

Traffic Accidents Involving Child Passengers Travelling on Powered Two-Wheel Vehicles

Eloi BOIX¹, Adrià FERRER¹, Juan José ALBA², Sergi FERRIS³, José A. AZPEITIA⁴

¹*Applus+ IDIADA, L'Albornar – PO Box 20, E-43710 Santa Oliva, Tarragona (SPAIN)*

²*Universidad de ZaragozaC/Mariano Esquillor s/n, E-50018 Zaragoza (SPAIN)*

³*SafeDsign, Avinguda Catalunya 6, E-43830 Torrededembarra, Tarragona (SPAIN)*

⁴*Babyauto, C/Amezti 3 bajo, E-20800 Zarautz, Guipuzcoa (SPAIN)*

Email: eboix@idiada.com, jjalba@unizar.es, sergiferris@safedesign.eu, josean@babyauto.com

Abstract: Over recent years motorcycle sales have increased significantly. At the same time, they are by far the most dangerous means of transport. Two groups (children and elderly people) are especially vulnerable due to their physical weakness with regard to the impact, reflexes and reaction to the accident, etc. The European Commission is not aware of any specific national standard in the Member States, apart from requiring helmet use by motorcycle drivers and passengers.

The KID-SHELL project aims to design and develop a protection system addressed to children who are travelling as Powered Two-Wheel passengers. A study to analyze the state of the art of the main characteristics of the motorcycles traffic accidents where passengers between 6 and 13 years old are involved was carried out. Taking into account the traffic accidents data, a test protocol based on biomechanical references was defined in the second phase.

Keywords: Motorcycle, Children, Protection system, Accidents, Test Protocol

1 Introduction

Over recent years motorcycle sales have increased significantly. The number of motorcycles throughout the European Union increased from 16 million to more than 22 million between 2001 and 2008 ^[1].

Taking all powered two-wheeled motor vehicles (PTW's) into account, in 2008 approximately 33 million vehicles were registered. At the same time, motorcycles are by far the most dangerous means of transport. In 2008, according to CARE database 5,126 fatalities amongst motorcyclists (EU-24), accounted for 14% of the total 37,234 road traffic fatalities in these 24 Member States. According to CARE, two-wheeled motor vehicles account for just 2% of all road vehicles, underlining the potential risk for motorcyclists on Europe's roads.

Among PTW users, two groups (children and elderly people) are especially vulnerable due to their physical weakness with regard to the impact, reflexes and reaction to the accident. 36 children under 14 years old on PTW's were killed on Europe's roads in 2010 ^[2].

The European Commission is not aware of any specific national standard in the Member States, apart from requiring helmet use by motorcycle drivers and passengers.

2 PTW Accidents

In 2011, 83,027 traffic accidents with casualties were reported in Spain with 2,060 fatalities, 11,347 severe injuries and 104,280 slight injuries. These figures suppose a decrease of 16.8% of fatalities and 5.4% of severe injuries with respect to the previous year ^[3].

The same year, 19,093 motorcycles and 8,527 mopeds were being driven in Spain. From those, 348 motorcycles and 71 mopeds were involved in fatal accidents.

2.1 Mopeds

In urban accidents involving mopeds, 12,87% of the casualties (7,284) were passengers. 10,82% were fatalities, 9,93% were severe injuries and 13,34% were slight injuries.

The youngest injured people due to an urban accident were between 6 and 9 years old: three slightly injured children. 1 fatality, 7 severely injured and 12 slightly injured were between 10 and 14 years old.

Statistics show the youngest casualty occurred at 1 year old (one case), but also 2 cases between 2 and 5 years old and 9 slight injuries between 6 and 9 years old. 43 slight injuries and 3 severe injuries occurred between 10 and 14 years old. The most usual moped accident is a collision against other vehicle in urban environment (65,18%).

2.2 Motorcycles

In Spain, on rural roads, 8,71% of the severely injured and 11,39% of the slightly injured were passengers. In urban roads, 9,09% of the casualties were motorcycle passengers (13,584), 4,12% of them were fatalities, 7,09% severe injuries and 9,34% slight injuries.

One casualty occurred between 2 and 5 years old on rural roads. However, 5 casualties (one severely injured) occurred between 6 and 9 years old and 10 casualties (one severely injured) occurred between 10 and 14 years old. Children represent between 6% and 10% of motorcycle passengers in the urban environment in Spain. Child casualties in urban areas show alarming statistics: 2 severely and 1 slightly injured between 0 and 1 year old and 23 injured between 6 and 9 years old.

According to statistics, collisions against other vehicles are the most usual accidents in urban accidents. On the other hand, rollovers and run-off-road collisions are the most frequent on rural roads ^[4].

3 Aspects to be considered in a PTW accident

Although the aspects to be considered in the event of an accident are not always clearly identified, some concepts can change the consequence of each accident and should be taken into account:

- Recognition of accident scenario
- Actions of the passenger
- Kind of accident

3.1 Recognition of accident scenario

The rider should be able to determine the risk of falling off or crashing against another vehicle and the probabilities that given scenarios could occur by positioning himself/herself in a defensive way in order to protect his/her body.

However, in most crashes, the passenger does not perceive the danger in the very first moments of the accident. This situation is of particular concern if the passenger is a child due to their smaller height.

3.2 Actions of the passenger

The reaction of the passenger in the event of a PTW accident may change the severity of the injuries of the PTW occupants. The most frequent situations in which the passenger is involved are as follows:

- In some accidents, the passenger uses the body of the driver as a shield to be protected.
- The passenger is ejected and his/her initial path is guided by the back of the driver, which acts as a springboard.
- The driver partially impacts the passenger while they are sliding after they have fallen down.

- The passenger could partially impact the driver and injure him/her.
- The passenger could change the path of the driver.

3.3 Kind of accident

One of the most important issues in the event of a PTW accident is whether the occupants fell before the first impact and whether they had been positioned in a defensive way or started to decelerate due to the friction against the ground. To analyze the injury mechanism, the fall before the impact needs to be considered.

The event of a PTW accident is divided in 3 phases:

- Conflict situation: the action which causes the accident.
- Initial contact: the PTW occupants slide on the ground with or without subsequent collision.
- Engagement and disengagement, sliding or projections between the occupants or the occupants and the motorcycle.

The road and mainly the environment conditions are decisive in most PTW accidents. The obstacles that the occupants impact in the path and their protection elements (helmet, gloves, etc.) should also be taken into account.

On the other hand, the main direction and the force of the impact are used to assess the severity of both the accident and the injuries of the occupants. The most severe PTW accident is the frontal impact against another vehicle because the energies of both vehicles are added. The most common and severe PTW accidents are as follows:

- Leaving the road: Normally located in curved paths. Over-confidence in adherence, inadequate speed, lack of uniformity and regularity of the road surface, gaps in the transverse coefficient of friction of the road are usually the main causes. Four possible scenarios may be generated in straight paths:
 - Maneuver to avoid a collision
 - Distraction
 - Glare
 - Drowsiness
- Frontal impact: Three scenarios may cause this kind of impact:
 - Invasion of the opposite direction lane
 - Loss of control of the motorcycle and invasion of the opposite direction lane
 - Overtaking maneuvers
- Side impact: It mainly happens in joining lanes or in T-junctions or crossroads.
- Collision against an obstacle: The driver loses the control of the motorcycle after avoiding the obstacle or he/she was not able to avoid the obstacle.
- Rear-end collision: Different speeds between 2 vehicles which were driving in the same direction. This scenario happens particularly in traffic lights zones in the amber phase and with stop and yield traffic signals.
- Side scraping collision: It normally happens in the event of a motorcycle overtaking.
- Road accident without damage in the PTW vehicle: The passenger normally falls because of the acceleration because he/she is not gripping enough.

4 The problem of children as motorcycle passengers

In Spain, people older than 12 years old can travel (but not drive) by motorcycle if fulfil the conditions as follows:

- They use a certified helmet.
- They travel astride.
- The feet are located on the side footrests.
- They seat on the corresponding seat behind the driver.

People older than 7 years old can travel (but not drive) by motorcycle if fulfil the conditions as follows:

- The motorcycle is driven by his/her father, mother, guardian or adults who authorize them.
- They use a certified helmet.
- The points of the previous paragraph are fulfilled.

Weakness: The use of a certified helmet of child size is not mandatory for children older than 12 years, so they can use any type of certified helmet. Moreover, the use of another active or passive safety element by children is not mandatory either.

4.1 General aspects of child arm strength

From the physiological point of view, strength is understood to be the ability a muscle has to produce tension when activated.

The passenger's ability to hold on to the motorcycle supports to coordinate and equilibrate the action of the forces associated with moving is of great importance. The analysis of the needs must consider the following:

1. Strength is developed throughout childhood.
2. Muscle contraction speed in children is lower than in adults.
3. Child bone structure is more elastic due to lower calcification causing a lower resistance to pressure and shear forces.

As a general rule, motorcycle hanging supports are allocated in such a way that they are ergonomically more efficient for deceleration than for accelerating manoeuvres. This is often balanced by the fitting of a back rest as shown in Figure 1 below.



Figure 1. Motorcycle with hanging support and backrest.

As can be observed in Figure 3, the child has little options to increase the balance on the motorcycle and poor equipment. This picture is a perfect example of the non-usage of the hanging support (1) and the currently used method (2).



Figure 2. Motorcycle lacking support for passenger balance

Figure 2 shows an example of the lack of a support structure for the passenger. In this case, deceleration can cause impact against the rider and acceleration falling from the vehicle. However, the foot support may compensate the problem in the acceleration cases.



Figure 3. Example of non-usage of the provided hanging systems

4.2 Motorcyclists accidents in the city of Barcelona

Barcelona is the European city with the highest rate of PTW's per inhabitant. The flexibility in terms of mobility that this type of vehicle provides added to the favourable climate makes this vehicle one of the preferred options by the citizens of Barcelona. The Public Health Agency of Barcelona (Agència de Salut Pública de Barcelona, ASPB) has, since 1997, managed accident data of seven hospitals of the city (Hospital Clinic, Dos de Maig, Hospital de l'Esperança, Hospital del Mar, Hospital Sant Joan de Déu, Hospital Sant Pau and Hospital de la Vall d'Hebron). They cover about 85% of the city's traffic emergencies.

An analysis of data of motorcycle and moped accidents occurred between 1997 and 2011 in which children between 7 and 12 years old were involved was carried out. During the period of the study, 184 children (107 males and 77 females) were identified and met the selection criteria. So, the sample consisted of 184 cases. It is observed that the number of cases increases according to the age and the year of the study. This may be due to an increasing use of

motorcycles as transportation means by this group and because the coding of the vehicle is improving; therefore more cases can be identified.

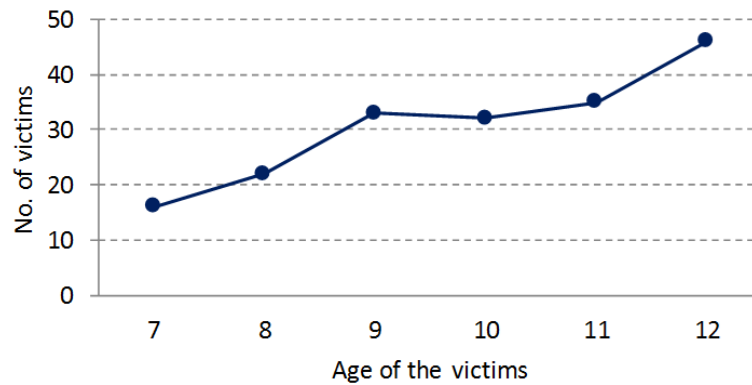


Figure 4. Casualties between 7 and 12 years old according to age



Figure 5. Casualties between 7 and 12 years old according to year

If the injuries are classified according to the Maximum Abbreviated Injury Score (MAIS), 74.1% are slight and only 1.7% are severe. The fact that the accidents occurred in an urban area means that impact velocities are lower than if they were produced on rural roads, so the consequences are not as severe.

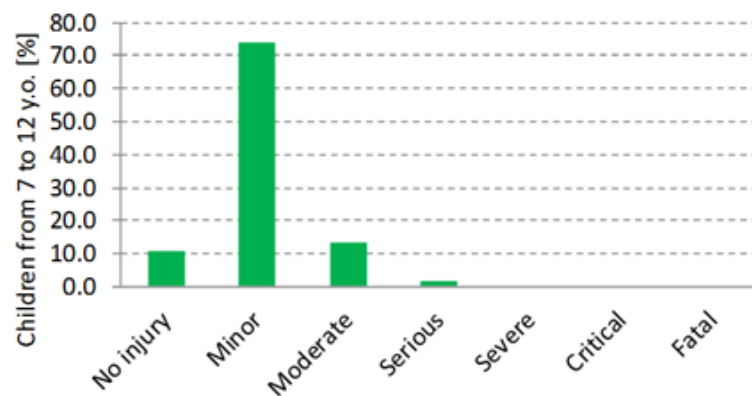


Figure 6. Casualties between 7 and 12 years old according to the MAIS

If the type of injury is analyzed, the most usual injuries are contusions (66.7%) followed by fractures (11,1%).

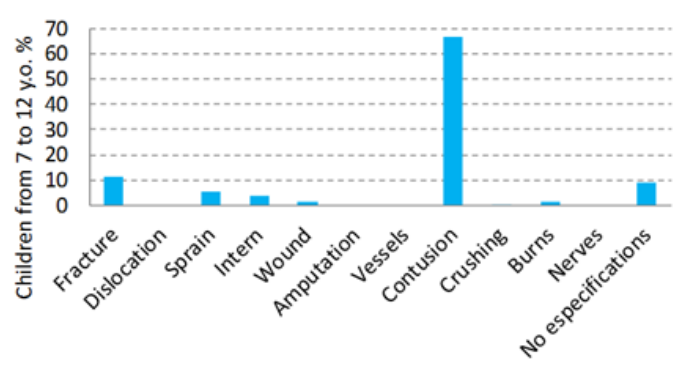


Figure 7. Type of injuries of children between 7 and 12 years old

According to body regions, extremities are the zones where most of the injuries occur (18.6% upper and 34.1% lower) followed by the head.

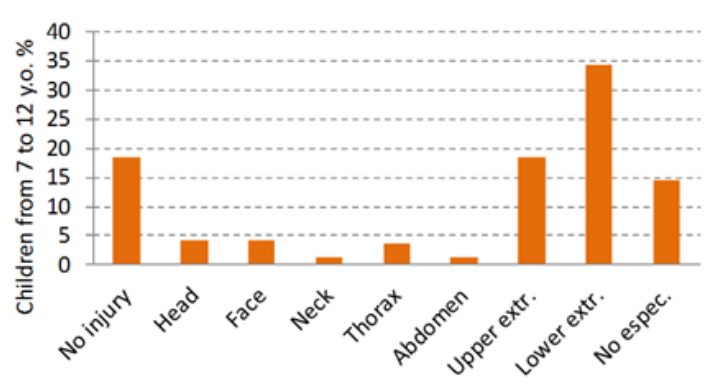


Figure 8. Body region where injuries occur of children between 7 and 12 years old

If injuries in other body regions are analyzed, 1.3% of the strains are produced in the neck, the same percentage results in the chest and 0.6% in the abdomen. 2.6% of the contusions occur in the chest and 0.6% in the abdomen. Although these kinds of injuries are less usual, they are especially important as they can seriously jeopardise different vital areas.

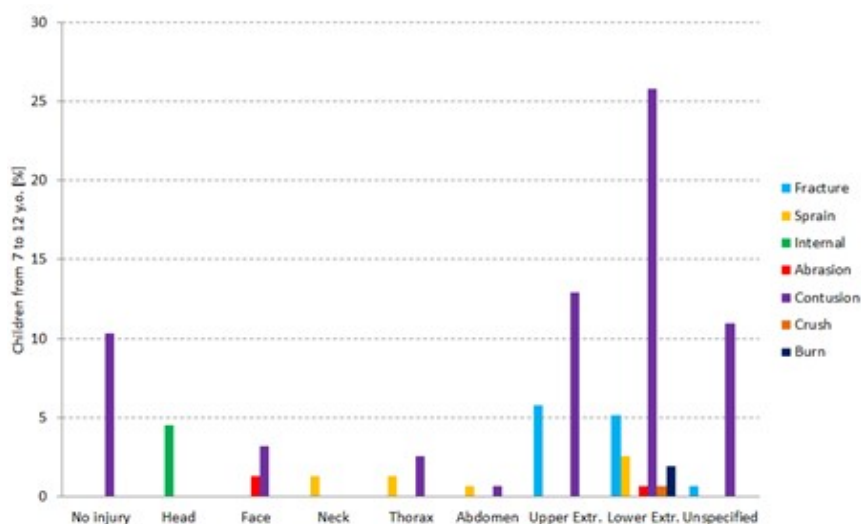


Figure 9. Body region where injuries occur of children between 7 and 12 years old according the kind of injury

In the case of injuries which do not occur in the extremities, each injury in each body region was classified according to the Barell matrix.

Table 1. Body regions (no extremities) according to the Barell matrix

Grouped Body Region	Body Region According to Barell	Type of Injury	n
Neck	Head/Face/Neck/Unsp	Contusion	5
	Cervical VCI	Sprains and Strains	3
		Contusion	1
Thorax	Chest (Thorax)	Sprains and Strains	1
		Contusion	3
	Trunk	Contusion	1
	Torso	Sprains and Strains	2
Abdomen	Abdomen	Contusion	6
		Contusion	1
	Trunk	Contusion	1

In the case of upper extremities, injured regions were classified according to the Barell matrix because they could be reduced depending on the area of the arm where they occurred.

Table 2. Injuries occurred in upper extremities according to the Barell matrix

Grouped Body Region	Body Region According to Barell	Type of Injury	n
Upper Extremities	Shoulder and Upper Arm	Fracture	2
		Contusion	2
	Forearm and Elbow	Fracture	4
		Internal	2
		Contusion	12
		Fracture	4
	Wrist, Hand and Fingers	Internal	1
		Contusion	8

2 fractures and 2 contusions occurred in shoulders and upper arms regions [5].

4.3 Testing protocol of back protection systems in PTW passengers

Based on the statistics data shown in the previous stage of the project, a testing protocol of back protection systems in PTW passengers was defined. The aim of this protocol is to compare the consequences in the zone of the back due to a PTW accident if the passenger wears a safety device or not.

The testing system consisted of one impactor and a dummy which represented the scenario where the passenger impacts against the floor with his/her back after a PTW collision. The impactor was a flat and rigid sheet and acted as the floor. The child was represented by a P-series dummy.

To achieve not only a repeatable but also a feasible test layout, the dummy will be lying down and will receive the impact from the floor.

The dummy will be impacted at an impact speed representative of PTW urban accident scenarios. The impactor's dimensions have to be bigger than the ones from the dummy. Several load cells will be placed under the dummy in order to register the transmission of the forces from the back area to the chest zone.

The tests will be carried out according to different impact angles and points to assess the areas of protection of the back device.

Finally, the results will be assessed in order to know if the safety device meets the established biomechanical limits.

5 Conclusions

The aim of this study is to know the state of the art of the main characteristics of the motorcycles traffic accidents where passengers between 6 and 13 years old are involved.

In the city of Barcelona, an analysis of data of motorcycle and moped accidents which occurred between 1997 and 2011 in which children between 7 and 12 years old were involved was carried out. Most of the injuries in children due to motorcycle accidents were slight and the most common kinds of injuries were not only contusions but also fractures. On the other hand, the body areas most frequently damaged were the extremities and the head.

People who want to transport children between these ages by motorcycle cannot find protective clothing and assume risks which they try to compensate for by decreasing the speed or adopting more cautious behavior.

Children often wear wrongly-sized helmets and rarely incorporate any additional safety clothing such as protective gloves or a jacket. One of the reasons for the lack of the use of safety clothes by children is that many families cannot afford the cost of providing the child with a special kit when he/she is growing up. Some manufacturers have tried to solve this issue by developing a grip system between the driver and the passenger. However, this product could even lead to similar trajectories between the two bodies in a fall scenario and, as a consequence, a partial risk of crushing (risk to both bodies).

A feasible partial solution could be to design and develop a device to protect the neck, shoulders, back and chest of the child in an impact scenario against abrasion and perforation. This solution would involve three key factors:

- Ergonomics: The system should be adapted to the shape of the child's back and should allow his/her mobility.
- Adjustment to child height and weight: The same system should protect a child in the period between 7 and 12 years old. The physical evolution of the child should be taken into account.
- Grip: The system should add different points of effective grip with ergonomically designed handles suitable for the pressure capabilities of child hands.

Taking into account the traffic accident data, a test protocol based on biomechanical references was defined in the second phase of the project to assess child protection systems in shoulder and back areas.

References

- [1] Association des Constructeurs Européens de Motocycles. Annual report 2010 (2011).
- [2] KfV (Austria), NTUA (Greece), SWOV (The Netherlands), TRL (United Kingdom), INTRAS-UEVEG (Spain), IFSTTAR (France): Annual Statistical Report 2012, DaCoTA, Building the European Road Safety Observatory, Workpackage 3, Deliverable No: D 3.9, p.49-50 (2012).
- [3] Dirección General de Tráfico: Anuario estadístico de accidentes 2011, p.5, 9-11 (2011)..
- [4] Instituto de Seguridad Vial del Motociclista: Análisis de riesgos de usuarios pasajeros de motocicletas, p.5-8 (2013).
- [5] Catherine Pérez, E. Santamariña-Rubio: Persones lesionades per trànsit ateses a serveis d'urgències a Barcelona 1997-2012 (2013).