- Do not allow infants on a motorcycle
- It should be prohibited by law
- Do more bio-mechanic research for appropriate helmet, infant seat, and infant sling related to speed limitation.
Possible option for minimally acceptable safety

- Design motor-tricycle which has a protected passenger room and a restraint system which is compatible with a child seat.

- An infant younger than nine months should not be transported by motorcycle since they are more susceptible to injury and an appropriate helmet is not available. An older infant should wear an age-appropriate helmet as additional safety equipment. (Bike helmet is available for children nine months and older).
Toddlers and preschoolers: 2 to 5 years old

3.1 Physical growth

Toddlers have relatively short legs and a long trunk, with lumbar lordosis and protruding abdomens. At 24 months, weight increases by 2 kg from 12 months of age, and height increases by 12 cm. By 24 months, children are about \( \frac{1}{2} \) of their ultimate adult height. After the second year, expect an annual gain of approximately 2 kg in weight and 5 cm in height. An average four-year-old weighs 16 kg and is 100 cm tall. Because of the larger proportion of mass still found in the heads of children, their overall centres of gravity are higher\(^{22} \).

Brain growth, with continuing myelinization, results in an increase in head circumference of 2 cm over the year. The head size of a child grows rapidly between ages 0 and four years, after which it grows more gradually. By age four, the size of a child’s head (as indicated by head breadth, depth and circumference) is 90% that of an adult and by age 12 it is 95% of adult size. It is not until age 20 that the bone plates of the skull fully close. The head circumference will increase only 5 cm between 3 to 18 years. However, the skull of toddlers and preschoolers has a specific shape according to their age: the proportion between each dimension is not proportional by smaller than the adult size. The facial structure of children is vastly different from that of adults. Children’s heads are smaller in vertical height than adults. An important consideration in helmet standard development was that adult-sized helmets can obscure children’s vision and not fit properly on their heads. This characteristic must be considered for most helmets in different age groups. Table 4 shows the example of some dimensions of head length, tragion to top of head, and head breadth in children\(^{23} \).

Children in this age group have flexible vertebrae which can displace more without fracture, but allow the spinal cord to stretch causing spinal cord injury without radiographic abnormality (SCIWORA)\(^{16} \).
Table 4: Head length, tragion to top of head, and head breadth in children 2 to 15.5 years of age

Tragion: An anthropometric point situated in the notch just above the tragus of the ear.

<table>
<thead>
<tr>
<th>Age (yrs)</th>
<th>N</th>
<th>Mean ± s.d.</th>
<th>Min</th>
<th>5th</th>
<th>50th</th>
<th>95th</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.0-3.5</td>
<td>75</td>
<td>11.4 ± 0.7</td>
<td>9.9</td>
<td>10.2</td>
<td>11.1</td>
<td>12.8</td>
<td>13.0</td>
</tr>
<tr>
<td>3.5-4.5</td>
<td>75</td>
<td>11.7 ± 0.6</td>
<td>10.3</td>
<td>10.5</td>
<td>11.6</td>
<td>12.7</td>
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Source: (Snyder RG, Schneider LW, Owings CL, 1977)
C-spine injuries in toddlers and preschoolers most commonly involve the upper C-spine. The C-spine injury study of Brown found that overall mortality rate was 18.5%, most commonly motor vehicle-related (95%), occurring in younger children (mean and median age 5 years) and associated with upper C-spine injuries (74%). C1 dislocations occurred in younger children (mean age, 6.6 years), most often as a result of motor vehicle-related trauma. A child’s ribs are also more flexible than those of adults, therefore intra-thoracic organ damage from compression was more common than rib fracture and pulmonary contusion. ARDS (acute respiratory distress syndrome) might be developed without any rib fracture. Toddlers and preschool children are also more likely to suffer a higher incidence of intra-abdominal organ injuries because their liver and spleen are not as protected by the rib cage as they will be later in life.

After four years, the torso slims as the legs lengthen. Children, 4 – 6 years old have the highest rate of bone lengthening compared to other age groups in pre-pubertal children as shown in Table 5. However, their legs are not long enough to be supported by most motorcycles’ foot rests.

Table 5: Tibial height and gluteal furrow height

<table>
<thead>
<tr>
<th>Age (ys)</th>
<th>%</th>
<th>Mean (cm)</th>
<th>Min</th>
<th>5th</th>
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Source: (Snyder RG, Schneider LW, Owings CL, 1977)
3.2 Motor, cognitive and psychosocial development

Two-year-old children can walk upstairs and downstairs holding on to a rail or wall two feet to a step, run safely, climb on furniture, throw a small ball overhand and forward, and sit on a small tricycle but cannot use pedals, just propel the vehicle forward with feet on the floor. Three-year-old children enjoy a wide variation in the range of motor activities such as walking with a mature gait, running back and forth, throwing, catching and kicking balls, hopping and jumping. They can also climb on furniture with agility and can usually ride a tricycle using pedals and can steer it round wide corners.

Four-year-old children enjoy the same kind of activities but become more adventurous – scrambling over play equipment, coming downstairs with one foot to a step like adults. By five years, children are even more adventurous performing risky stunts on play equipment, running hard and competing with others\(^22\). They are very active and spontaneous and may be capable of coordinating the skills to ride a two-wheeled bicycle. By this age the fine motor coordination improves further. The hand, arm and body all move together under better command of the eye. They can grip strongly with either hand.

By the time children are two years old, the other ocular apparatus is mature. The eyeball is near its adult size and weight. All anatomical and physiological aspects of the eye are complete, but the perceptual abilities of young children are still incomplete. Although children are able to fixate on objects, track them, and make accurate judgments of size and shape, numerous refinements still need to be made. A young child is unable to intercept a tossed ball with any degree of control. Difficulty with letter and number reversals is common, and a child’s perception of moving objects is poorly developed, as are figure-ground perceptual abilities, perception of distance, and anticipatory timing\(^24\).

Two-year-old children use 50% or more recognizable words appropriately, understand many more, attend to communications addressed to self and begin to listen with obvious interest to more general conversation, and enjoy picture books. Four-year-old children understand some abstract concepts, e.g., ‘one of’, ‘before’ and ‘after’, ‘if’. They listen to and tell long stories, sometimes confusing fact and fantasy, show concern for younger siblings and sympathy for playmates in distress. The preschool period corresponds to Piaget’s preoperational (pre-logical) stage, characterized by egocentrism, perception-dominated thinking, and magical thinking.

Egocentrism refers to a child’s inability to take another’s point of view. Erikson’s learning development theory called this age group as “Learning Autonomy Versus Shame (Will)”, occurring during early childhood, probably between about 18 months or 2 years and 3½ to 4 years of age. Children in the early part of this psychosocial crisis can exhibit tantrums and negativism. However, beginning before the second birthday, the child’s sense of right and wrong originates from the desire to earn approval from the parents and avoid negative consequences. Empathic responses to others’ distress arise during the second year of life, but the ability to consider another child’s point of view remains limited throughout this period\(^25\).
Thinking of children in this age group is dominated by their perception over logic. Such misunderstandings reflect young children’s developing hypotheses about the nature of the world. For example, in one experiment, water is poured back and forth between a tall, thin vase and a low, wide dish, and children are asked which container has more water. Invariably, they choose the one that looks larger (usually the tall vase), even when the examiner points out that no water has been added or taken away\(^25\). Magical thinking includes confusing coincidence with causality, attributing motivations to inanimate objects and events, and unrealistic beliefs about the power of wishes. Attitudes about risk taking behaviour and violence could be formed. An early exposure to TV programmes and advertising has been associated with later behaviour problems\(^25\).

Play dominates the preschool years. Children engage in play mainly because it is enjoyable rather than because it is useful in achieving external goals. Play involves learning, physical activity, socialization with peers, and practicing adult roles\(^25\). Play increases in complexity and imagination, from simple imitation of common experiences, such as sitting and riding on a motorcycle (2 or 3 years of age), to more extended scenarios involving common events, such as going on a trip (3 or 4 years of age), to the creation of scenarios that have only been imagined, such as flying in a car (4 or 5 years of age). By about four years of age children’s symbolic play, a make-believe play often combines complex actions, objects language, and coordination with other people. Symbolic thinking helps preschool children organize and process what they know\(^26\). This is a great time for pre-schools and child care centres to provide opportunities to identify the picture of safe and unsafe road behaviours, road signs, and to play/rehearse specific safe road behaviours.

Play is also governed by rules, from early rules about asking and sharing (2 or 3 years of age), to the beginning of the recognition of rules as relatively immutable (5 years of age and beyond). Social interaction plays a fundamental role in the development of cognition.

Critical foundations for later literacy are established during the preschool years. In this age group, picture books have a special role not only in familiarizing young children with the printed word but also in the development of verbal language\(^25\). Children’s vocabulary and receptive language improve when their parents consistently read to them. Reading aloud with a young child is an interactive process in which a parent repeatedly focuses the child’s attention on a particular picture, asks questions, and then gives the child feedback. Picture books about traffic safety stories may yield both language learning and give a chance to parents to interactively talk about safety behaviours with a child.

### 3.3 Implication for motorcycle safety

What is the minimum age for a child to ride as a pillion passenger on a motorcycle? Should toddlers be carried on a motorcycle as a pillion rider?

A study of motorcycle-related injuries in upcountry Thailand found that passengers tended to be younger than drivers. The youngest passenger was one year
old and the oldest was 71 years. The median passenger age was 19 years. Six percent of injured passengers were below 10 years, and about 44% were 11 to 20 years.

Reviewing age limit laws for child pillion passengers in 17 European countries found that 12 countries have no age limit. However, most countries have regulations for helmet use and child height that stipulate that the feet can reach the footrest in a sitting position on an appropriate passenger seat, as in Table 6 below:

Table 6: Age limit laws for child pillion passengers in 17 European countries

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<th>Country</th>
<th>Motorcycle/Scooter</th>
<th>Sidecar</th>
</tr>
</thead>
<tbody>
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<td>Denmark</td>
<td>No age limit but feet must reach footrest. Child must wear approved helmet.</td>
<td>No restrictions or limits</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Must use safety belt if there is one.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Must wear an approved helmet.</td>
</tr>
<tr>
<td>Finland</td>
<td>No age limit</td>
<td>No age limit</td>
</tr>
<tr>
<td>France</td>
<td>No age limit but children under 5 years must use approved seat incorporating handles and foot pegs. Children above 5 years must reach foot pegs. You are allowed to carry only 1 child. Child must wear approved helmet.</td>
<td>No age limit</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Maximum 2 children if approved by the manufacturer. Must use safety belt if there is one and wear an approved helmet.</td>
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<tr>
<td>Germany</td>
<td>No age limit Children under 7 years must use special seat. Child must wear a helmet, but it does not need to be an approved helmet.</td>
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<tr>
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<td></td>
<td>Must wear a helmet, but it does not need to be an approved helmet.</td>
</tr>
<tr>
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<td>No age limit Child must wear approved helmet.</td>
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<tr>
<td>Norway</td>
<td>No age limit Child must wear approved helmet. Child must sit on passenger seat. Child may not be strapped to the rider. It is recommended that the child is tall enough to reach foot pegs.</td>
<td>No age limit</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Child must wear approved helmet.</td>
</tr>
<tr>
<td>Sweden</td>
<td>No age limit If child is over 7 years, he/she must wear a helmet.</td>
<td>No age limit</td>
</tr>
<tr>
<td></td>
<td></td>
<td>If child is over 7 years, he/she must wear helmet. Safety belt recommended.</td>
</tr>
<tr>
<td>Turkey</td>
<td>No age limit Child must wear approved helmet. Child must sit on passenger seat. Feet must reach foot pegs.</td>
<td>No age limit</td>
</tr>
</tbody>
</table>

Child development and motorcycle safety
<table>
<thead>
<tr>
<th>Country</th>
<th>Motorcycle/Scooter</th>
<th>Sidecar</th>
</tr>
</thead>
<tbody>
<tr>
<td>United Kingdom</td>
<td>No age limit</td>
<td>No age limit</td>
</tr>
<tr>
<td></td>
<td>Child must wear approved helmet.</td>
<td>Special chair recommended.</td>
</tr>
<tr>
<td></td>
<td>Child must sit on proper passenger seat.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Feet must reach foot pegs.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Driver legally responsible for passengers’ support.</td>
<td></td>
</tr>
<tr>
<td>Belgium</td>
<td>Minimum 3 years</td>
<td>Minimum 3 years</td>
</tr>
<tr>
<td></td>
<td>Child must wear approved helmet.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Feet must reach foot pegs.</td>
<td></td>
</tr>
<tr>
<td>Portugal</td>
<td>Minimum 7 years</td>
<td>No age limit</td>
</tr>
<tr>
<td></td>
<td>Child must wear approved helmet.</td>
<td></td>
</tr>
<tr>
<td>Austria</td>
<td>Minimum 12 years</td>
<td>No age limit</td>
</tr>
<tr>
<td></td>
<td>Feet must reach foot peg.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Small children under 12 years must have child seat</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tall children under 12 must wear a seat belt.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The sides of the sidecar must be at child’s chest</td>
<td></td>
</tr>
<tr>
<td></td>
<td>height.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Two children at the same time is permitted.</td>
<td></td>
</tr>
<tr>
<td>Czech Republic</td>
<td>Minimum 12 years</td>
<td>No restrictions or limits</td>
</tr>
<tr>
<td></td>
<td>Child must wear approved helmet.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Feet must reach foot pegs.</td>
<td></td>
</tr>
<tr>
<td>Luxembourg</td>
<td>Minimum 12 years</td>
<td>No age limit</td>
</tr>
<tr>
<td></td>
<td>Child must wear approved helmet.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Feet must reach original foot pegs.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Maximum two children in the sidecar.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Child must wear approved helmet.</td>
<td></td>
</tr>
</tbody>
</table>

Source: The Motorcycle Action Group (MAG UK), 2004

Age limit laws and some specific requirements for riding on a motorcycle in several countries prohibit toddlers and preschoolers less than 6 to 7 years from being carried on a motorcycle. However, this is not the case in developing countries. It is common to find toddlers and preschoolers being carried on a motorcycle as a pillion passenger although this practice is prohibited by law in some developed countries.

Toddlers enjoy motor activities. They can climb up a motorcycle when it is parked, and also jump down from a motorcycle when it runs. Toddlers are more mobile and coupled with increasing curiosity about the environment so they are at greater risk. Owing to their cognitive immaturity, toddlers and preschool children are often impulsive and may frequently be unable to judge accurately the level of safety in situations. Parents need to supervise the child at all times. Parents and caretakers need to take responsibility for managing the high risk of children when travelling on a motorcycle.
3.4 Fall from a motorcycle

Falls from different levels are common in this age group. After one year of age, fall was found to be the leading cause of injuries. As many as 60% of all visits to the emergency department due to unintentional injuries in children aged one year were because of fall. Peak rates of injury from fall from furniture were at 15 to 17 months.

Falls from motorcycles are also a common problem. Children in this age group can climb up a motorcycle causing falls. Children should also know the dangers of climbing up a parked motorcycle on a side stand to avoid the bike from falling over, or worst, falling over them! A smart driver should avoid having children around a motorcycle, as simple crashes can easily occur.

The retrospective study of Bevan, California, found that 167 patients of the 3163 patients aged 16 years and younger, presenting to Emergency Department with motorcycle injuries, needed admission to the Children’s Hospital. Seventy percent of those (167 patients) were in single-vehicle crashes, mainly after a fall (53%) or collision with a stationary object (23%), with only 13% caused by collision with another vehicle. These patients sustained a total of 390 injuries (excluding 107 skin abrasions), and 122 patients (73%) sustained multiple injuries. Fractures were the most common injuries and about half of the patients with fractures required surgery. Forty patients (24%) sustained head injuries. A total of 95 operations were performed on 69 patients, most of which were orthopaedics (59%).

The child who is allowed to be on a motorcycle should be (1) old enough to maintain body control and body support while on the motorcycle, be (2) large enough to wear all of the required protective gear, and be able to (3) understand the basic concepts required when riding as a passenger.

Children under five years do not have a strong grip to hold a driver and always lose their concentration. Hence, when they sit behind the driver, a sudden change of direction or velocity without restraint may cause them to fall off. A sleepy child or a child losing concentration can also easily fall off the motorcycle. Carrying a child in front of the driver could interfere with the operation of the motorcycle. Sitting between two adults increases the chance for “supervision at all time” and can prevent accidental fall of a child from a motorcycle. However, this practice cannot prevent injuries from a crash or spontaneous motorcycle accidental event. It may also increase the risk of a crash as there is more than one passenger on the motorcycle.

Safety equipment aimed to restrain a child while riding on a motorcycle might prevent fall injuries. There are two kinds of uncommon restraint equipment for children on motorcycles of which there is no research evidence as yet supporting their efficacy and effectiveness. An example is the mounted child seat. Riding on a special seat for small children which is firmly attached behind the seat of the operator and is installed with a restraint system might prevent the problem of falling off motorcycles.
for a child pillion passenger. However, no special child seat for a motorcycle pillion has been developed by any country. On the contrary, this is a common practice for child bicycle safety. In some countries carrying a child younger than four years on an adult bicycle without a child seat is illegal. The example of a child seat mounted on a bicycle is shown in Figure 3.

Figure 3: Bicycle safety equipment

However, as in bicycles, the mounted child seats would place the child’s head around 1.2 to 1.5 m above the road surface, high enough for head injuries in the child who falls off. Also, the child who is properly restrained by a belt may be at even greater risk for head injury when the motorcycle tips over or crashes. The head describes an arc with a 1.5-m radius and the impact must absorb both the momentum of the child and the motorcycle.

For bicycle-related injuries, studies show that the majority are accompanied by substantial laterally projected forces when the bicycle falls over, but most seat designs provide virtually no head protection. There is a need to redesign the safety seat to protect lateral impact force. The other example of carrying an infant safely is the Infant sling or kangaroo care for a young pillion rider. The safety of children when being transported has always been of concern and continues to receive serious attention. Infant harnesses have for a very long time been used for retaining young infants in their high chairs, and in automobiles. Infant carriers are also used for carrying an infant on the back of a parent, such carriers having straps to pass around the shoulders of the parent. However, there is a need for protecting a child from falling off a motorcycle when riding as a pillion passenger.
The use of a CRV Riding Belt (children’s recreation vehicle riding belt) has been mentioned in some magazine articles. This belt enables small children to ride on the back of most recreational vehicles. While not sold as a safety device, it does allow the child to be attached to the operator through a system of straps. It may be especially useful if the child falls asleep or loses hold of the operator while riding. However, it has no crash test or bio-mechanic study to prove its safety efficacy.

There is information from USA/Canada regarding a safety harness for attaching the passenger on a motorcycle, particularly a child, to the driver of the motorcycle. A feature is a vest to be worn by the passenger, with a pair of straps attached to the vest and forming shoulder loops to be worn by the driver. This way, the upper torso of the passenger is securely attached to the driver. A feature by which this is achieved is by attaching the straps to the back of the vest and crossing the straps over the vest so that two large crossing-over loops are formed that pass between the legs of the passenger. This has the advantage of not only securely enveloping the passenger, but additionally the straps “lock” the passenger in the vest even if the vest should inadvertently come loose. The product characteristics, and use instructions are shown in the following pictures and product specifications (Figure 4):

*Figure 4: Infant sling characteristics, and use instructions*

**Specifications**

- Belt weight ............ 1.5 kgs., (3 lbs)
- Shipping size........... 25cm X 25cm X 48cm, (10” X 10” X 19”)
- Belt type ............... Heavy nylon
- Pad type ................. High density foam
- Handle grips ............. B.M.X. Style
- Solid nylon buckles
- Pad cover ............... Waterproof nylon
- Child size ............... Maximum 45.5 kgs, (100) pounds
Child uses the handles to hold the pad against the body. The neck support and shoulder harness are brought over the child's head.

The waist belt is fastened first, then the shoulder straps, followed by the crotch straps.

When all is secure the driver will sit on the vehicle and set the driver’s belt ensuring a snug fit. Then the buckle is fastened.

India also has a similar product called “Kangaroo care, two-wheeler pillion children safety belts” (http://www.tradekey.com/selloffer_view/id/3417477.htm). However, adequate research is required to assess the protectiveness and the adverse effect, if any, when there is a crash.

**Motorcycle-related lower limb injuries**

*Lower-limb injuries: a common injury among motorcycle riders and pillion passengers*

Lower-limb injuries have been identified as a common form of injury among young motorcycle riders and pillion passengers. Several hospital-based case series studies have shown that the proportion of lower-limb injuries among injured riders and pillion passengers account for nearly 50% of such injuries. Lower limb injuries might lead to extended and costly medical treatment and permanent disability.

The study conducted by the Victorian Injury Surveillance System, Australia between 1989 and 1993 showed that 43% of injuries involved the legs and feet\(^{31}\). The study in Singapore found that of the 1,809 motorcyclists covered, 1,056 (58.3%) sustained lower-limb injuries\(^{32}\). The study covering a group of 700 motorcycle riders in crashes in Los Angeles County in 1988-1989 found that lower extremity injuries were diagnosed in 301 (56%) of non-fatally injured riders and in 75 (46%) of fatally injured riders. Drivers and passengers did not differ in their risk for lower extremity injuries. The author suggested that modifications in motorcycle design and rider apparel may prevent some lower extremity injuries in motorcycle crashes\(^{33}\).

The study in a developing country, Pakistan, to determine the spectrum and severity of injuries seen in child passengers, who get their feet entangled in the spokes of bicycle and motorcycle wheels, including 92 consecutive patients, found that the average age was 3.9 years, 80 children were injured while riding a bicycle, the rest had their feet entangled in motorcycle spokes\(^{34}\). Motorcycle injuries caused more severe injuries than a bicycle. Front wheel injury mainly caused inversion, with laceration over dorsum and medial aspect of the foot and medial malleolus. Rear wheel injury mostly caused eversion, with skin damage to the lateral and posterior aspect of the foot and ankle, with lateral malleolus at risk\(^{14}\). The study showed that both bicycles and motorcycles which are important means of transport for the whole family in most third world countries can cause severe injury to the feet of young passengers if sitting without proper footrests and unguarded spokes. The author suggested that improved training via motorcycle driver education, better design of motorcycles and protective footwear may help to reduce this problem.

Studies on motorcycle-and bicycle-related foot injuries among young children were also conducted in several other developing countries. The main reason for bicycle and motorcycle spoke or wheel-related injuries is that the maximal tibial height of toddlers and preschoolers is 30.2 cm (Table 5) which is not long enough for their feet to be on the foot rests of a bicycle or motorcycle.
For this reason, in developed countries, a mounted child seat for bicycles has been developed and recommended. It is illegal for adults to take children under 5 years on a bicycle without an appropriate mounted child seat with helmet.

**Case 1: Foot entrapment of a 6 year-old-boy riding as a passenger**

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**Children as Pillion**

**The Story:**

6 year old boy riding as a pillion with his father who is a driver on the freeway around 100km/h. Suddenly he shrieked, shouted to stop the bike, and his body pulled to the left of the bike as if he was getting off. His father grabbed him with his left hand and stop the bike safely with no clutch hand.

---

Boot was entrapped between the tyre and the chain with the chain guard. The hard rubber and leather of the boot prevented the tyre and chain from “Grabbing” the child shoe/foot. Severe burn and soft tissue damage to toe area where the Chain rubbed against the Boot!!

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**Lesson learnt:**

The advice when considering riding with a child as a passenger:

- Child must be stable on the Bike
- Specific training course for the driver to ride with a passenger, and a child passenger
- Educate the Pillion: this is a responsibility of driver and should be done by the knowledgeable driver who passed the specific training course of “Riding with a passenger”

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Case 2: Lower-limb injuries in infants...

On 23 August 2007, a one-month-old boy was held by his mother while riding on a motorcycle as pillion with his father who was driving. They were going to the temple to worship and perform religious activities as usual. The baby’s body was covered by a thin blanket which covered the baby’s feet. This practice is quite common in Thai low-middle class families who use the motorcycle as a family transportation mode. Suddenly, the end of the blanket slipped down and got entangled around the wheel core, between the wheel spoke and chain frame. The baby was pulled down and his feet and leg were entrapped in that space and also crushed by the wheel spoke. He was amputated on the spot by the Emergency Medical Service (EMS) and referred to the hospital.

In another case, a one-year-old child was a pillion rider on his father’s motorcycle with his mother. The end of the wrapping cloth round his body got entangled in the motorcycle chain and his right leg was crushed and had to be amputated.

**Motorcycle foot pegs**

A study in Thailand covered the presence or absence of rider and passenger foot-peg of motorcycles involved in crashes. The passenger foot-peg were mainly metal folding pegs with rubber covers (94.7%), without rubber covers (1.9%), and there were 12 motorcycles (3.3%) without passenger footrest⁴. Most foot-rests are too low for toddlers and preschoolers to reach and can cause serious injury. (Table 5).

**Mounted child seat for bicycles to prevent spoke injuries**

Not only does it help to prevent falls, the mounted child seat is also the main strategy to reduce bicycle-spoke injuries. Bicycle-spoke injuries are very common in children under 5 years who are passengers on bicycles³⁵,³⁶. Studies involving wheel-related, lower limb injuries and use of mounted child seat could help in preventing bicycle-related injuries.

The study in California during 1977-1986 showed that the rate of bicycle-spoke injuries in passengers rose from 17% to 28% of all reported bicycle-related injuries in children in this age group³⁵. The study from the department of plastic and reconstructive surgery, Fukuoka Tokushukai medical centre, Japan reported 716 lower extremity injuries caused by bicycle spokes. Patients ranged from 2 to 19 years, with a mean age of 5.6 years. The rear wheel injured the majority of patients (89%).
The Achilles tendon was the most common site of injury (63%). The typical types of wounds observed included 41% of laceration with partial avulsion of skin and subcutaneous tissue, 33% of laceration forming a distally based flap, 26% of abrasions with bruises and friction burn from the shearing effect of the spokes creating a partial-to full-thickness skin defect. The wound healing time was 27-29 days. The author commented that this prevalence was not different from the first report of bicycle-spoke injuries half a century ago, showing that prevention has not improved36.

Figure 5: Bicycle-spoke injuries

Injuries due to mounted child seat

Injuries from bicycle-mounted child seats have also been reported. The study, in California during 1977 – 1986 found an increased frequency of these injuries, with the rate of passenger injuries rising from 17% to 28% of all reported bicycle-related injuries in children 5 years old and younger37. The study covering a detailed sample of 52 injuries related to the use of bicycle-mounted child seats, found that 42% occurred when the bicycle crashed or tipped over and 25% occurred when the child fell out of the seat. Sixty-five percent of the injuries involved the head and face, and 27% of the head injuries were serious. Substantial morbidity associated with these injuries could be ameliorated if children using these seats wore appropriate bicycle helmets.

According to data from the US Consumer Product Safety Commission (CPSC) study in 1978-1988 concerning injuries related to bicycle-mounted child seats used for carrying children on adult bicycles, there were an estimated 4960 injuries to children during the 11-year period. The peak age of injury was two years. Falls accounted for 80% of the estimated injuries. Head (51%) and face (21%) injuries predominated. Nineteen percent of the estimated injuries were severe, and involved the head or face38.
Child seat for motorcycles to reduce falls and spoke injuries

To reduce falls and spoke injuries among small children on motorcycles, injury data and the knowledge learnt from bicycle safety studies show that the safest place for children 2 – 5 years old, or weighing around nine to 18 kg, on a motorcycle is the rear seat on a “Back-Belt” child seat which comprises a high seat back, harness, and leg-foot support. However, further studies on the effectiveness of this installation to reduce motorcycle crash-related injuries are needed.

3.5 Head injuries in children related to motorcycles

According to the injury surveillance (IS) systems that are operating in countries of the South-East Asia Region, (India-IS pilot in two cities, Nepal – pilot in three districts, Sri Lanka – pilot in four hospitals and Thailand – a national surveillance system in 28 hospitals, covering 27 provinces) in 2009, children aged less than 15 years who were injured while using motorcycles accounted for 17.2%-61.9% of transport injuries in children (India 17.2%, Nepal 24.6% and Thailand 61.9%).

Among child vehicle users, motorcycle injuries were the most common, accounting for 40.3%-69.7% of all injured vehicle users in India, Sri Lanka, Nepal and Thailand with 40.3%, 42.6%, 46.4% and 69.7% injured respectively.

Almost all child motorcycle injuries were among non-helmet users (in 2007, India (95.7%) and Thailand (96.4%) of motorcycle injuries did not wear helmet). 37.2% of motorcycle injuries patients had head and neck injuries and 8.3% had severe brain injury (coma score: 3-8) suggesting severe injury to the brain.

In developed countries like the USA and Australia, motorsports have been increasing in popularity in recent years. Many people, including children engage in motorsports on unstructured tracks, in potentially hazardous situations. Between 1997 and 2002, the number of injuries related to motorsports according to the Consumer Product Safety Commission (CPSC) nearly tripled. Motocross* racing is a rapidly expanding example of children’s motorsports activities. This form of motorcycle racing is held on enclosed off-road circuits. Linked to motorsports, the participants are children less than 16 years. According to CPSC, between 1994 and 1996, about 40 000 injuries related to 2-wheeled motorized off-road cycles were treated in emergency departments each year and more than one-quarter were sustained by children younger than 15 years of age. From 1990 through the first quarter of 1995, at least 50 deaths related to mini-bike and trail-cycle use were reported to the CPSC, and nearly half were in children 16 years old or younger. Despite this CPSC data, there are currently no helmets or helmet standards specifically designed to protect children who engage in motorsports. These children, many of whom are as young as 6 years, tend to use adult motorcycle helmets, which are ill-fitting and heavy, and do not take into account children’s unique anatomy.
Effectiveness of adult helmet to prevent head injuries

Brain injuries can be classified into two categories: diffuse injuries and focal (localized) injuries. Diffuse injuries consist of brain swelling, concussion and diffuse axonal injury (DAI). Focal injuries consist of epidural and subdural hematomas, brain hematomas, and brain contusions. Brain injuries sustained by road crash victims fall into the diffuse type in three out of four cases, with one out of four cases of brain injury being of the focal type.

Helmets are the key factors for prevention of head injuries related to motorcycle crashes. This is shown by biomechanical and epidemiological evidence. In adults and adolescents, studies on the effectiveness of helmets to prevent motorcycle-related brain injuries showed both mortality and morbidity reduction in motorcyclists. The 61 observational studies were reviewed and showed that motorcycle helmets reduced the risk of death and head injury in motorcyclists who crashed. From four studies, standard quality or higher helmets were estimated to reduce the risk of death by 42% (OR 0.58, 95% CI 0.50 to 0.68) and from six studies standard quality or higher helmets were estimated to reduce the risk of head injury by 69% (OR 0.31, 95% CI 0.25 to 0.38). The study to compare helmet–users and non–users found a higher death rate, longer stay in intensive care unit and hospital, and a higher number of skull trauma in the non-user group.

Implementation and enforcement of a mandatory motorcycle helmet law has proved its effectiveness to reduce mortality due to motorcycle-related head injuries. The State of Texas, USA, implemented a mandatory motorcycle helmet law for all operators and passengers, effective September 1, 1989. Subsequently, during the year after the law was implemented, a study found an additional decline of 12.6% and 57.0%, respectively, for total and head-related fatalities. Mertz KJ assessed changes in helmet use and compared motorcycle-related head injuries with non-head injuries from 2001-2002 to 2004-2005 aimed to evaluate the 2003 repeal of Pennsylvania’s motorcycle helmet law, and found that helmet use among riders in crashes decreased from 82% to 58%. Head injury deaths increased 66%; non-head injury deaths increased 25%. Motorcycle-related head injury hospitalizations increased 78% compared with 28% for non-head injury hospitalizations. The one-year study to evaluate the effect of the motorcycle helmet law implemented in Taiwan since June, 1997 by collecting data on 8795 cases of motorcycle-related head injuries from 56 major Taiwanese hospitals found that, after implementation of the law, the number of motorcycle-related head injuries decreased by 33%, from 5260 to 3535. Decreases in length of hospital stay and in severity of injury and better outcome were also seen. This study also found that full helmets were found to be safer than half-shell helmets.

However, speed may be an effect modifier on the odds of death for helmeted riders. Shibata found that the effectiveness of a helmet to prevent deaths for those travelling 30km/h to 50km/h was significantly higher than non-use riders (adjusted OR 0.03, 95% CI 0.002 to 0.42), but not for those traveling over 50km/hour (adjusted OR 0.47, 95% CI 0.086 to 2.32). Goldstein 1986 maximum likelihood probit model found that helmet-wearing resulted in no change in the probability of survival after accounting for kinetic energy of the rider and alcohol use.
The study of Chiu WT found that full helmets were safer than half-shell helmets. Tsai’s study, which adjusted for confounders, found full-face helmets compared with no helmet significantly protective against head injury (adjusted OR 0.26, 95% CI 0.14 to 0.47). Meanwhile helmets without a chin-bar and less head coverage (defined as full helmet or partial coverage helmet) compared with no helmet were not significantly protective against head injury (adjusted OR 0.72, 95% CI 0.38 to 1.37). However, Hurt’s study found that full-face helmets and non-full-face helmets compared with no helmet were both significantly protective against head injury (OR 0.29, 95% CI 0.17 to 0.49 and OR 0.24, 95% CI 0.16 to 0.36, respectively). Liu BC did a meta-analysis and concluded that there was insufficient evidence to demonstrate whether differences in helmet type confer more or less advantage in injury reduction.

Helmets also reduce the risk of facial injuries. A six-year study in Texas shows that facial injuries in riders that use a helmet are 19.6%, and brain damage rate is 30.7%; while non-user’s rate is 39.2% and 54.1% respectively. Sauter found helmets to significantly protect against facial injury after adjustment for confounders (OR 0.34, 95% CI 0.24 to 0.48).

Meanwhile helmet use significantly decreased the risk of head and facial injuries. Moskal A revealed that there was no association between helmet use and the occurrence of neck or cervical spine injuries. The adjusted odds ratios for non-helmeted riders were 0.86 (95% CI 0.60 to 1.23) and 1.04 (95% CI 0.78 to 1.39), respectively.

However, information or research reports about use of child helmet in developed countries are very scarce. Because of low exposure, toddlers and preschoolers account for a low proportion in terms of victims of motorcycle-related head injuries. The low magnitude of this problem makes child helmets an issue of low priority.

In contrast to children in developed countries, children in developing countries are highly exposed to motorcycles even as early as 2 to 3 day-old newborns as pillion passengers. However, information and research reports on motorcycle helmets for toddlers and preschoolers from developing countries are also scarce.

*Effectiveness of crash helmets for bicycle-related head injuries among children*

Many children in these age groups sustain head injuries caused by riding on a bicycle. Several research papers to reduce head injuries have been published in developed countries. We can learn from bicycle-related head injuries and apply the lessons to better understand the need for child helmets for use on motorcycles.

The effectiveness of crash helmets has been studied for decades, and they are known to reduce the risk of severe head injury by about one-third. In one of the largest of the comparative studies, Maimaris collected data on 1040 patients who attended the emergency department of a Cambridge hospital following a bicycle crash, of whom 114 had worn bicycle helmets when the crash occurred. There were
two deaths following collisions with motor vehicles, but in neither case had a helmet been worn. There were no significant differences between the two groups of cyclists with respect to the nature and site of injuries sustained, except in the incidence of head injury. Head injury was sustained by four out of 114 (4%) of helmet wearers, compared with 100 out of 928 (11%) of non-wearers. The risk reduction effect was therefore over 60%. Statistical analysis showed a protective factor of 3.25 for wearing a helmet. Not only were the odds of head injury significantly reduced (by a factor of three) by wearing a cycle helmet, but also the protective effect of wearing a helmet was present for all ages and all types of crashes including collisions with motor vehicles. When helmet wearers sustained head injuries, they were less severe\textsuperscript{48}.

During 1991 and 1992, a case control study was conducted covering 445 children aged 14 years or less, presenting with bicycle-related injuries to the two main children’s hospitals in Brisbane. The case group was composed of 102 children with injuries to the upper head area, including injuries to the skull, forehead and scalp, or loss of consciousness. The control group consisted of the 278 cyclists who were treated for injuries other than to the upper head or face. The study revealed that the risk of injury is reduced 63\% for head injury and 86\% for loss of consciousness, when a helmet is worn. This translates to a risk of injury to the upper head 2.7 times higher among non-helmet wearers than among helmet wearers. For loss of consciousness, the risk was 7.3 times higher among non-helmet wearers than among helmet wearers\textsuperscript{49}.

**Crashed test helmet for children under 6 years of age on a motorcycle**

The brain, as a mass, will expand or get enlarged when a force is applied to it. During impact, this expansion/enlargement may be linear or rotational. Rotational force is much more dangerous than translation force and is likely to cause diffuse brain injuries. During the impact process energy is transferred, and because the brain is not rigid, it may result in injury. To minimize brain injury, the basic aim of head protection is to reduce the transferred force to the brain by absorbing the kinetic energy or distributing the impact load. This is done by an inner padding and a hard outer shell of the protective helmet that serves to distribute the impact load over a large area. To reduce transferred energy from rotational force, an absorbing mechanism is much more effective than a force distribution mechanism.

In order for a helmet to provide protection in a given crash, two conditions must be satisfied. First, the helmet’s ultimate protective capacity must be greater than the impact severity. Then, the helmet’s characteristics must be such that peak acceleration does not exceed the level of the wearer’s tolerance.

The ultimate protective capacity depends on both the stiffness and the wall thickness of the helmet. Stiffer helmets, by resisting crushing, manage greater impact severities than softer helmets of the same thickness, but impart higher peak accelerations. Thicker helmets manage greater impact severities than thinner helmets of the same stiffness. However, thicker helmets will increase in size which must be considered for paediatric use as a risk of neck injuries.
On March 31, 2003, the Snell Memorial Foundation convened a meeting at The Children’s Hospital of Philadelphia. The purpose was to review what is known about paediatric head and neck injury relevant to protective helmet design so as to determine what needs to be considered when developing a helmet standard for children who pursue motorsports. The following is a summary of this conference:

1. **Differences in injury patterns between children and adults**

Head injuries of children and adults have different patterns. Animal studies have revealed that age affected the response and recovery of the brain to a focal impact and to rotational load. The degree of damage by focal impact, as measured by brain cell death, increased with the animal’s age. Piglets equivalent in age to human infants experienced the least amount of damage, one-week after injury and the most damage was in piglets equivalent to 11-13-year-old humans. The oldest piglets were more prone to late swelling, from such a brain injury, compared to younger piglets.

With regard to diffuse brain injury, three times more axons were damaged in infant piglets within six hours after injury than in adult pigs given the same non-impact rotational load. The report of the National Academy of Sciences on soccer and head injuries in children also found that children were more likely than adults to suffer severe consequences from concussions, one form of diffuse brain injury. These consequences included second-impact syndrome, which was often fatal or resulted in learning impairment.

These studies concluded that older children may be more prone to focal impact damage than younger children and adults, while diffuse injuries from rotational load were more prone in younger children than older children, and in older children than adults. Therefore, helmet standards for older children may need to be different than those for younger children or for adults.

2. **Anthropometric and biomechanical differences between children and adults**

By age 4, the size of a child’s head (as indicated by head breadth, depth and circumference) is 90% that of an adult. An important consideration in helmet standard development is that the facial structure and head size of children is vastly different from those of adults. Children’s heads are smaller in vertical height than adults’. Consequently, adult-sized helmets can obscure children’s vision and not fit properly on their heads. In a small child, the adult-sized motorcycle helmet may actually rest on his shoulders and the child may not be able to get his head deeply enough into the helmet to even test the crown fit. Even older children may find that the chinstrap will not secure the helmet properly as chinstrap anchor points are placed according to adult anatomy.
3. **Develop a motorsports helmet standard for children, 6 years and above**

Based on the discussion on the incidence of the damage to children’s brain, the participants attending the meeting decided to focus on developing a paediatric motorsports helmet standard for children 6 years and above. However, there was no consensus on this issue; some participants expressed concern that motorsports were dangerous for children and a paediatric helmet standard that includes younger ages should not be developed because it might encourage parents to allow their children to participate.

4. **The paediatric helmet standard**

Based on the discussion to develop a basic paediatric helmet standard, the following need to be considered:

- A paediatric motorsports helmet standard should be designed to include protection from head impacts with a hard surface.
- Until more data suggest otherwise, the 300g acceleration limit should be considered, as in the adult helmet standard, in a paediatric motorsports helmet standard.
- In the labeling of a motorsports helmet standard, it should be specified that it was to protect against permanent brain injury from a single impact event.
- There was some discussion as to whether a motorsports helmet should protect from concussion as well as permanent brain injury. No helmet currently is designed to offer protection from concussion. Some participants thought repeated concussions in children were problematic and helmets should offer protection from mild traumatic brain injury. But other participants pointed out that low impact (resulting in concussion) and high impact (resulting in permanent brain injury) protection may be incompatible in a single helmet of a reasonable size and mass. Most agreed that the helmets must protect at least against high impact. It was suggested that well-designed epidemiological studies would reveal where the injuries are and provide guidance for the area of focus of helmet standards.
- To offer more protection from mild traumatic brain injuries, the padding of helmets must be made thicker. To keep the helmet the same size and weight, the outer shell must be made thinner. But a thinner shell has less space to provide energy attenuation and therefore has lower protective capability from permanent brain injuries. A few participants suggested this trade-off might be overcome with innovative materials. But others questioned its feasibility, especially whether the use of such materials is likely to result in a helmet that is too expensive for the average consumer.
- Most of the discussion centered on how to reduce the size and weight of a helmet for paediatric motorsports yet increase the energy absorbing ability at the same time. To reduce the mass limit for helmets designed for children, it was recommended that the scaling approach as in Table 7 be used.
Child development and motorcycle safety

Table 7: Helmet weight limits based on stiffness scaling ratios

<table>
<thead>
<tr>
<th>Age Group (Years)</th>
<th>Lower limit (Kg)</th>
<th>Higher limit (Kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.23</td>
<td>0.72</td>
</tr>
<tr>
<td>3</td>
<td>0.35</td>
<td>0.86</td>
</tr>
<tr>
<td>6</td>
<td>0.91</td>
<td>1.1</td>
</tr>
<tr>
<td>12</td>
<td>1.24</td>
<td>1.60</td>
</tr>
</tbody>
</table>

A paediatric motorsports helmet standard should also consider surface friction and head pocketing.

- *Currently, there were no testing head forms that approximate a child’s head.* Without such head forms, a helmet designer or compliance engineer could not adequately assess how a helmet would affect a child’s vision, remain secure during an impact, let alone how well it would protect the child from head injury.

- It was recommended that testing of helmets for children should include roll-off testing and testing to ensure the helmet fits close enough to the child’s head.

5. **Action and research needs**

Current action and research needs include:

- Conduct better surveillance of motorsports injuries in children.
- Conduct more modeling and animal studies that can indicate injury criteria for the brain in impact situations akin to motorsports-like events. The validity of models should be tested with data from actual crashes.
- Develop a preliminary paediatric motorsports helmet standard based on the information available to date. This standard should then be modified, if necessary, once more information is acquired.
- Once a paediatric motorsports helmet standard is developed, a follow-up study should be conducted to determine the effectiveness of helmets that meet the standard to prevent head and neck injuries in children who use them during motorsports competitions.

In future, for paediatric helmets, this would require researchers to develop computer models of children’s heads for a range of different ages and to establish the tolerance levels of children’s brains.

**Safe behaviour modeling**

The age of 2 to 5 years is an important factor in road safety, as it is at this age that children observe and copy the behaviours modeled by their parents and caretakers. There are many recurring moments and modeling opportunities as they travel together.”
Children could start learning road safety behaviour since they are one year old by imitation and by carefully observing adults. Parents and care-givers influence children’s behaviour through experience, discovery and observation. Copying parent’s behaviour and attitudes will have serious consequences for safety outcomes for the child both immediately and in the future.

If appropriate and realistic training methods are used, even quite young children’s understanding and behaviour can improve. It can also support the delivery of road safety education to children aged five years or younger. Studies showed that children had extensive exposure to traffic at this age, and also that their road skills were already developing but not to the level of independent road use.

According to the Siegler and Chen study, older children transfer problem-solving schema under a broader range of conditions than do younger ones. They warn that if younger children are only taught a vague understanding of ‘rules’ they do not take the next step and look for deeper understanding or application of the problem they face. If children do not understand the problem they can’t generalize the rule to a new problem. Hence it is important for children to not only learn rules for using the road, but also understand why the rule is applied. It should not be assumed that if children know and understand road rules that are correct and legal, safe road use behaviours will follow.

Positive parenting to develop safe behaviour for a toddler 2 to 3 years old includes:

- **Safety books**: Setting a daily schedule to read books with a toddler, selecting safety books, road safety books as a tool to create awareness about safety in the mind.

- **Safety pretend play**: Encouraging a toddler to engage in pretend play, using a safe rider-driver, a traffic police as a model instead of a car racer or a violent driver.

- **Safety talks**: Exploring child surroundings with a toddler by taking a toddler on a walk and teaching or asking simple questions to introduce road safety environment.

- **Safety songs**: Teaching a toddler simple songs of safety, or road safety.

Positive parenting to build safe behaviour for a preschooler 3 to 5 years old includes:

- **Safety books**: Continuing to read to a preschooler, taking a preschooler to the library or bookstore and also showing him safety books and road safety books.

- **Safety play with peers**: Encouraging a preschooler to play with other children concerning the value of sharing and friendship.

- **Safety rules and discipline**: Teaching a preschooler to ride a tricycle under safety rules such as riding on the sidewalk and away from the street, using a helmet, and being consistent for disciplining a preschooler and modeling the safe behaviour that is expected from a preschooler.
3.6 Recommendations

Maximal safety for toddlers and preschoolers

(1) Do not allow toddlers and preschoolers under 6 years to be carried on a motorcycle as a passenger.

(2) It should be prohibited by law.

(3) Do more bio-mechanic research for appropriate helmet, and child seat (comparing benefit and risk of increasing momentum) related to speed limitation for safety recommendations in future.

Possible options for minimally-acceptable safety

(1) Children 2 to 5 years old must use all available protective gear when being carried on a motorcycle such as the following:

(1.1) Mounted seat: Children 2 to 5 years old whose feet cannot reach the footrest be transported on a motorcycle with a well-designed child seat for a motorcycle passenger and some basic safety rules should be followed:

- A child seat must be mounted on the rear wheel.
- A child passenger is always belted into the child seat.
- A child seat should include spoke protectors for the child’s feet.
- The back of the seat should be high enough to provide adequate head support for the child.
- A motorcycle child seat should be designed to protect the head from laterally projected forces when the motorcycle falls over.

(1.2) Crash helmet: A child pillion passenger must wear his/her own crash helmet which fits his/her head. This need to develop, first, age-appropriate testing head forms that approximate a child’s head in various age groups, and a roll-off testing to ensure the helmet fits close enough to the age-specific child’s head.

(1.3) Clothing: A pair of pants is necessary because it can protect his/her leg in case of a crash, that skirts or shorts would not do.

(1.4) Footwear: Rubber or leather boots would prevent foot injuries in case of a crash or foot entrapment.

(2) Only motorcyclists who have passed an additional motorcycle test for carrying a child passenger can carry children under 12.

(3) Using a motor-tricycle as a safer mode instead of a motorcycle, a child passenger aged 1-5 years or weight of 9 to 18 kg could be transported in a protective passenger with a child safety seat.
School-age children to middle-adolescents: 6 to 15 years old

4.1 Physical growth

The period of 6-10 years is a period of slow and consistent growth before the rapid growth spurt of adolescence. While weight increases of 3 kg per year on average, height increases by 6-7 cm per year. The head grows only 2-3 cm in circumference during this period. Children grow steadily during middle-childhood from about 115 cm and 20 kg at age six to almost 150 cm and 32 kg at age twelve. Body habitus is more erect than previously, with long legs compared with the torso.

Towards the later part of this lifespan stage, girls tend to become significantly taller than boys of the same age. The difference results from the timing of the growth spurt associated with puberty for each sex, and girls’ earlier puberty. For girls a spurt in height usually precedes the growth of breasts and pubic hair. For boys, a spurt in height tends to follow the other physical changes of adolescence. Growth of the mid-face and lower face occurs gradually. Adult teeth erupt from 6 years on, at a rate of about four per year. Pre-molars erupt by 11-12 years of age.

Muscle mass and strength gradually increases as ‘baby fat’ decreases. Children double their strength capabilities during these years. Because of their greater number of muscle cells, boys are usually stronger than girls. Muscular strength and coordination increases progressively, as does the ability to perform complex movements. Children now find some specific physical skills are easier to learn, such as riding a bicycle or a motorcycle. Such higher-order motor skills are the result of both maturation and training; the degree of accomplishment reflects wide variability in innate skill, interest, and opportunity. In gross motor skills involving large muscle activity, boys gain greater control over their bodies and usually outperform girls. Girls in particular can sit and attend for longer periods of time. This difference in patience and ability to attend appears to be evident in, and related to male impulsivity when crossing roads.
Children should be encouraged to participate in regular physical activity. Participation in organized sports or other organized activities can foster skill, teamwork and fitness, as well as a sense of accomplishment. Pre-pubertal children should not engage in high-stress, high-impact sports, such as power lifting or football, because skeletal immaturity increases the risk of injury.

Adolescents are generally healthy. However, they experience certain health risks and are more likely to be injured in motor vehicle crashes, misuse alcohol and other substances, and require mental health support or interventions.

4.2 Motor, cognitive, and psychosocial development

Visual-motor perception

Apart from growth, muscle strength, and skeletal maturity, success of complex physical tasks depends on visual-motor perception.

From the moment of birth, children begin to learn how to interact with their environment. This interaction is a perceptual as well as motor process. Visual acuity, figure-ground perception, depth perception, and visual-motor coordination are important developmental aspects of visual perception.

**Visual acuity** is the ability to distinguish detail in objects. Static visual acuity is the degree of distinguishable detail that one is able to detect when both the individual and the object of visual regard are stationary. Dynamic visual acuity is the ability to distinguish detail in moving objects. It is less frequently assessed than static – visual acuity for various reasons, but it is of interest to anyone required to make precise judgments based on visually guided tracking. Static – visual acuity is mature by 10 years and, in general, is less developed in children 5-6 years old. By 12 years, static – visual acuity is generally like adults. Dynamic visual acuity appears to mature somewhat later than static – visual acuity. It improves in individuals up to 20 years of age\(^2\). Boys display better visual acuity (both dynamic and static) than girls at all ages.

**Figure-ground perception** is the ability to separate an object visual from its surroundings. Various combinations of blending and/or distracting backgrounds influence the ability of 6-year-olds to distinguish objects visually from their surroundings. Combinations that caused a maximum amount of blending and distraction were most disruptive of the children’s ability to distinguish a figure from its background in the performance of a simple stepping test. Conditions in which only colour blending or visual distractors were present were less disruptive. The development of figure-ground perception is stable between 8 and 10 years of age. Prior to that, however, slow improvement occurs between 3 and 4 years, with greater improvement seen from 4 through 6 years. Smaller changes were reported from ages 6 to 7 followed by a slight spurt between 7 and 9 years. Figure-ground perception becomes increasingly refined from 8 to 13 years and even continues to 17 or 18 years of age. One may conclude that mature figure-ground perception involves elements of attention as well as visual-motor maturation\(^2\).
Visual-motor coordination refers to the ability to track and make interception judgment about a moving object. By age 5 or 6 children can accurately track moving objects in horizontal plane, and by age 8 or 9 they can track balls moving in a arc.

Object interception, or coincidence-anticipation timing as it is frequently referred to in motor learning literature, involves the ability to match estimates of an object’s location with a specific motor response. For example, the batter in baseball must estimate where the ball will be at a certain point in time and simultaneously activate the motor system to bring the bat into contact with the ball at just the right moment. Object interception abilities improve greatly with age and practice.

4.2.1 Cognitive development

Cognitive development varies widely in timing, intensity and context during this period. School-aged children increasingly apply rules based on observable phenomena, factor in multiple dimensions, and interpret their perceptions using physical laws. Piaget documented this shift from “preoperational” to “concrete logical operations” also known as “mental activities focused on real, tangible objects and events”. They may revert to pre-logical thinking when under stress. Concrete operations allow children to understand simple explanations for injuries, illnesses and necessary treatment.

Children in this period can attend to more than one feature of a problem at a time and also have different perceptions of the same object, combining them in logical ways. Children can group things in more than one way at a time by about age seven. They know that a person can be both a parent and a teacher at the same time, that a vehicle can be both okay and a danger to them.

Piaget found that after about age seven, most children are able to arrange objects in sequence according to some dimension such as length or size. They understand temporal relations or the nature of time, better than they did as preschoolers: children at age eight can represent the spatial relations of their surroundings. They can make maps and models of familiar places, such as their homes, their classrooms or the road environment.

The change in cognition allows the child to understand “if/when” clauses. Increased responsibilities and expectations accompany increased rights and privileges. Discipline strategies should move toward negotiation and a clear understanding of consequences. Emotional factors including external rewards (eagerness to please adults and approval from peers) and internal rewards (competitiveness, willingness to work for a delayed reward, belief in one’s abilities, and ability to risk trying when success is not ensured) interact with cognitive ability.

Beginning in the third or fourth grade, children increasingly enjoy strategy games. Children develop the ability to play games with rules. This understanding of rules can also be transferred to the road environment. Currently, video and computer games for children are common leisure time activities.
During adolescence, most young people go beyond concrete operational thoughts and begin developing a more abstract way of thinking called formal operational thought. This allows them to be more fully logical and systematic in analyzing ideas\textsuperscript{26}.

**Psychosocial development**

During middle-childhood, children increasingly separate from parents and seek acceptance from teachers, other adults, and peers. Self-esteem becomes a central issue, as children develop the cognitive ability to consider their own self-evaluations and their perception of how others see them.

The home and family remain the most influential. Parents should make demands for effort in school and extracurricular activities, celebrate successes, and offer unconditional acceptance when failures occur. By the age of 6 years, children have developed a conscience, meaning that they have internalized the rules of the society. In this age, children can distinguish right from wrong. Initially, children have a rigid sense of morality, relying on clear rules for themselves and others. Children will adopt family and community values, seeking approval of peers, parents, and other adult role models. Social conventions are important, even though the reason behind some rules may not be understood. Children who meet with repeated failure may exhibit “extreme” behaviour to win acceptance.

Media exposure to adult materialism, sexuality, and violence may be frightening, reinforcing children’s feeling of powerlessness in the larger world. Compensatory fantasies of being powerful may fuel the fascination with heroes and superheroes. A balance between fantasy and an appropriate ability to negotiate real-world challenges indicates healthy emotional development.

During adolescence, young people can exam their own thoughts, other’s thoughts and what others are thinking about them and can understand society. They develop a sense of personal identity which provides the basis for understanding themselves and others and for maintaining a sense of autonomy and independence\textsuperscript{26}.

They develop knowledge of what is right and wrong. They also develop a personal morality, however, they tend to view moral problems differently and this may impact on road use behaviour\textsuperscript{26}.

Peer groups are an important component of an adolescent’s social network. Peers can affect their actions, attitudes and feelings. Peer groups can also exert a powerful pressure to conform that can be disruptive during early adolescence\textsuperscript{26}.
4.3 Implications for motorcycle safety

Appropriate safety devices for a child passenger

In developing countries, motorcycles have been used as a popular mode of family transportation including child passengers. The study of motorcycle crash victims in Thailand found that the youngest passenger was one-year-old and the oldest was 71. The median passenger age was 19 years. Nine per cent of passengers were below 10 years, and about 44% were 11 to 20 years old.

About two-thirds of the motorcycle passengers claimed that they used motorcycles for basic transportation and 25% for recreation.

The majority of passengers involved in crashes (81.5%) were in the normal riding position, seated behind the motorcycle rider, at the time of the collision. There were 15 cases in which the second passenger was seated in front of the rider and 13 cases where the second passenger was seated behind the first passenger.

The same as with toddlers and preschoolers, children in this age group also need all available safety devices while pillion-riding on motorcycles which are appropriate for age and have been proved to decrease injuries. These include;

1. **Foot-pegs or footrest:** A child in the school-age group should be tall enough to put his/her feet on foot-pegs or footrests when required. Any passenger must always rest their feet firmly on the foot-pegs. The mounted seat is not necessary for this age group. If a child is too small to reach the foot-pegs, then he/she is too young to ride safely.

   A child should ride on the seat above the rear wheel. The position in front of the driver is not an appropriate place for her/him.

2. **Crash helmet:** A child pillion passenger must wear his/her own crash helmet which fits his/her head. Age-appropriate testing head forms that approximate a child’s head in various age groups, and a roll-off testing to ensure the helmet fits close enough to the age-specific child’s head are both required to be developed.

3. **Clothing:** A pair of pants is necessary because it can protect his/her leg in case of a crash unlike skirts or shorts.
Study of crashes involving motorcycles in Thailand: Lower-torso garment effectiveness

Lower-torso coverage was judged to have reduced or prevented injury in 54 of 242 cases of lower-torso contact (22%) to the rider, and in 16 of 100 passenger contacts as shown in the Table below:

<table>
<thead>
<tr>
<th>Coverage effect on injuries</th>
<th>Motorcycle rider</th>
<th>Motorcycle passenger</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency</td>
<td>Percent</td>
</tr>
<tr>
<td>No effect</td>
<td>188</td>
<td>52.4</td>
</tr>
<tr>
<td>Reduced injury</td>
<td>48</td>
<td>13.4</td>
</tr>
<tr>
<td>Prevented injury</td>
<td>6</td>
<td>1.7</td>
</tr>
<tr>
<td>No contact</td>
<td>117</td>
<td>32.6</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>359</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

Source: (Kasantikul V, 2001)

**Footwear:** Rubber or leather boots would prevent foot injuries in case of a crash or foot entrapment.

Study of crashes involving motorcycles in Thailand: Footwear effectiveness

Light sandals worn by both riders and passengers could neither prevent nor reduce any kinds of injury in about one-third of the riders and one-fourth of passengers. Evaluations of footwear effectiveness are shown in the Table below:

<table>
<thead>
<tr>
<th>Footwear effect on injuries</th>
<th>Motorcycle rider</th>
<th>Motorcycle passenger</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency</td>
<td>Percent</td>
</tr>
<tr>
<td>No effect</td>
<td>113</td>
<td>31.5</td>
</tr>
<tr>
<td>Reduced injury</td>
<td>5</td>
<td>1.4</td>
</tr>
<tr>
<td>Prevented injury</td>
<td>5</td>
<td>1.4</td>
</tr>
<tr>
<td>No contact</td>
<td>236</td>
<td>65.7</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>359</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

Source: (Kasantikul V, 2001) (No link with main body)

School-aged child as a driver

In developing countries, a child driving a motorcycle is common. The study of crashes involving motorcycles in Thailand found that the youngest injured driver was 12 years old. The median age was 25 years. About one-third of all drivers were under 21 years (112/359 cases)\(^4\). This study also revealed that the majority of crash-involved riders were self-taught (76%) followed by those who learned to ride the motorcycle from family and friends (22%).
Another case series study of 1088 injured motorcycle-riders from 12 provincial hospitals in Thailand found that 7.4% (80 cases) of those were children under 15 years\(^5\). Even though it is not permitted by Thai traffic law for children under 15 years to ride motorcycles, of all 1088 cases, 49% started to ride when they were 8-14 years old, 56% learned by themselves and 32.3% were taught by their parents.

<table>
<thead>
<tr>
<th>Rider’s age (years)</th>
<th>Crash</th>
<th>Total cases in crashes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Non-Fatal</td>
<td>Fatal</td>
</tr>
<tr>
<td>11–20</td>
<td>111</td>
<td>1</td>
</tr>
<tr>
<td>21–30</td>
<td>123</td>
<td>4</td>
</tr>
<tr>
<td>31–40</td>
<td>60</td>
<td>4</td>
</tr>
<tr>
<td>41–50</td>
<td>34</td>
<td>2</td>
</tr>
<tr>
<td>51–60</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td>&gt;60</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>347</strong></td>
<td><strong>12</strong></td>
</tr>
</tbody>
</table>

Source: (Kasantikul V, 2001) (No link with main body)

In developed countries this problem has also shown a rising trend. Bevan CA found that child motorcycle-related injuries requiring hospital treatment increased by about 10% per year in Victoria during 2000 to 2004, and most occurred off road, where there is no legislative framework to protect children. Most patients were male; roughly half were aged between 10 to 14 years, one-quarter were younger than 10 years, and some children were even younger than 5 years. Over the same period, the Royal Children’s Hospital Trauma Registry recorded 167 admissions — 17% for major injury, 41% requiring operation, 13% requiring admission to intensive care, and there were two deaths\(^7\).

**Riding a motorcycle: a complex task**

Riding a motorcycle, the same as driving a passenger car, is a complex task needing multiple skills, attention capacity, attitude to risks, and training complied with experience. The abilities to perform these complex skills improve greatly with age. The study of young car drivers in the United States shows that rates of crash involvement are high throughout the 16–24 years period. The crash rate for 17-year-olds is 50% higher than that for 18-year-olds, and the rate for 16-year-olds is two and a half times higher than that for 18-year-olds, even though the latter have a higher crash rate than any older age\(^5\).

It is very doubtful if children under 15 years, and certainly those under 12 years, have the developmental ability to control motorcycles or control their own
psychological strength, or perceive hazardous situations. If this is so why do many developing countries allow their children to use motorcycles?

There may be various factors related to adolescent development that make young drivers more crash-prone than older drivers. Such factors can be grouped as immaturity, and inexperience. Immaturity is a more important influential factor in serious crashes. Meanwhile lack of experience appears to play a role for minor crashes.

**Immaturity: physical and psychological immaturity**

Immaturity means the driver is too young to control high speed vehicles or motorcycles. “Too young” covers both physical and psychological development.

1. **Physical development: Motor, visual-motor perception and coordination, and cognitive elements**

Riding a motorcycle as a driver on a public street or off the road needs skill consisting of several different components, including motor, visual motor perception, coordination, and cognitive elements such as balancing, steering, distinguishing detail in moving object, making interception judgment about a moving object, matching estimates of an object’s location with a specific motor response, understanding task requirements, concentration, and decision making.

The abilities to perform these complex skills improve greatly with age. For example, dynamic visual acuity appears to mature in individuals up to 20 years of age. Figure-ground perception improvement continues till 17 or 18 years of age. There is evidence from MRI research that the prefrontal cortex (the area of the brain responsible for planning, impulse control, and executive decision-making) does not mature fully until the early to mid-20s. Although some legislators are using such brain-development research to support limits on teenaged driving, no scientific data have yet been published that link driving behaviour to neuroimaging findings.

2. **Psychological development: risk-taking behaviour**

The rate of crashes is not only related to motor and cognitive development, but also to psychological factors associated with children’s attitudes to risk or risk-taking behaviour. Compared with older drivers, younger people are more likely to drive at excessive speeds, follow too closely, violate traffic signs and signals, overtake other vehicles in a risky manner, allow too little time to merge, and fail to yield to pedestrians.

Most young people begin developing abstract, logical and systematic thinking around 12 years or older, or as adolescents. They develop knowledge of what is right and wrong in societal perspectives and also develop a personal morality. These developments could involve making decisions about using roads in a conforming and conservative way or in an unsafe or illegal way.
Peer groups also influence their thoughts, actions, attitudes and feelings, and can be a disruptive influence during early adolescence. It is normal for adolescents to take chances, succumb to peer pressure, overestimate their abilities, and have emotional mood swings. These behaviours expose the teenaged driver to greater risk of crashes. Males seem to be at especially high risk, possibly as a result of social norms and media images that equate fast driving and ability to perform difficult driving maneuvers as masculine.

In addition, experimenting with alcohol and recreational drugs can impair the teenager’s driving ability. Also, teenage drivers tend not to use their helmet and other safety gears. They also like to drive at night. Night-time driving is more difficult for anyone, especially the novice driver. However, teenagers tend to do disproportionately more driving at night, increasing their risk of a fatal crash, as compared to daytime driving.

**Inexperience: Hazard perception, and novice task**

Lack of experience means the teenaged driver is less able to detect and respond to traffic hazards. Compared with experienced drivers, the novice adolescent driver is not only less proficient in detecting and responding to hazards, but also to be susceptible to distraction by irrelevant stimuli. Younger children have difficulty sustaining a state of concentration in many tasks. (Plude, Enns, & Brodeur, 1994; Sandels, 1970). A young, novice driver, who performs a novice task with conscious control, requires a large proportion of cognitive processing capacity. Such increasing task load leads to deterioration in performance. Experienced older drivers perform driving as an automatic task which tends to be quick and efficient and requires little cognitive processing. In a study of young cyclists, several researchers have argued that limitations in attention capacity play a key role in causing traffic crashes.

**Driving education and training programmes**

The findings of a study in Thailand clearly showed a major problem regarding the lack of appropriate training for motorcycle riders. All too often, training by family or friends amounts to instruction in how to operate the throttle, clutch, gear shift and brakes, but very little or no training on defensive riding strategies, proper braking, collision avoidance skills, etc. The data collected in this study clearly show that most riders lack proper training in defensive riding strategies and crash prevention. The lack of formal training also suggests that many riders have no appreciation of proper protective equipment and they do not understand the importance of proper collision avoidance action.

Driving education and training courses have proved their effectiveness in decreasing crash risk for novice drivers. Studies have showed that the risk of having a crash during the learner-permit stage is low, because the teenager is supervised and is generally not driving in high-risk conditions. In contrast, the highest crash rate is seen during the first month after the teenager gets his or her license (120 crashes per 10 000 drivers). After the first month, the crash rate decreases rather quickly over the next five months (70 crashes per 10 000 drivers) and then shows a slower decline.
for the next 18 months (50 crashes per 10 000 drivers). Because rapid improvement is seen over such a short time period, driver experience appears to be a very important factor in decreasing crash rates.

The mechanisms of decreasing crash rates in young novice drivers by driving education and training programmes include not only increasing driving experience but also by delaying the onset of driving to a more mature age. Other mechanisms are keeping people out of high-risk driving situations while they learn and accumulate experience, and increasing sensitivity in detecting impaired drivers, such as those with severe Attention-Deficit/Hyperactivity Disorder (ADHD) and not issuing a driving license to them.

### Attention-Deficit/Hyperactivity Disorder

Teenage drivers with attention-deficit/hyperactivity disorder (ADHD) are 2 to 4 times more likely to be injured in a motor vehicle crash than are their peers without ADHD. They are also more likely to have repeat traffic citations and to have their licences suspended or revoked. Driving performance of teenagers with ADHD seems to improve with psycho-stimulant medication, primarily because of decreased errors of inattentiveness. Compared with 3-times-a-day doses of methylphenidate, longer-acting, controlled-release medication may result in better driving throughout the day and, particularly, during the evening.

Source: Committee on Injury, Violence, and Poison Prevention, Committee on Adolescence, American Academy of Paediatrics, 2006

The mechanisms of decreasing crash rates in young novice drivers by driving education and training programmes

1. **Gaining knowledge and skill for safe driving and hazard perception**

The learning objectives of the driving education and training curriculum should be to gain knowledge and skill for safe driving, and hazard perception. There is a 15-hour “Safety Riding Training Programme” in Thailand and in many other countries developed by a motorcycle industry which caters to all ages to help drivers get a licence.

- Knowledge-in-class instruction (5 hours): Laws and regulations, motorcycle check-up, basic riding structure and safe riding, hazard perception test (riding simulator), principles of riding techniques.

- Riding skill (10 hours): Preparation, static riding control, dynamic riding control, starting and stopping, shifting gear, speed control, breaking (normal stop/quick stop), curve course, slalom course, balance: rough surface, narrow board, uphill/bridge, intersections, traffic law, summary of safe riding. (http://www.aphonda.co.th/aphonda-csc/aph-csr-customer-care.html.)
Though some research studies reveal a reduction in the number of traffic offences, crashes, injuries and deaths in novice drivers, due to such training, (Bill Heimer, 1996, Noordizij 2001, Patarawan, Atiporn, Pomthip and Paibul 2013) there is, however, conflicting evidence.

The Cochrane review in 2010 examined the effectiveness of motorcycle rider training on reduction of traffic offences, traffic crash involvement, injuries and deaths of motorcycle riders. The findings suggested that mandatory pre-license training may be an impediment to completing a motorcycle licensing process, possibly indirectly reducing crashes through a reduction in exposure. It is not clear if training (or of what type) reduces the risk of crashes, injuries or offences in motorcyclists, and therefore the best rider-training practice can not be recommended. As some type of training for riders is likely to be necessary to teach motorcyclists to ride a motorcycle safely, rigorous research is needed. (Kardamanis K, Martinink A, Ivers RQ, Stevenson, Mr Thisththwaittek 2010).

While pre-license motorcycle driver training has a conflicting research result in terms of overall benefit, the Cochrane review has stated that there is no evidence that driver education in schools reduces teenage involvement in road traffic crashes. Moreover, school-based driver training encourages earlier licensing and may lead to a modest but potentially important increase in the number of teenagers involved in road traffic crashes (Robert IG, Kwan I 2008). It needs to be stressed in all countries that driving-training in standard schools, should not be allowed. Training should be provided only at driving schools.

Supervised driving for the first highest-risk period

The highest-risk for beginners comes immediately on licensure, starting with the first month. Data for 16-year-old novice drivers in Nova Scotia (prior to graduated licensing) indicate that the crash rate during the first month of licensure was 241 per 10 000 compared with 107 per 10 000 at 9–10 months. Afterwards, the crash rate declined more gradually through 24 months. During the first months of driving, when crash rates are highest, unsupervised driving in situations of highest risk should be restricted.

Limitation for driving in high-risk situations

The study on car driving by young drivers found that the two high-risk situations addressed in graduated systems are late night driving and driving with passengers. The driving task is more difficult when it is dark. Driving at night is associated with increased risk of serious crashes for all ages. However, the night-time risk is much higher for young drivers compared with older drivers.

At night, risky driving by young drivers is generally associated with recreational activities. Fatigue and alcohol also are more likely to contribute to crashes during nighttime hours. The fatal crash risk for 16–17-year-olds during the 9 pm - 5.59 am period is about three times the daytime risk.
Carrying a passenger is also a complex task, requiring more driving experience, and maturity. Also young drivers, who are younger than 18 years and are classified as “children” by law, should not be the person who has to take responsibility for the adults’ or children passengers’ lives. In addition, a heightened crash risk has been recognized when teenagers drive with their peers. This situation can distract the novice driver who needs to pay close attention to the driving task. Inducements to take risks and show off also may be created.

**Delaying onset of driving till driver is more mature**

In developed countries a “Graduated Driver Licensing System (GDL system)” has been established aimed to decrease the burden of injuries among young drivers. The GDL system has three stages: a learner’s permit, an intermediate or provisional stage, and a regular driver’s license. Each stage has specific components, restrictions, and minimum time requirements. To graduate to the next stage, the novice must spend the required time at the lower stage, acquire and demonstrate proficiency in driving skills, and not incur a driving violation for a defined period.

The provisional stage, with its restrictions, is designed to give the novice a chance to gain extensive driving experience under low-risk conditions. A Cochrane Database review of 13 studies evaluating 12 GDL programmes in the US, Canada, New Zealand, and Australia. Among 16-year-old drivers, the median decrease overall crash rate during the first year was 31% crashes resulting in injuries median 28% range (4%-43%), and crashes resulting in hospitalization (35%).

It is unlikely that safer driving by young teenagers is the main reason for decreased crash rates seen with GDL. Between 1993 and 2003, the percentage of 16-year-olds who were licensed decreased by 26%, and there was a 13% decrease for 17-year-olds and a 5% decrease for 18-year-olds. Over the same 10-year period, the likelihood that a 16-year-old license holder would be involved in a fatal crash remained unchanged (73–74 crashes per 100 000 license holders). Fatal crash rates per licensed driver also remained unchanged for older teenaged drivers.

In addition to delay in licensure, it appears that the three provisions of GDL responsible for the most benefit are (1) limits on night-time driving, (2) restrictions on the number of passengers during the intermediate stage, and (3) requirements that novice drivers remain crash-and violation-free for a certain period of time before advancing to the next level.

### 4.4 Recommendations

**Maximal safety for school-age children to middle adolescents**

1. Never allow children under 15 years to drive a motorcycle. This needs both law enforcement and also social agreement support. The dimension of law enforcement support and social agreement must extend from child behaviour, parental supervision, community responsibility through organization and corporate responsibility and practices.
(2) Children whose feet are not long enough to reach the foot-rest of the motorcycle must not be transported on a motorcycle.

(3) For maximal safety of pillion passengers, children must use all available protective gear when being carried on a motorcycle including the following. (This needs both law enforcement support and also social agreement.)

(a) Motorcycle crash helmet: A child pillion passenger from 2 years and older must wear his/her own standardized motorcycle crash helmet which fits his/her head.

(b) Clothing: A pair of pants is necessary because it can protect his/her leg in case of a crash, than skirts or shorts.

(c) Footwear: Rubber or leather boots would prevent foot injuries in case of a crash or foot entrapment.

(4) Only motorcyclists who have passed an additional motorcycle test for carrying a child passenger can carry children under 12 years. This needs law enforcement support.

(5) Consider postponing the legal permissible age for motorcycle driving license to 18 years, the same as cars.

**Possible options for minimally acceptable safety**

(1) Children less than 2 years should not be transported on motorcycles.

(2) Children 2 years or older, whose feet cannot reach the foot-rest must be transported on a motorcycle with a well-designed child seat for a motorcycle passenger and must wear standard motorcycle helmets for safety.

(3) Design a new driving license permission system for young motorcyclists and conduct research on its efficacy and effectiveness.

The new driving license permission system must ensure that the novice young drivers are:

- supervised during the first highest-risk period (especially in the first few months of driving),
- limited for high-risk situations (no driving on highway, no passenger, nighttime curfew),
- increase the legal age to obtain licence.

The supervision and limitation criteria should be more stringent for younger age groups, such as more serious criteria in the age group of 15 to 17 years than 18 to 20 years.
References


(23) Snyder RG, Schneider LW, Owings CL. Anthropometry of infants, children and youths for product safety design. Michigan: Highway Safety Research Institute, the University of Michigan, 1977.


Road safety management needs to be strengthened with vision, direction, coordination, management, funding, interventions, advocacy, monitoring and evaluation. Many countries need to be strengthened with sustainable, cost effective and scientific policies. The five pillars of the Decade of Action on Road Safety 2011-2020 including safe roads, safe vehicles, people, post-crash care and efficient management need to be implemented in all Member States. Information through good research is an important building block for all these activities with strong, robust and quality data that can drive activities in future. The report provides an overview of the road safety information systems in the South-East Asia Region, the current knowledge scenario on road safety in the region, priorities for research, research methods and recommendations.