Safety of Children as Motorcycle Passengers

Dinesh Mohan [a]

[a,] *Transport Research and Injury Prevention Programme, Indian Institute of Technology Delhi, New Delhi 110016, India.*
[a] *E-mail: dmohan@iitd.ac.in*

Abstract: This study reports the results of a literature review of the involvement of children in motorcycle crashes with special reference to the South East Asia Region and the possibilities of developing an appropriate helmet design standard for children The results suggest that the involvement of young children, especially under 4 years old is very low and not enough biomechanical knowledge is available for a consensus on helmet standards.

Keywords: Children, Asia, Motorcycles, Helmet, Head Injury, Safety

1. INTRODUCTION

Injuries account for an estimated 1.4 million deaths and 54 million disability-adjusted life-years (DALYs) in South-East Asia Region (SEAR) of the World Health Organization. This Region alone accounts for 27 per cent of the global mortality and 31 per cent of the global burden of injuries. Road traffic injuries alone were ranked as the primary cause of disease among children in the age group of 5 to 14 years, and the third leading cause among people between the age of 15 to 29 years in 2000. Injuries are a leading cause of death in the working age group and in India the years of life lost (million) due to injury for individuals older than 4 years, is greater than that for neoplasms, cardiovascular causes and infectious and parasitic diseases (Peden, M. et al., 2004). It is an irony that thousands of children saved from nutritional and infectious diseases were killed or maimed by injuries. Over a period, such a heavy burden can have a major impact on the quality of life and economy of nations. Injuries can occur everywhere, on the road, at home, at work, at public places or during recreational and leisure time activities.

The details of distribution by road user category and age are not available for any country in the SEAR. A literature search of published articles done by Hyder et al (2006) on road traffic injuries among children and adolescents in urban South Asia, found that age distributions of victims by road user type are not available. They report that that the majority of injuries occurred in males (67–80%) and the most frequent age group injured was between ages 0 and 9 representing 40% of cases. Among those injured a majority were pedestrians. However, it is observed that it is a relatively common practice for children to be carried as passengers on motorcycles as in the SEAR, but here is little information available regarding their involvement in crashes and the injuries sustained by them. In this study we report the results of a literature review done to elicit information on motorized two-wheeler (MTW) crashes in general and injuries sustained by MTW children passengers in particular. This has been done to prepare a report on the safety of children transported on motorcycles with special reference to the South-East Asia Region because motorcycle use is a very significant part of traffic in these countries.

2. METHOD

1. The road traffic safety situation in the SEAR was reviewed to understand the gravity of public health burden of road traffic injuries (RTI) in the region.
2. Significant scientific papers dealing with motorcycle crashes published worldwide were scanned to get an overall view of children's involvement in motorcycle crashes. The papers published were obtained by using Scopus using the 'Articles and Conference Papers' option. Children were defined as those below 14 years old with special reference to the age group 5-9 years.
3. Those papers dealing specifically with motorcycle associated RTI involving children were reviewed in detail to assess the magnitude of the problem, trends and associated issues.
4. Scientific reports and publications dealing with biomechanics of paediatric injury with special reference to head injuries and helmet design were reviewed to understand the present situation and possibilities for implementing countermeasures in the future.

3. RESULTS

3.1 SEAR Country Studies

3.1.2 Bangladesh

Motorized two and three wheelers occupy the largest share of the vehicle population in Bangladesh (60%), followed by cars/jeeps (33%) (W.H.O., 2013). This indicates that MTW riders would form a significant proportion of the fatalities. Table 1 gives the age distribution of road traffic fatalities in Bangladesh.

Table 1. Age distribution of road traffic crash victims in Bangladesh (Source: Key road safety facts in Bangladesh, 2004)

Age, years	0 - 5	6 - 10	11 - 15	16-45	>45
Proportion, percent	4	10	6	59	20

A road accident costing study estimated the casualties by road user type in Bangladesh and the results show that motorcycle occupants constituted only 3 percent of the fatalities and 10% of the serious injuries (Murray, C. J. L. et al., 2012). The age specific data shows that children 0-10 years were only 14% of the road crash victims and majority of these were pedestrians. If we combine these two statistics, it is possible that children under 10 years may be less than 2% of the total road crash victims in Bangladesh.

3.1.2 India

Official road traffic crash data do not include fatalities by road user category in India. Such data are only available from a few cities and research studies done on selected locations on rural highways. Table 2 shows traffic fatalities by category of road users in Delhi (capital city of India) and selected locations on national highways (Mohan, D. et al., 2009, Tiwari, G. et al., 2000). These data show that MTW occupants constituted 21 percent in Delhi and 24 percent on rural highways.

Table 2. Traffic fatalities by category of road user in Delhi and selected locations on national highways .

Type of road user	Location (percent)	
	Delhi 2001-2005	Highways* 1999
Truck	2	14
Bus	5	3
Car	3	15
Three-wheeled scooter taxi	3	-
Motorized two-wheeler	21	24
Human and animal powered vehicle	3	1
Bicycle	10	11
Pedestrian	53	32
Total	*100*	*100*

The data are for 11 selected locations, and thus might not be representative for the entire country. (Tractor fatalities are not included).

According to official statistics available children age 14 years and younger comprise only 6% of the fatalities, though their share in the population is 32% (NCRB, 2012). This might mean that children less than 14 years could comprise less than 6% of the fatalities on motorcycles as a large proportion of the child victims are pedestrians. Another way of estimating the proportion of children involved in MTW traffic is to estimate their presence in medical treatment in hospitals. A review of the medical records of 2,748 patients treated for maxillofacial injuries at Sri Ramachandra Medical and Dental College and Hospital in Chennai between January 1999 and December 2005 showed that 1,332 (42%) had soft tissue injuries, 1,176 (37%) had mid face fractures, and 512 (16%) had mandibular fractures. Of these patients, MTW riders comprised 62%, and children (0-10 years) only 3% of the total respectively (Subhashraj, K. et al., 2007). Since MTW fatalities comprise about 20-25% of the total it is likely that children under 14 constitute less than 2-3% of MTW rider fatalities in India as pedestrian fatalities form the major bulk of the total. This is supported by a study from Delhi in which 3% of the MTW victims hospitalized were in the 0-14 age group (Mishra, B. K. et al., 1984).

3.1.3 Indonesia

According to statistics available MTW constitute a vast majority (74%) of road traffic crashes in Indonesia and Table 3 the age distribution of fatalities (Parasnis, R., 2005). The proportion of children involved is about 3% and their number below 10 years would be less than 2% (Table 7). However, the proportion of reported motorcycle RTI in Indonesia is much higher than that in India or Bangladesh

3.1.4 Sri Lanka

MTW involvement in fatal crashes in Sri Lanka was 20%, less than that of pedestrians but more than cars, and children under 10 years old comprised 9% of all the fatalities (Kumrage,

A. S. et al., 2003).

Table 3. Age distribution of road fatalities in Indonesia

Age	Death	%
5-15	955	3.13
16-20	7928	26.02
21-30	10185	33.43
31-40	7008	23.00
41-50	3307	10.86
51-60	1082	3.55

3.1.5 Thailand

Table 4. Road traffic fatalities in Thailand

Year	Number of fatalities	Population	No.of vehicles	Death rates /10^5 pop
1984	2908	50583105	-	5.75
2003	14446	63079765	26706357	22.96

Source: Thailand Road Safety Action Plan,2004

Table 5. Age distribution of traffic fatalities in Thailand

Age (yrs)	Fatalities percent
<5	1.6
5-9	1.8
10-14	2.7
15-40	60.4
>40	33.5

Table 4 shows the statistics of road traffic fatalities in Thailand. Head injuries are a major cause of death and disability related to RTI, and 70-75% of traffic crashes in Thailand involve motorcycles (Phuenpathom, N. et al., 2000). According to Phuenpathom et al. most patients were aged between 11 and 40. A study based on data derived from a trauma registry at the Khon Kaen Regional Hospital in the northeast Thailand showed that children 0-9 comprised 1.8 to 3.9 % of the MTW patients treated at the hospital (Ichikawa, M. et al., 2003). This proportion is similar to the total RTI fatalities for this age group as shown in Table 5 (Krishna, K., 2012).

In the SEAR countries road traffic injuries of MTW riders comprise a reported 25% to 70% of the total victims. Of these victims, children less than 10 years appear to be 2-3% of the MTW victims.

3.2 Evidence on Children MTW Injuries in Countries Other Than SEAR

3.2.1 Asia and Africa

A study of 1160 cases of MTW riders suffering craniofacial injuries taking treatment in 12 hospitals in Taipei showed that children 0-15 years old comprised 2% of the total victims (Lee, M. C. et al., 1995).

A study on the effect of the Taiwan motorcycle helmet use law on head injuries showed that the proportion of children 0-9 years involved in MTW crashes remained relatively unchanged at 1.0-1.2% of the total and that there were higher rates of head injuries among those aged 20 to 29 years and 70 years and older than among those in the rest of the population (Chiu, W. T. et al., 2000).

A study of 314 cases of mandibular fractures in two urban centres in Nigeria showed that RTI were the leading cause (67.5%) and the commonest site of fracture was the body of the mandible. The age group 0-10 comprised 1.6% of the patients (Adeyemo, W. L. et al., 2008).

The commonest mechanisms of paediatric injuries in Jos in Nigeria were RTI (41%). Of those injuries resulting from RTI 87% were pedestrian related. Even though children ride as passengers on MTWs, their proportion was very low (Gukas, I. D. et al., 2006).

3.2.2 Australia, Europe and USA

A comprehensive prospective injury registration was carried out at the Central Hospital and Emergency Clinic in Rogaland county in Norway 1990 to 1996 among a defined population aged 0–24 years and incidence of traffic injury by the type of transport of the victim was analysed. Moped injuries represented 9% of all (hospitalized and non-hospitalized) traffic related injuries and brain concussion was suffered by 8% of the population. Children under 10 years were a small proportion of the population (Kopjar, B., 1999).

A study of severe paediatric motorbike-related injuries in Ohio showed that unhelmeted riders had significantly higher injury severity scores than helmeted ones (11.5 vs 8.4). Of all injuries, the most commonly injured body parts were lower extremity (23.4%),head (22.2%), abdomen/pelvis (13.4%), upper extremity(12.4%), and face (11.8%). The 0-9 year age group comprised only 19% of the 0-25 sample (Pomerantz, W. J. et al., 2005).

A study of the incidence and risk factors of severe traumatic brain injury resulting from road accidents in the Rhone region of France showed that children 0-14 had an incidence rate of ~1 per 100,000 persons as compared to 10-15 for the 15-34 year age group. The odds ratio for severe injury was lower for the youngest age group than older persons (Javouhey, E. et al., 2006).

- A study of 3163 children aged 16 years and younger with motorcycle-related injuries who attended Victorian (Australia) emergency departments in a 4-year period showed that most were off road riders and those 0-9 year sold were 22% of the total (Bevan, C. A. et al., 2008).

In all countries, the use of helmets by MTW riders reduces head injury rates substantially. Children do not constitute a significant proportion of motorcycle riders in most countries, but even where they do their involvement in serious injury crashes is generally less than 2-3% of the total victims.

3.3 Children's Helmets

The biomechanics of safety for children has been mainly evaluated using child dummies in the field of car crash safety. However, dummies have limited biofidelity and don't offer detailed injury mechanism. A project called CHILD (standing for Child Injury LED Design) was started in Europe to increase the knowledge in areas specifically regarding children, and for application in child restraint systems design, testing and regulation. The CHILD project's objectives were to enable the investigation of injury mechanisms and tolerances for different ages of children and the establishment of injury criteria and corresponding risk curves:

- To determine the physical parameters corresponding to various child injury mechanisms,
- To prescribe limits under which severe injuries can be avoided.
- To develop new test procedures for determining the effectiveness of child restraint systems for cars, using biofidelic dummies fitted with reliable instrumentation.

However, the efforts are still at the research stage and all helmet standards for children are still using HIC and acceleration values based on work done more than a decade ago.

A conference on Review of Pediatric Head and Neck Injury: Implications for Helmet Standards was held in Philadelphia (USA) at the Children's Hospital of Philadelphia, on March 31, 2003. The proceedings of this conference include one of the better summaries on the subject of children's safety and helmet standards. A summary of their discussion is given below (Arbogast, K. B. et al., 2003)

- Studies suggest that older children may be more prone to focal impact damage than younger children, and that helmet standards for older children may need to be different than that for younger children or for adults. More research needs to be done to ensure that animal findings are relevant to children.
- Children are more likely than adults to suffer severe consequences from concussions. These consequences include second impact syndrome, which is often fatal or results in learning impairment.
- By age 4, 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.
- Facial structure of children is vastly different from that 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.
- The brain and skull of a child have different biomechanical properties than adults'. The greater water content in a child's brain makes it stiffer than that of an adult, noted Dr. Margulies. In addition, her research has found that skull stiffness increases with age. Based on her studies in pigs and young children, she concluded that the infant's less stiff skull properties are likely to increase the magnitude of intracranial strains that occur during head injuries involving impact. But she noted that whether that is also true for older children is not known.
- The neck, in contrast to the head, is only 75% of adult size at age 4 and 85% of adult size by age 12, according to UMTRI data. The head-volume to neck-area ratio at age 12 is still greater than what is seen for adults. In addition, the neck muscles of children are weaker than adults, and children's neck ligaments can stretch more. Children bend their necks at higher vertebral levels than adults, and their vertebral joints are flatter so

they don’t restrict forward motion as much as in adults. Children’s spinal columns also have more cartilage and less bone.

- Although children younger than 6 years of age participate in motorsports, many of the speakers and participants argued for not developing a helmet standard for such young children. Based on the discussion at the conference, Snell participants decided afterwards to focus on developing a paediatric motorsports helmet standard for children 6 years and older. For that standard, it was decided by conference participants that there was not enough information on how children differ from adults to justify changing the 300g acceleration limit that is currently the standard for adult motorcycle helmets.
- 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, therefore, 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 the feasibility of this, especially whether the use of such materials is likely to result in a helmet that is too expensive for the average consumer. Another problem with increasing the padding thickness in helmets is that the thicker the padding, the greater the likelihood of neck injuries, as modeling studies of adult head and neck injuries at Duke University suggest. Their studies conclude the presence of head constraint can pocket the head and decrease the ability of the neck to escape the moving torso, thereby predisposing the neck to injury. Thus, injury prevention devices and environments (helmets, car interiors, crash mats, etc.) while providing protection to the head should be designed to consider head and neck motion. Dr.Michael Prange stressed that helmets be designed to facilitate head an d neck motion and cautioned that engineers be wary of adding thick padding to their helmet designs.
- Most of the discussion centred on how to lower the size and weight of a helmet for paediatric motorsports without compromising the degree of protection the helmet gives from brain injury. Other parameters such as liner thickness, liner density, and shell material can influence the relationship between helmet mass and head injury protection. The typical motorcycle helmet mass is 1.5kg and the typical bicycle helmet mass is 0.3kg. User fatigue and acceptance limit the weight of helmets sold in the marketplace.

3.3.1 Summary of issues concerning helmet design for children

A great deal of biomechanical work has been done on the issue of head injury tolerance and helmet design in general, and with respect to children helmets in particular. However, the measures being used to judge impact severity only include peak/average acceleration and/or the Head Injury Criterion. The values being used for children are similar to those for adults, and there is no agreement on changes in these values at present. Some standards are proposing lower headform masses for children helmets, but others do not. It appears that current bicycle helmets for children do provide protection to children and would do so in motorcycle crashes also except to for facial injuries. However, it is accepted that helmets for children should be much lighter and have different dimensions than adult helmets, especially so that they do not rest on the shoulders. On most major issues there is still a great deal of disagreement. We do not expect any major change in the current state of the art for the next few years.

4. CONCLUSIONS

1. The proportion of children involved in fatal motorcycles crashes as passengers seems to be less than 1-3% of all motorcycle fatalities in most countries around the world.

2. Bicycle helmets have been shown to be effective in reducing injury among children in road traffic crashes. Therefore, these helmets would also be effective in reducing severity of head injuries for children on motorcycles.

3. There seems to be no evidence that children, especially ages 3-12 years, differ significantly from adults in impact patterns in motorcycle crashes either in the probability. Therefore, there is no reason to believe that they will suffer more or less head, neck or other injuries as compared with adults. However, since it is accepted that children are more fragile than children, their presence on motorcycles cannot be encouraged.

4. As motorcycle passengers, the most effective safety measure during a crash is the motorcycle helmet. Except for the head, there are no very effective safety measures for other parts of the body for adults or children.

5. Motorsport helmet standards as being developed by Snell Foundation may be a good base to think of standards for paediatric motorcycle helmets.

6. No consensus is likely to emerge in the near future for changing the indices used for helmet impact severity standards.

7. In the near future there is no likelihood of the development of a helmet for children less than 3 years old based on scientific criteria that will be acceptable to a majority of experts. It may be impractical to develop a helmet for these children as their presence among motorcycle crash victims is almost negligible.

8. There are no easy or economical ways to protect any other part of the body except the head for motorcycle riders.

9. Current knowledge and standards should form the basis for developing a consensus for paediatric motorcycle helmets for the SEAR countries and a committee of experts may be formed to do the same.

10. Research for developing guidelines for optimisation of motorcycle helmet shell and liner properties for paediatric helmets must be encouraged and funded in two or three centres.

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