EUROPEAN ENHANCED VEHICLE-SAFETY COMMITTEE

EEVC Working Group 18 Report
Child Safety - February 2006

Accompanying remarks from the EEVC Steering Committee to this publication

This EEVC Working Group 18 Report was scheduled to be published shortly after February 2006, however for logistic reasons this did not happen.
Whilst the EEVC Steering Committee acknowledges that some references are now out of date, it feels that the content remains relevant and worthy of publication without revision especially the content related to accidentology.
Where reference is made to the latest Q-dummy research, it is hereby noted that there has been recent activity in this area and a separate EEVC Q-dummies Report on the Advancement of Child Dummies and Injury Criteria (on frontal impact protection) is due for release in Spring 2008.

EEVC Steering Committee - March 2008

OVERVIEW

SUMMARY

Main results accident in-depth studies and existing databases in Europe

A synthesis to define the body segments to be protected in priority has been done for frontal impact, by age classes of children and by type of CRS used. Injury distribution has been also analyzed for side impact, rear impact, and rollover. Conclusions are based on the review of all existing accident databases in Europe, and on relevant projects regarding child protection in cars.

Frontal impact

Rearward facing infant carrier (Group 0/0+)

These systems seem to offer a good protection to their users in frontal impact. Severe head injuries are most frequently observed injuries with such CRS suggesting that introduction of effective padding may significantly reduce head injury risk. Three different injury mechanisms are possible: impact by the shell with the dashboard, direct impact of the head on supporting object, and rebound. For these systems, limbs are also representing a high number of injuries, but only few are considered as severe injuries. Therefore limb injuries are common but seem to be of less a priority.

Rearward facing system with harness (Group I)

Most popular in Northern Europe, rear facing CRS have been seen to be more effective in frontal impact when compared to forward facing CRS. Severe head injuries are less frequent in frontal impact with such devices than with rearward facing infant carriers. Limbs (especially arms) can also be injured.

Forward facing systems (Group I)

For this type of system head injury is still a big issue. Impacts are one cause, but diffuse brain injuries are also observed due to angular acceleration that can occur either with or without impact. The neck is an important area to protect for children in such devices (younger than 4 years) even if these injuries are not very frequent. Chest and abdominal injuries are not very frequent with such systems but are found.

Booster seat or booster cushions and adult seatbelt (Group I/II/III)

Head is still the most important body area in terms of frequency of injury, but the relative importance of abdominal injuries increases with such restraint systems. The intrusion of the seatbelt into the soft organs creates injuries at the liver, the spleen, and the kidneys. For these systems, the protection of the abdominal area is clearly a priority to ensure a good protection of children using a CRS on which they are restrained by the adult seatbelt. The chest does not seem to be a priority in terms of frequency of injuries; nevertheless, as the chest cavity protects vital organs, it remains an important body segment.

Adult seatbelt

It was observed that a lot of children were only restrained by the adult seatbelt, while they could be better protected by using an additional CRS. The body segments that are protected for children restrained by the adult seatbelt only are the same as for the ones using booster cushions but with worse injury outcome, especially in the abdominal region.

Side impact

Despite the small sample sizes, the head still remains the priority, 42 to 62%, even on the non-struck side, and whatever the sample considered (CSFC-96 vs. CREST). Chest and abdomen follow (respectively 5-16%, and 19-11%). Finally, in the CSFC-96 sample, upper limb injuries represent 29% of all injuries (all severity).

Rear impact

The head injuries represent 30% of the total, which is the lowest number compared with other accident configurations, but it still remains the most important body area injured. The number of lower limb injuries has increased and tends to be equal to the one of the head. Injuries to the neck are found for 13%.The sample is not important enough to focus on severe injuries.

Rollover

Head injuries still remain the highest in number. For the upper limbs, the number is 23%. Neck injuries and abdominal injuries also have to be considered in terms of number and severity.

Non use and Misuse

The main priority to reduce the number of children killed or severely injured is to get them properly restrained in an appropriate CRS, and to limit misuses. A significant step could be done using education, public information, in combination with law enforcement.

REGULATION EVOLUTION

After more than 20 years, improvement of regulation in this area is needed. The knowledge both in accident research and in biomechanics has evolved in a positive way these last years. Results from major European projects (NPACS, CHILD) will be disseminated in the next months. Results will include accident in-depth analysis, accident reconstruction, risk curves and injury criteria for children. Furthermore, in their common work, WG12 and WG18 have set up a test program in order to compare the responses between P series and Q series dummies in R44 conditions. The matrix was made of more than 300 tests using different types of restraint systems from the European market, and the different sizes of Q/P dummies. Tests have been completed. A first analysis has been conducted and a publication of the results has been done at the ESV 2005 conference [14].

From the results of the assessment of Q-dummies and ECE-R44 injury criteria in frontal impact as presented in this paper, the following conclusions are made:

- Head, neck, chest and abdomen need priority in protection (focus depends on age).
- Q0, Q1, Q1.5, Q3 and Q6 are available.
- ECE-R44 mass groups are covered as soon as Q10 is available (expected in 2006).
- Biofidelity targets, based on scaled criteria, are derived for the Q-dummies.
- Q-biofidelity results are good, except for the (linear scaled) thorax requirement.
- Q-measurements show good repeatability.
- Q-dummies are durable for ECE-R44 and EuroNCAP test conditions.
- P- and Q-dummies show similar results with respect to ECE-R44 requirements.

- For CRS evaluation, potential merits of Q-dummy family lie in the extra measurement capabilities.
- In near future, when the analysis of the validation program will be finalized, a recommendation for the implementation of the Q-dummies R44 can be proposed.
- The child dummy assessment as described in this paper focuses only on R44 frontal impact loading. It is recommended to assess a similar program with child dummies for side impact, because side impact legislation is expected in the near future.

In 2006, important results from CHILD project, and from WG12/WG18 common work, should provide the relevant knowledge, in terms of risk curves and injury criteria, to use adequately the enhanced dummies. Work is still in progress. When completed, all these new data must be merged to contribute for a proposal of the regulation. The definition of a test program (i.e. test trolley bench, crash severity, dummies, instrumentation, biomechanical criteria) remains a major issue to evaluate the consequences of the proposed evolutions:

Stature seems to be more relevant than weight for the parents as they buy clothing for the children with length sizes. To increase safety even further, the stature intervals can be written between the slots for a seat with an integral harness or guiding for the adult belt. The seat can easily be measured to check that the stature intervals recommended by the manufacturer are correct. There is no need for new dummies if we choose to use stature instead of weight intervals. There is no obvious need for groups but it is important to emphasize that the seat must meet the needs of the children it is intended for. E.g. a newborn can not sit 90º upright whereas the one-year-old toddler prefers the upright position. Taking into account the fact that there is no need to change either the dummies or any part of the test set up, it should be fairly easy to implement this amendment.

INTRODUCTION

In October 2000, during the 47th Steering Committee Meeting held in Madrid, the European Enhanced Vehicle-safety Committee created a working group dedicated to Child Safety (WG 18). The mandate of this Working Group was initially given for a period of 18 months, starting on from the date of its first meeting (January 2001).

The terms of reference of this group are defined as follows:

- Review accident statistics with respect to car child occupants and injuries in all type of car accidents.
- Review research with respect to car child occupant safety.
- Describe the state-of-the-art taking into account all existing regulations.
- Identify lacks in knowledge, methods and tools

In March 2002, the terms of reference were extended by the EEVC Steering Committee to include the situation in coaches and buses.

<u>List of nominated delegates</u>

Jean-Yves LE COZ	France, Chairman	(01.2001→ 03.2004)
Hervé GUILLEMOT	France, Chairman	
Cees HUISJKENS	The Netherlands	(01.2001→ 02.2003)
Kate de JAGER	The Netherlands	
Marianne LE CLAIRE	United Kingdom , secretary (2003-2006)	
François BERMOND	France	(01.2001→ 03.2004)
Jean Philippe LEPRETRE	France	
Reiner NETT	Germany	(01.2001 → 09.2001)
Roland SCHAEFER	Germany	(01.2002 → 02.2003)
Britta SCHNOTTALE	Germany	
Michele IANNONE	Italy	(01.2001→ 10.2003)
Manuela CATALDI	Italy	
Luis MARTINEZ	Spain	(01.2001 → 02.2003)
Gonzal TEJERA	Spain	
Thomas TURBELL	Sweden	

<u>Industry advisors</u>

Philippe LESIRE	France, Secretary (2001-2004; 2006 →)	(01.2001→ 03.2004)
Waldemar STOPPLER	Germany	(04.2001 → 10.2002)
Michael DEGENER	Germany	(10.2002 → 05.2004)
Stephan HARTWEG	Germany	
Friedrich BEISSWAENGER	Germany	
David BURLEIGH	United Kingdom	(01.2001→ 10.2003)
Farid BENDJELLAL	United Kingdom	
Bjorn LUNDELL	Sweden	

Since its creation, Working Group has met on 20 occasions, with sessions lasting from 1 to 2 days (Table 1). The work was undertaken through two approaches:

- Initially, each country carried out their experience and analysis. Some members of the group went on to carry out a collective analysis work.

- Information exchanges with experts or representatives of organizations having an enlightened opinion on the protection of the children during road travel.

#	Date	Hosted by	City	Country
1	January 2001, 24th & 25th	CCFA	Paris	France
2	April 2001, 20th & 21st	TUB	Berlin	Germany
3	June 2001, 28th & 29th	IMechE	London	UK
4	September 2001, 20th & 21st	TUB	Berlin	Germany
5	January 2002, 24th	CCFA	Paris	France
6	April 2002, 8th & 9th	BAST	Koln	Germany
7	June 2002, 13th & 14th	TNO	Delft	Netherlands
8	August 2002, 29th	GDV	Munich	Germany
9	November 2002, 20th	CCFA	Paris	France
10	January 2003, 17th	IMechE	London	UK
11	February 2003, 5th & 6th	TUV	Koln	Germany
12	November 2003, 12th	CCFA	Paris	France
13	February 2004, 16th	PSA	Paris	France
14	May 2004, 26th	TRL	London	UK
15	September 2004, 16th	BAST	Koln	Germany
16	January 2005, 18th	Audi Forum	Munich	Germany
17	April 2005, 22nd	CCFA	Paris	France
18	June 2005, 28th	INRETS	Lyon	France
19	October 2005, 5th	IMechE	London	UK
20	January 2006, 31st	CCFA	Paris	France

Table 1: WG 18 meetings

Due to the common research areas of accident analysis, injury mechanisms, human biomechanics and injury criteria, a series of joint meetings were organized between WG 12 and WG 18, beginning September 2003 (Table 2).

#	Date	Hosted by	City	Country
1	September 2003, 17th	CCFA	Paris	France
2	December 2003, 17th	CCFA	Paris	France
3	January 2004, 23rd	CCFA	Paris	France
4	March 2004, 11th	LAB	Paris	France
5	May 2004, 25th	TRL	London	UK
6	October 2004, 14th	FTSS	Heidelberg	Germany
7	January 2005, 19th	Audi Forum	Munich	Germany
8	April 2005, 21st	CCFA	Paris	France
9	October 2005, 4th	IMechE	London	UK

Table 2: WG12/WG18 joint meetings

The task of WG 18 focused on child injury causation (distribution of injured body segment, classification of accident, age, child classes and CRS used), whilst the work of WG 12 focused on biomechanics, biofidelity, tool response and relevance, sensors related to injury mechanisms in improved dummies. The objectives were to assess new child dummies and criteria for child occupant protection in frontal impact. The two groups carried out a large test program. This was designed to gain a better understanding of child behavior, the influence of dummies, any lack of knowledge and possible improvements that could be made to the current Regulation 44. The initial analysis from this research was presented at the ESV 2005 conference [14].

Intermediate reports have been written and submitted to the Steering Committee, dealing with accidentology in cars, accidentology in coaches and buses, background in biomechanics, development of dummies, and legislation review. The current report gives a synthesis on the work done and includes recent updates.

There have been a number of membership changes during the period 2001-2005, and the current participation in WG 18 was updated Feb. 1st, 2006, as follows:

Hervé GUILLEMOT	France, Chairman	
Philippe LESIRE	France, new Secretary	appointed Feb. 1st, 2006
Marianne LE CLAIRE	United Kingdom	
Kate de JAGER	The Netherlands	
Jean-Philippe LEPRETRE	France	
Britta SCHNOTTALE	Germany	
Manuela CASTALDI	Italy	
Gonzal TEJERA	Spain	
Thomas TURBELL	Sweden	
Kostas N. SPENTZAS	Greece	New member
Industry advisors		
Friedrich BEISSWANGER	Germany	MPA
Farid BENDJELLAL	United Kingdom	BRITAX
Stephan HARTWEG	Germany	AUDI
Bjorn LUNDELL	Sweden	VOLVO

ACCIDENTOLOGY IN CARS

- [ToR 1: Review accident statistics with respect to car child occupants and injuries in all type of car accidents]
- [ToR 2: Review research with respect to car child occupant safety]

OVERVIEW OF EXISTING DATA BASES

A review of the existing accident databases has been completed according to the quality criteria concerning the conditions of the accident, the vehicle analysis, the occupant description, their injuries and the protection device used. For that, the databases have been classified in three categories:

- **European data**, extracted from the IRTAD database, have been collected in different countries and stored in a large database where clear definitions have been given and data have been checked before being introduced in the database. This kind of data cannot lead to in-depth analysis of the protection of children in cars, but can show the size of the problem the working group is dealing with. It is possible to compare countries in terms of number of children killed as car occupants, relative risk of being killed per 100.000 of population, the trends over the last five years. Unfortunately, no data is available on restraint use, type of impact or even on the exact age of the children, who is just recorded in age categories.

- **National data** are the official figures from European Governments. An in-depth analysis is possible for each country taking into account specific definitions and constraints of the databases. Data are available in Germany, France, United Kingdom, Sweden, Italy and Spain. The analysis has led to conclusions specific to each country and more generally that the quality of the data collected is not homogenous through the countries concerned. Very few have information on the types of crashes in which children were involved, and on restraint uses, which are determinant parameters to study the protection of children in cars. A more uniform way of data collection is necessary on two different points. The first one concerns the definitions and the data that is necessary to collect; the second point concerns the reliability of the collected data. The results obtained in the different countries could then be compared more easily.

- **Specific data**, which are collected by private institutes or European Research Projects that have specific aims related to child safety. The different databases of this report are: CREST (Child REstraint STandards), CHILD (CHild Injury Led Design), CCIS (Co-operative Crash Injury Study), GIDAS (German In-Depth Accident Study), Questionnaire, CSFC 96 (LAB-CEESAR), CASIMIR (LAB-CEESAR), and the one of GDV, a German insurance association.

IRTAD

The IRTAD (International Road Traffic Accident Database) was created in the late 80's. It is an extension of an existing database from BAST (Federal Highway Research Institute, Germany) that has been adapted in order to store all of the relevant data existing in the OCDE countries.
Its main purpose is to enhance the comparability between countries of road accidents and traffic data by giving clear definitions for all fields, to extend the amount and quality of relevant and

updated data of OCDE members' countries, and to give access to this information for different kind of analysis.
29 countries and regions participated in its formation and have regularly given their data to update and fill this database from the 1970's to date.
Only data on fatal and accidents with injuries and their victims are included; there is no information on material damage. The BASt does the management of the IRTAD.
Data are collected and entered into tables by each country, and are checked by the database manager for consistency and compliance with the data base definitions and if necessary corrected before being introduced into the database.
The IRTAD is a very general database where each person involved in a road traffic accident is included. The content can be used for the comparison between different countries but only a few fields are related to children, this does not permit an in depth analysis.
Children are put in three age classes (0 to 5 years, 6 to 9 years and 10 to 14 years old) which approximately correspond to the use of different adapted restraint systems. There is no information concerning the use of restraint systems for children in the IRTAD.

CREST

The CREST project, funded by the European Commission, was initiated to develop knowledge on the kinematics behavior and tolerances of children involved in car crashes. The final aim of the project was to propose enhanced test procedures for evaluating the effectiveness of child restraint systems (CRS) [1,2].
The CREST accident database contains 405 documented cases in which 628 restrained children were involved. These cases met specific criteria in terms of crash configuration and severity, so this accident database *is not representative of the real-world accident situation*.
Teams involved in the accident collection were: LAB, (PSA and Renault - France), ELASIS S.C.p.A. (on behalf FIAT Auto SpA - Italy), the Institute for Vehicle Safety of the German Insurance Association (GDV) (Germany), the Accident Research Unit of the Medical University of Hannover (MUH) (Germany), and the Vehicle Safety Research Centre (VSRC), Loughborough University (United Kingdom). The studies were both retrospective and prospective according to the teams involved and every accident was presented and discussed before being included in the database. When put together, the accident cases provided by each team made a significant contribution to the field of accidentology and injury biomechanics. The CREST project has been completed in 2000 and proposed a procedure for evaluation of the protection offered by CRS in frontal impact, based on the accident database and reconstructions of some of these accidents. Results were published at ESV 2001 conference in Amsterdam [3].

CHILD

The CHILD project, partially funded by the European Commission, was launched in 2002 for duration of 46 months [6,7,8,9]. The objective of the project was to better understand the mechanism of injuries sustained by restrained children in cars, and to propose injury risk curves for frontal and side impacts on improved child dummies and validated test procedures. It is based on the CREST results and the collection of accident data has been continued by the same teams as the previous program. Furthermore, SAAB has been able to bring accident data with restraint systems specific to northern countries, as well as IDIADA in Spain, from where no data was available in previous project.
The criteria for an accident to be included in the CHILD accident database are really close to the ones of the CREST accident database, so this accident database *is not representative of the real-world accident situation*. The CHILD project accident data collection led to 250 new cases with restrained children that are currently analyzed (together with the CREST cases) before being

presented in May 2006, during the CHILD dissemination workshop. In the analysis phases, a specific focus will be done on side impact protection.

CCIS

The Co-operative Crash Injury Study (CCIS) is concerned with the in-depth analysis of road traffic accident data collected from approximately 1500 vehicles and their occupants each year. The CCIS database consists of the analysis of real world accidents in the UK, and provides information about how car occupants are injured. A detailed examination of vehicle damage is made by professional accident investigators, and is compared with the occupants' medical data from hospital records, occupant questionnaires and post-mortem reports as appropriate. The database was searched to find accidents that involved child occupants (restrained or unrestrained) aged 12 or under. The results of this search identified 425 cases.
The database contains good information about impact conditions and vehicle damage along with the injuries to the occupants involved. In cases that also contain comprehensive information about child restraint system and how it was attached to provide very good case studies. However it is not possible to carry out an analysis on the data in general, as it is very difficult to obtain information about how the children were restrained in the vehicles. It was claimed that 39 percent of the children were restrained in vehicles, but with no further verification. In addition, for 12 percent of children the type of CRS was not known.

Questionnaire

This database was designed to look at child safety in vehicles. It was created by TRL Limited for the UK Department for Transport. TRL send out blank questionnaire forms to some child restraint system manufacturers, who include the forms with the paperwork contained within new CRS packaging. If parents who has bought one of the seats have an accident they can fill in the form and post it to a freepost address, which returns the form to TRL. The information provided on the form is then entered onto the questionnaire database. This database gives very good information about what types of child restraint are being used for children of different ages, where the child restraints are positioned in the vehicle and the impact direction of the crash. The information about the injuries to the car occupants has to be treated with caution as it is based on the judgment of the parents. However, DfT can be confident that although they may not know the actual extent of the injuries, they know which body regions were affected. Adults who have caused accidents are less likely to fill in the forms so the database has a relatively large number of rear impact cases.
To give an idea of the type of information available in the questionnaire database, a sample that contains data from accidents that happened between 1995 and 2000 has been analyzed. A total of 158 vehicles were involved which represent 230 children (0 and 12 years of age).

CSFC-1996

In 1995-96, a child safety related study was conducted in France. During a four-month period, each police report where a child was involved in a road accident was collected. In addition, police forces and medical staff were asked to fill in a form for each child in order to collect the necessary data for an in-depth analysis. Only children involved as car passengers in car to car or car to fixed obstacle accidents were included. All the police reports were analyzed and coded by experts in child safety, accidentology and medical doctors. In order to do this, they had access to pictures taken by police, accident sketches, statements from people involved, children's medical reports, specific information about the child restraint systems, age, height and weight of children. The information was then entered into a database.

In France, three different police forces are reporting accidents. The Gendarmerie Nationale supplied reports with sufficient information to allow an in depth analysis. The area of the investigation of the Gendarmerie Nationale was countryside and small towns. The sample considered for the study was representative of car to car and car to fixed obstacle out of cities and in suburbs in France, where the risk of a child being killed or severely injured is the highest. Results are available in the literature [4].

GIDAS

GIDAS is a co-operative project between the German Federal Highway Research Institute (BASt) and the Automotive Industry Research Association (FAT) carried out in Hanover and Dresden. In depth accident investigations are conducted in order to bring additional information to the official accident statistics particularly causes and consequences of accidents. Specialist teams go directly to the scene of the accident, immediately after it has occurred.
A geographical area has been defined surrounding Hanover, including the city itself, for the collection of accidents. It gives representative results. In 1999, the geographical area was extended and a second team was set up near Dresden. Both teams are using a common methodology in order to compare the results easily and to enter them in a common database. Since that date, about 2000 accidents are investigated annually and most of them are reconstructed using a proven software in order to determine the exact conditions of the crash events. The number of collected data for each accident is between 500 and 3.000. Analyses are regularly conducted with this data base and reports are provided. Some specific topics can be analyzed if requested.

GDV

GDV (Gesamtverband der Deutschen Versicherungswirtschaft e.V.), a German assurance association has an Institute for Vehicle Safety which is collecting data on road accidents since 1969. Some studies were carried out specifically on child safety.
Three materials are available at GDV which correspond to different periods. The first one has been analyzed at the end of the 80’s. It contains 870 accident cases in which more than 1150 children (0 - 12 years) were involved. This study was done according to an accident form which contains a lot of information. The second one was collected in the years 1990 and 1991. On 16.000 accident analyzed, nearly 600 restrained children were involved.
The third material is a collection of accident cases between 1992 and 2002. Information sources are insurance companies, Police forces and co-operation with other institutes. The number of accidents available today is around 350. No results were published with this material up to now, but it has been used in specific projects, as CREST accident database.

CASIMIR

CASIMIR (Child Accident Survey Investigating Mortal Incident on the Road) is a new project conducted in collaboration by CEESAR and LAB. It is based on all police reports of accidents in which a child as car passenger has been killed on a two years period (approximately 250 children). This will allow to better understand the conditions in which children are killed in cars and enable to give clear priorities. The data contained in police reports are coded by accidents experts, crash severity and configurations are defined, but also the use of restraint systems and sometimes medical data are available for codification and determination of injury mechanisms. When possible misuse situations are determined, they will be considered in the analysis. The work of this project is in progress and the analysis of the data itself should be completed by the end of summer 2006, and published in conferences related to Child safety, accidentology and biomechanics subjects.

GENERAL TRENDS

From the very general databases, some results can be shown. Considering the 15 countries from the European Community plus Poland, Hungary, Turkey and the Czech Republic, it appears that nearly 10 children are killed as car passengers each week, with around 60.000 children injured each year on European roads when traveling in cars.
It is also possible to see that the size of the problem of child safety is not the same in all countries. The distribution of the numbers of children killed (0 - 14 years) as car passengers in E.U. during 2002 are given in Figure 1. It clearly shows that the number of children killed is far greater in France than in other countries, these being 25% of the total. Germany is in second position (18%), with Poland, Italy and Spain following closely.

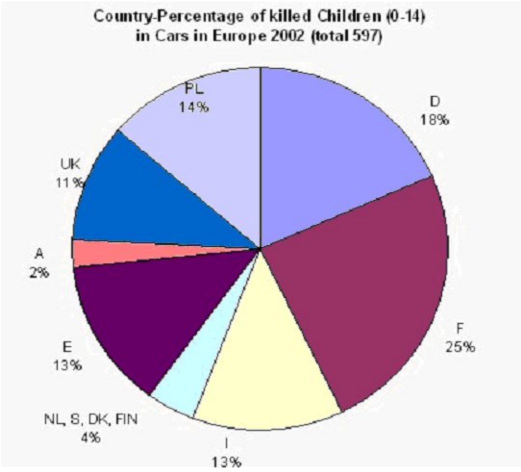

Figure 1: A global reduction of the number of children killed, and different situation according countries:

The evolution of the situation in the 19 countries considered for this study is shown on Figure 2. From 1995 to 2002, in France, Germany, Poland, Italy and Portugal the number of children killed has decreased, whilst remaining stable in the United Kingdom and Spain.
In the other countries considered, the number of children killed each year was less than 30 displaying a decreasing trend.

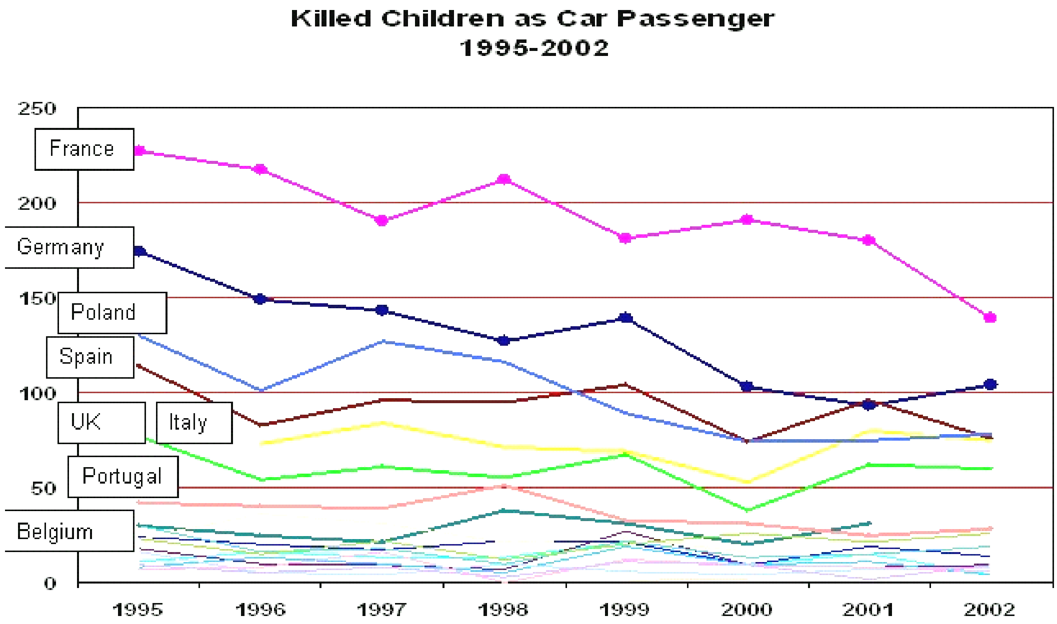

Figure 2: Children killed as car passengers 1995 - 2002

For this study, the risk to be killed as a car passenger per 100.000 inhabitants of the same age groups has been defined. EEVC WG18 considers risk to be:

- high when greater than 1 (Belgium, France, Austria, Spain, Poland, Czech republic and Hungary; Portugal had no data available for 2002 but had a score of 3, in 1998);
- moderate between 0.5 and 1 (Germany, Italy, Switzerland);
- low when lower than 0.5 (The United Kingdom, the Netherlands, Sweden, Denmark and Finland).

The risk for a child to be killed as car passenger according to the different countries in 2002 is shown in Figure 3. Countries where the ECE R44 regulation was adopted a long time ago seem to score a lower risk.

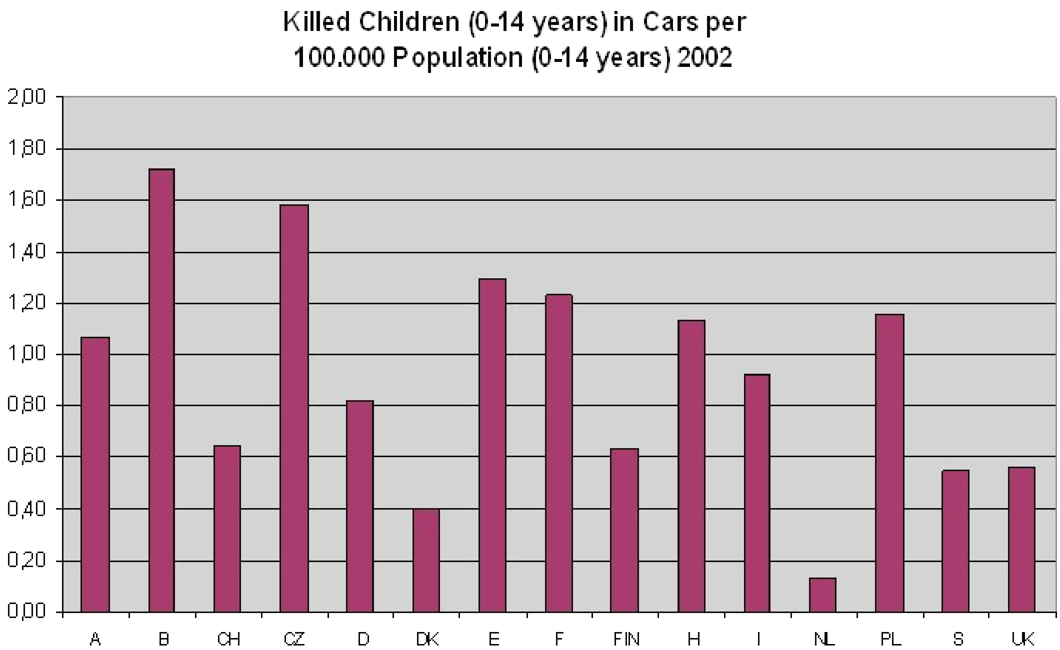

Figure 3: Children Killed in cars per 100.000

National statistics give a good indication of where the problems may be, but lack detail. In order to obtain more data about how children are being injured in more severe accidents, it is necessary to query the other accident databases.

From national databases, it appears that the rate of use of CRS is known only in some countries. Differences also exist in the definition of a child and data on the exact age of child is not always available. In France, Germany, and in the United Kingdom, it is possible to have a distribution of children killed according their age. It is shown that due to the increase of mobility when children are growing, the risk of being killed or injured becomes globally higher as children are getting older. The reported numbers of injured children and the definitions of level of injuries are very different from one country to another one, meaning no comparison is possible.

Some national databases, or some specific ones like the Questionnaire database (which is a compilation of the answers from parents with a child involved in a car accident), bring information on the use of different restraint systems. For example, approximately 25% of children younger than 9 months travel forward facing and the rate of use of rearward systems decreases to 10% for children between 10 and 18 months.

Focusing on the main types of impact sustained by children in cars, frontal impacts are more numerous (50%), with side impacts representing about 25% of the total number of accidents. Rear impacts and rollovers follow.

Children are most often seated directly behind the front passenger seat. The second most often position is directly behind the driver. The front seat is used for very young children and for children older than 10 years of age and the rear centre position is used about 10% whatever the age considered.

Only some specific databases, like GIDAS, CREST/CHILD, CCIS, and CSFC-96 contain reliable information on the configuration and severity of the crashes. They all lead to the conclusion that the risk of being severely injured is very small for correctly restrained children, up to a delta V of 40 km/h for frontal impacts.

RESTRAINT SYSTEM EFFICIENCY

Both CCIS and CSFC96 databases clearly indicate that the use of child restraint systems has a positive effect in frontal, side, rear impacts and in rollovers on the protection of children. This is illustrated in Figure 4, Figure 5 and Figure 6.

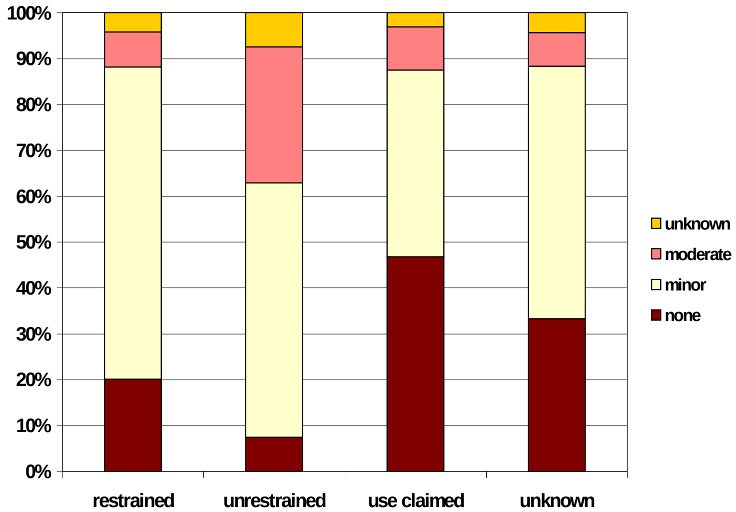

Figure 4: - CCIS database - Distribution of injuries /restraint use in frontal impacts

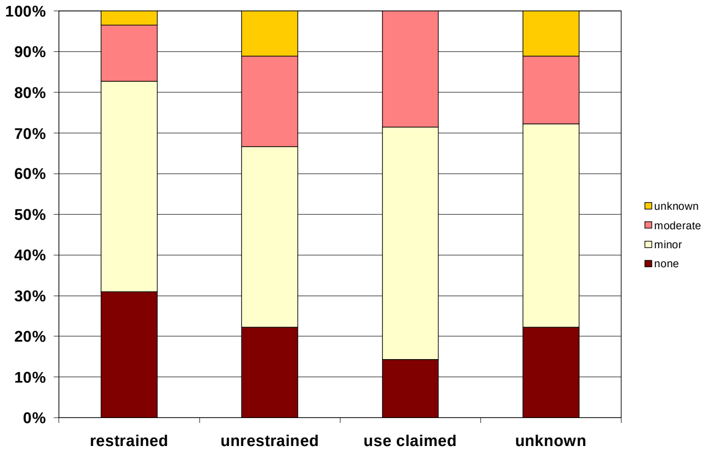

Figure 5: - CCIS database- Distribution of injuries /restraint use in side impacts

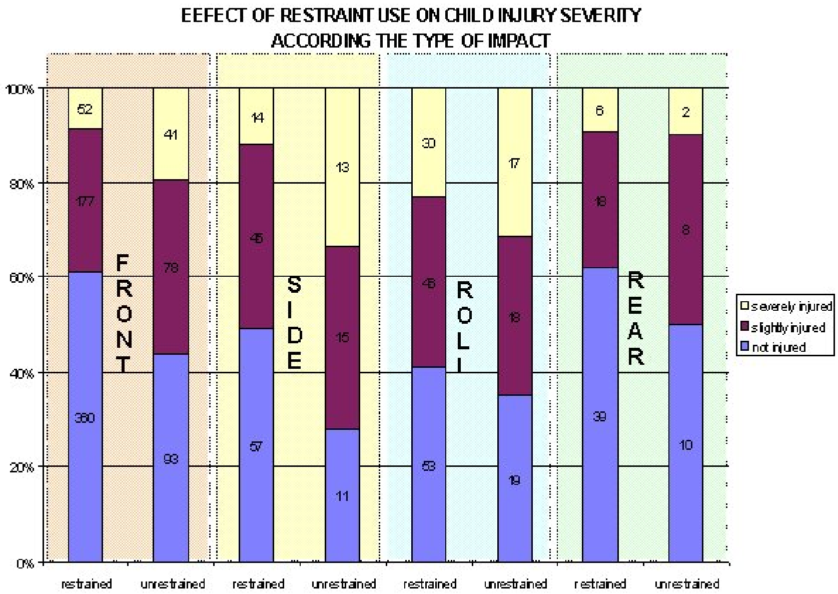

Figure 6: - CSFC 96 database- Distribution of the nb of injuries /restraint use / type of impact

In addition, the specific databases clearly show that children involved in accidents as car passengers and secured only with the adult seatbelt run a higher risk of injury than ones secured in an appropriate CRS. The CREST accident database is able to indicate the rate of inappropriate use (about 30%) but also to give this rate according the age of children. This is shown in the table below (Table 3).

Age	Total	non appr./ total
<6 months	26	23%
6-11 m	36	22%
12-17 m	45	4%
18-23 m	39	13%
24-35 m	73	12%
3 years	59	22%
4 years	71	27%

Age	Total	non appr./ total
5 years	47	30%
6 years	52	56%
7 years	34	47%
8 years	42	79%
9 years	32	78%
10 years	28	
11-12 years	44	
Total	628	29%

Table 3: Inappropriate use of CRS

The use of inappropriate CRS by children between the ages of 3 and 9 increases with age, but the causes are different. Children of 3, 4 and 5 years had a lower rate of inappropriate use (22, 27 and 30% respectively) but this group was still very vulnerable to injury, particularly when using the adult 3 point belt as the means of restraining both the children and their CRS. The levels of inappropriate use of CRS amongst older children increases up to 9 years, and is largely attributable to them not using an appropriate booster cushion. This is a matter of education and the effects of social and peer pressure, as children no longer want to use a “baby” seat and their parents do not understand why they should still be using a booster cushion. Again it must be emphasized that, as the data in the CREST Accident database is not representative, the situation may be different within the road population at large.
In some northern European countries, rearward facing systems of group 1 are commonly used for children up to 3 years of age. For this population, around 90-95 % of protection effect has been notified which has to be compared to the 60-70 % seen for forward facing seats of the same group.

MISUSE

It is obvious that CRS use, CRS behavior in accident situations and the real effects of misuse in terms of injury are important factors in the protection of children, but are not currently well known. All crash tests are performed with appropriate child restraint systems and no misuse, which is only reflecting the best protection that you can offer to a child but as the effect of misuse on the level of protection to children is not known. This does not necessary reflect reality.

Very few accident databases contain information on misuse (wrong use) of CRS. In addition, the methods used for collecting accident data are not appropriate for estimating misuse if they are retrospective. It is then necessary to use studies dedicated to misuse, aside from accident databases to have a clearer view on the subject at that point. Some of them (data source BRITAX and FOLKSAM) have been presented to EEVC WG18 and have shown that the rate of misuse of CRS is high, but it is very much dependent upon the type of CRS used. These show that about 60% of the installations can be considered as satisfactory. 21% of the CRS presented major misuse and 16% were not compatible with the bench and the belt systems of the cars.
When similar analyses are conducted on the different kinds of restraint systems, large differences are shown. Forward facing seat (Group 1) increased to 75% satisfactory installation, with group 0+ seats having nearly 90% of satisfactory installations. The most common misuse on the rear infant carrier is the diagonal route of seatbelt being inverted. Combination seats (CRS that can be used first rearward facing and then forward facing) have the worst results in terms of good installation (less than 40%). The second category of CRS with a high average of poor installation is those covering a very large range of use (very often 9 to 36 kg). These CRS are very often what people are looking for because essentially of the economic advantage. This type of studies should be conducted with the same level of details all over Europe.

Second hand CRS are also a source of misuse because very often the user manual is not present (when a seat is sold to the next owner) and the labels are often unreadable (or nor existing). As the history of such systems is rarely known, people who buy it have no possibility of knowing if the configuration they are using the CRS is equivalent to the one it has been approved for. For example, harnesses are rarely mounted in a correct way after washing the seat cover without any documentation. In addition the characteristics of plastic parts are time dependant and the CRS does not respond in the same way as a new one after years of use.

The European CHILD project is working on a synthesis of the existing misuse surveys and also conducting two field studies in Spain and France. Here the rates of CRS misuse are expected to be higher than those from the previous studies conducted in the UK and Sweden, where the child safety is more prevalent culturally.

A report was issued at the end of 2003 and this brings interesting data in the understanding of the main ways to improve child safety on European roads:

- CRS of group 1 show a rate of misuse higher than other systems;
- Information given to parents is insufficient; they often use a trial and error approach;
- CRS are misused more during short trips (less than 15 minutes);
- 25% of faults result in a higher risk of serious injuries;
- Head and abdomen are the body segments on which injury severity should be increased through misuse.
- A field study conducted in France in 2003 revealed that nearly 75% of CRS were misused, and that a majority of them show several misuse conditions at the same time (combination).
- Use of an inappropriate CRS in terms of height/weight of children is also an important factor of injury source, i.e. the neck of children younger than 1 year of age and abdomen of children seated on booster cushion/seat instead of being restrained in harness systems. This was not considered in this study as a specific misuse scenario, but information is available.

Because of the importance of misuses and additional injury risk, this task of the CHILD project has been extended to an ad-hoc group on the influence of misuse on child protection. This group is composed of people from different fields: Car manufacturers, CRS manufacturers, National Institutes of transport, car industry suppliers, approval tests laboratories, universities, accident investigators and a consumer organization.
The aim of this ad-hoc group is to improve the knowledge of the different factors in the child safety activity in order to be able to give priorities in future actions to other working groups and to establish a link between the risk of injury and misuses. In order to have results scientifically valid, a test program has been set up and more than 100 dynamic tests (R44 - severity) with Q3 and Q1 dummies will be conducted to compare normal and approximately 60 misuse situations. Injury criteria (results from Child project) and kinematics analysis will be good indicators for the determination of the decrease of protection of child safety due to misuse. Publications of these results are planned next year with different technical levels (for expert groups but also for information of the public).

ISO TC22 SC12 WG1 is also working on the item of misuse and currently validating a methodology to assess the risk of misuse of a given, CRS in a given car. This work has been initiated for ISOFIX devices initially and is on-going for other systems.

Special attention should be paid to avoid misuse, and a lot of effort has been done during the recent years in this way, for example introducing ISOFIX, but to date none of the accident database contains data with children restrained in ISOFIX devices.

INJURY BODY SEGMENT REPARTITION ACCORDING TO THE TYPE OF CRS USED

Whatever the impact direction considered, the head remains the body area the most injured. This is followed by the chest in frontal impacts and by the neck in side and rear impacts.
It is possible to focus on the effect of the type of restraint system on the different body segments of children. In the CREST database, it has been possible to conduct an analysis of typical severe injuries for frontal impact on a sample of 460 restrained children.
Before focusing on the injuries of restrained children involved in the CREST accident database, it must be reiterated that the data are not representative of the real-world and can only be considered as representative of a selection of very severe accidents. Nevertheless, this database remains the most detailed of a size sufficient for analysis. The following study was based on the

number of injuries of restrained children with respect to the body area where they occurred. Then the AIS3+ injuries were selected. No distinction between cases with misuses and cases with correct restraint use has been done for this analysis.

Frontal impact

Rearward facing infant carrier / forward facing seat:

Due to the low number of children restrained with rearward facing devices, the results shown in the Table 4 cannot be used for statistical analysis, but they can show trends towards the typical injuries encountered in severe crashes according to the type of CRS used. The number of severe head injuries is high and for rearward facing systems can be the result of an impact of the CRS with the dashboard. In Table 4, is the number of neck AIS 3+ injuries with children using group 1 forward facing systems but no neck injuries at all with rearward facing systems. Another interesting point is that the number of limb fractures (upper and lower) is high for both types of CRS.

	Rearward facing systems		Forward facing systems	
Nb of children	31		144	
Injuries:	AIS1+	AIS 3+	AIS1+	AIS 3+
Head	18	5	46	16
Neck	0	0	24	10
Chest	3	0	16	6
Abdomen	1	0	9	3
	AIS1+	Fract.	AIS1+	Fract.
Limbs	8	4	39	20

Table 4: CREST accident database Rearward facing / forward facing devices

Number of children: number of children with medical information
Injuries: number given for head, neck and limbs is the number of injuries
Fractures: number of fractures which are maximum AIS 2 for children

Rearward facing infant carriers and seats/forward facing seats - the situation in Sweden

For 30 years, the recommendation from Swedish authorities has been to use a rearward facing child restraint at least up to 3 years of age and preferably up to 5 years of age. The legislation, however, states that a child restraint is mandatory up to 6 years of age but does not have any requirements on the direction. In practice, a vast majority of infants and toddlers in Sweden are traveling in rearward facing child seats. A thorough investigation on child restraints based on insurance claims addressing injury patterns in correlation with direction of child restraint was conducted by Aldman et al 1987 [10]. The database was gathered from insurance claims, which means that all types of accidents are present. The driver was injured in about 10% of the accidents. The main findings were that unrestrained children were at greatest risk whereas children in rearward facing restraints were at the lower risk. It was also concluded that child restraints were effective in all directions of collisions. Only 3 (1%) children out of 253 who were using a rearward facing restraint were injured. All three received skull or face injuries. Out of 624 children in forward facing restraints, 43 (7%) received injuries. A comparison between children 0-4 years gave an increased risk up to almost five times for those sitting in forward facing restraints compared with those sitting in rearward facing restraints. As a large number of children in the study were unrestrained conclusions were drawn of the overall effectiveness of different types of restraints compared with no restraint at all. The rearward facing systems were 90% effective and forward facing systems in a rear outboard position were almost 60% effective of reducing injuries. Forward facing systems, including adult seat belts only, were over 60% effective in protecting the head (including face) but had an adverse effect of 30% on neck injuries. A similar adverse effect was observed on the abdomen and pelvis area (40%). The forward facing seats proved to be distinctly more effective in frontal collisions than in side collisions. No child was reported injured in the 55 side collisions where a rearward facing seat was present. There were 52 rear collisions with rearward facing systems but no injured children. In forward facing systems, six per cent of the children were injured in 140 rear collisions. It is important to note that none of the forward facing seats had an internal harness since they were all booster seats.

Booster cushion + seatbelt / adult seatbelt:

When comparing the injuries occurring to children using a booster cushion and a seatbelt to those using only the adult seatbelt (Table 5) a lot of abdominal injuries were observed in the cases without a booster cushion. The kinematics of the child was, in those cases, totally different due to the poor positioning of the lap section of the seatbelt. In addition, there were more AIS3+ neck injuries to children on boosters, whilst there were more AIS 3+ chest injuries sustained by children using only the adult seat belt. In both cases a lot of limb fractures were observed.

.	Booster + seatbelt		Adult seatbelt only	
Nb of children	108		148	
Injuries:	AIS1+	AIS 3+	AIS1+	AIS 3+
Head	39	7	44	8
Neck	22	11	25	6
Chest	24	9	45	18
Abdo	28	9	68	27
	AIS1+	Fract.	AIS1+	Fract.
Limbs	53	25	88	38

Table 5: CREST accident database booster and safety belt / safety belt only

Nb children: number of children with medical information.
Fract: number of fractures
Injuries: The number given for head, neck and limbs is the number of injuries

The CSFC 96 database allow us to go one step further for frontal impact and the distribution of the risk of severe injuries / body area/ type of CRS for 100 children of the sample is shown on Figure 7. Unfortunately, as the data has been collecting in 1995 and 1996, infant carriers were not so popular in France at this time and their number is too low to use it in the analysis. For other types of current CRS, the sample is statistically significant.

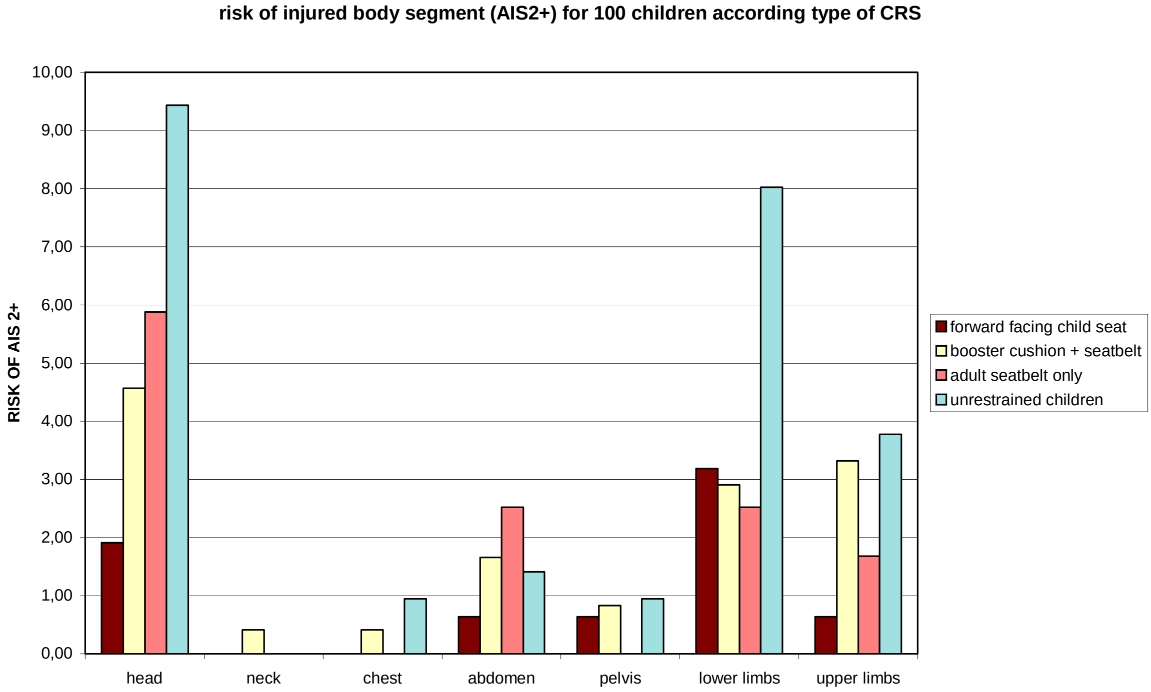

Figure 7: CSFC96 database - frontal impact - severe injury distribution/type of CRS

The risk of having a severe head injury for children restrained in forward facing child seats with a harness in a frontal crash is lower than for other restraint systems. It is even lower than the risk of having a lower limb fracture. The risk of injury at the abdominal area is lower than other restraint systems, due to the fact that children are not directly in contact with the seatbelt when restrained with such systems. Children restrained using a booster cushion in addition to the seatbelt have a risk of 4.5 out of 100 of having a severe head injury and of 1.7 out of hundred of having an injury in the abdominal area. This is twice more than with forward facing child seats; however the risk remains lower than if only the three-point seatbelt was used.
The risk for all body areas is lower for children using a forward facing system with harness than for unrestrained children. This shows a real effectiveness of these systems in the protection of young children. The use of booster cushions and seatbelts shows an important decrease in injury risk to the head, chest, pelvis and limbs but the risk of having a severe injury to the neck and abdomen is higher than for unrestrained children.

Side impact

For side impact, the sample in the different database is small and it is not possible to go so far in the analysis. Nevertheless, some child safety specific databases indicate the body segments the most often severely injured in side impacts. The CREST accident database contains 168 restrained children who were involved in severe side impacts (not representative of real world situation). Of these, 27 were not injured, and 115 of them had a detailed medical report (including 14 children fatally injured). The total number of injuries collected was 424. When focusing only on the severe injuries (AIS 3+), in order to see where effort has to be applied to reduce the risk of these injuries occurring, their number was 105. The distribution of the injuries according to the different body regions is given in Figure 8. Head injuries accounted for 62 percent of all the severe injuries recorded in all types of CRS. When comparing the injuries for the different CRS types, severe head injuries always accounted for more than 50%. Thus, the protection offered around the head area of the rigid parts in the car or the intruding object is currently not sufficient.

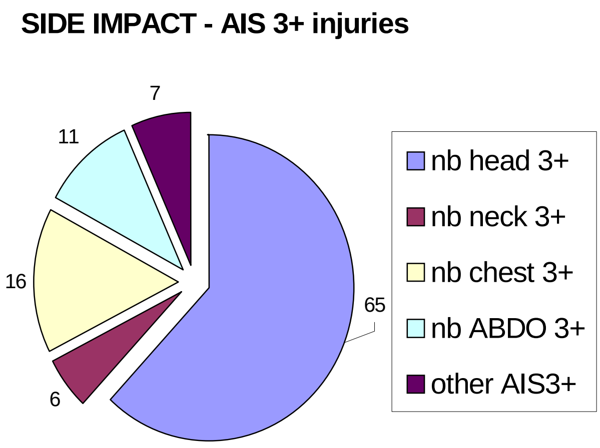

Figure 8: CREST accident database - severe injuries in side impacts

Severe injuries also occurred around the chest and the abdomen. They were mainly observed when the child was sitting on a booster cushion or just using the adult belt. For those systems, the chest accounted for 22% and the abdomen 16% of injuries. These injuries were rarely seen in CRS with a shell, either forward or rearward facing, where the protection of those body regions appears to have been more efficient.
The neck appears to be injured less frequently than the other body regions and the injuries noted occurred mainly on young children using forward or rearward facing child restraint systems. Even though the number of injuries observed was low, it has to be said that each time an AIS3+ injury was observed on the neck in a side impact during the CREST program, the child was fatally injured.

In the CSFC database, side impacts are the second most important type of impact type in terms of the number of children involved. In this study, side impact represents 15.5% with 206 children. Out of these, 37% were uninjured, 43% sustained minor injuries and 20 % were severely injured. The analysis has been divided into two categories of children, the ones seated on the struck side and the ones seated on the non-struck side. 82 children were in the first category, with 33 uninjured.
A focus on the moderate injuries for children seated on the struck side regardless of whether or not they are restrained is given in Figure 9. The body area that was injured most often was the head with 42% and remains the priority. The amount of upper limb injuries is 29% and the abdominal injuries are represented by 19%.

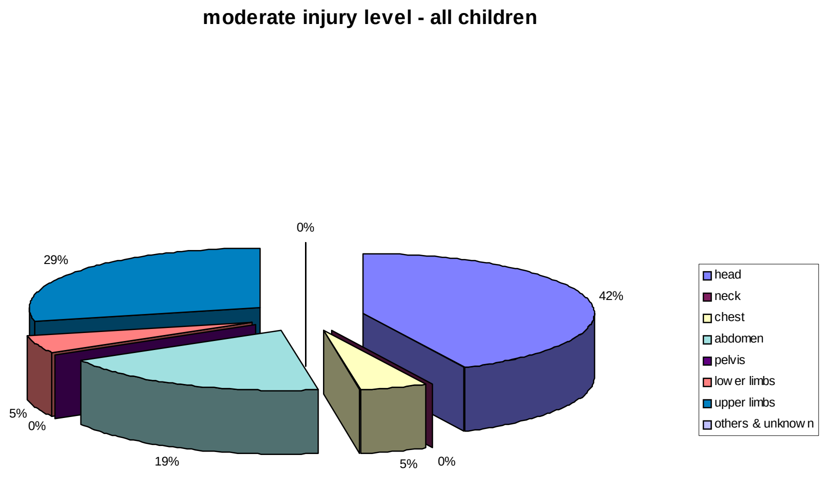

Figure 9: CSFC-96 : Moderate injuries distribution - struck side

Concerning the distribution of the body areas for moderately injured children involved in side impacts seated on the non-struck side, it is remarkable that when compared with children seated on the struck side frequencies are equivalent, with injuries to the head remaining around 40% and the injuries to the chest and lower limbs significantly increased. Severe injuries to the neck and pelvis have also been noted.
As the number of children severely injured in side impact is low, it was not possible to take this analysis further, especially with regard to the effectiveness of different restraint systems. What can be said is that injuries to the head remained very high and seemed to be around 75% of the total body area injured for children involved in side impacts who were restrained in forward facing child seats on the struck side. This reduced to around 50% under the same conditions but for a child using a booster cushion in addition to the seatbelt and around 40% for children using only the 3 point belt. The difference seen here is not only due to the restraint system but also to the difference in height of the children and corresponding impact areas with the interior of the vehicle.
A first draft analysis of the content of the CHILD accident database has been completed in order to see the influence of different parameters on the injury severity and the distribution of injuries on the different body segments.
It has been clearly indicated that intrusion was an important parameter on the injury severity level, and that the direction of the impact does not seem to make great difference on the protection of children. However, more focused analysis is necessary, taking into account the influence of the intrusion at the position where the child is seated for the different type of restraint systems, the influence of type of opponent object (vehicle/fix obstacle) etc., but this will be only conducted when the CHILD accident database is completed. Presentation of results is planned in June 2006.

Rear impact

For the rear impact configuration, CSFC-96 database is the only one to show the distribution of injuries on the different body segments.

On a sample of 83 children involved, about 60% sustained no injury, 30% were slightly injured and 10% received severe injuries. The distribution of the 47 body areas injured (all injury severities) for this configuration is shown in Figure 10. The head represents 30% of the total, which is the lowest number compared with other accident configurations, but it still remains the most important body

area injured. The number of lower limb injuries has increased and tends to be equal to the one of the head. Injuries to the neck make up 13%.
The sample is not important enough to focus on severe injuries occurring to children involved in rear impacts.

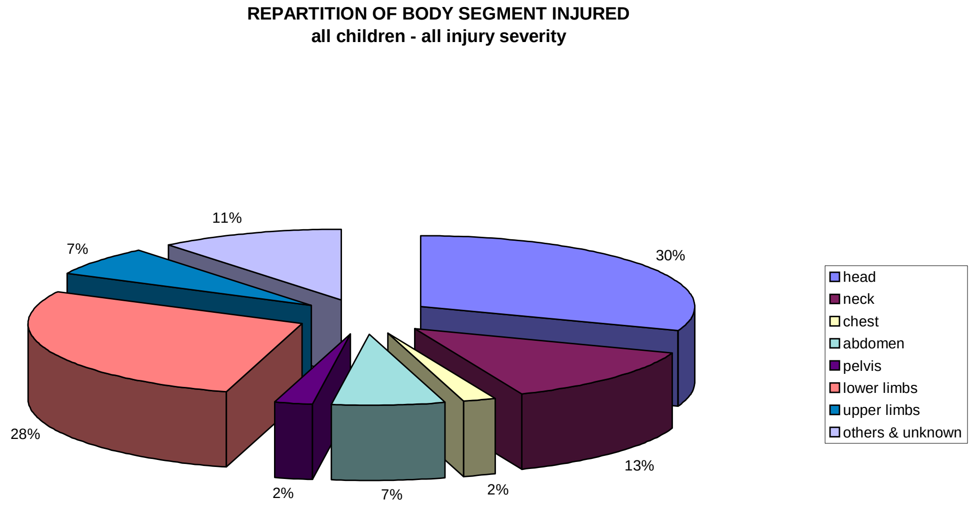

Figure 10: CSFC 96 - rear collision - injury distribution

Roll-over

For this configuration, only CSFC-96 database shows the distribution of injuries on the different body segments. The number of vehicles involved only in rollover in the CSFC96 database is 131, with 184 children involved in this crash configuration. Of this number, 73 were not injured, 35% were slightly injured and 26% sustained severe injuries. With 26% of the children sustaining severe injuries, this configuration is where the risk of severe injury to children is the highest, with side impact next (20%), then frontal impacts (12%) and finally rear impacts (10%).
Focusing on severe injuries, 66 body areas sustained injuries at this level and the distribution is shown on Figure 11.
Head injuries still remain the highest in number. For the upper limbs, the number is 23%. Neck injuries and abdominal injuries also have to be considered in terms of number and severity.

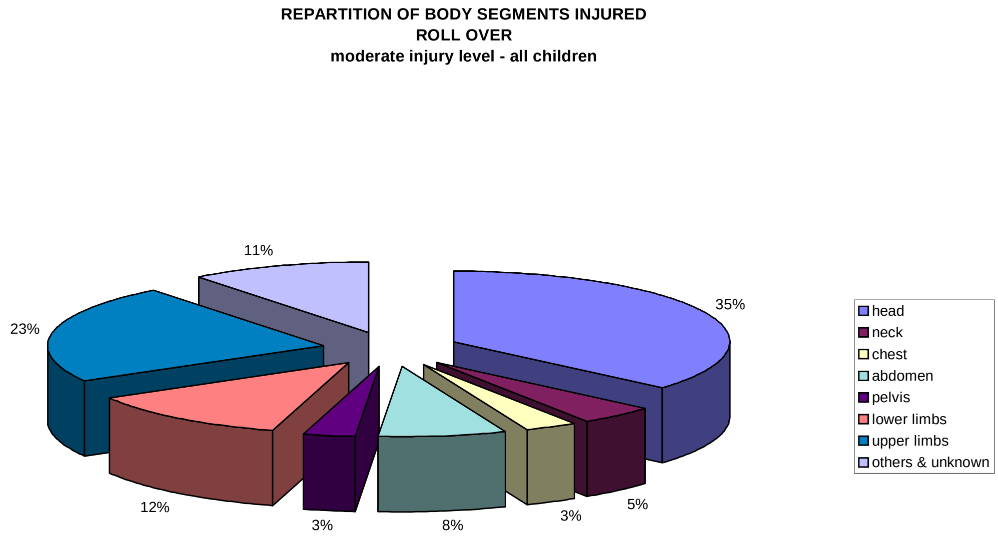

Figure 11: CFSC 96 - Roll over - moderate injuries / body segments

Recommendations

Whatever the direction of the impact, restrained children are better protected than not restrained. Protection is even better when using an appropriate CRS (Child restraint Systems). The main way of reducing the number of children killed or severely injured is to ensure they are appropriately restrained. This should be done using education, public information, in combination with law enforcement.

Another significant step for child safety would be to massively reduce misuse (wrong use of a CRS). Studies into real situations and the effects of misuses in accidents are necessary to quantify this (including the danger of interaction of child restraint systems with advanced restraint systems like airbags).

A large European database is necessary for in-depth analysis of different accident configurations, different types of restraint use and different levels of injuries. It would be even more interesting, if it were representative of the real world situation in Europe. Studies on evolution of the situation, in terms of rate of use of restraint, restraint design, car stiffness and the relative effect of these parameters on child safety in cars should be then more easily conducted.
For the moment, it has clearly appeared that general databases were not adapted for the study of the situation of children transported in cars. Specific research project on child safety have very detailed databases but the low size of the sample (less than 500) do not always allow an in depth analysis of the distribution of severe injuries for every type of impact.

Nevertheless, some databases are useful to show the size of the problem, and others are able to give main directions of efforts in order to enhance the protection of children in cars showing the most vulnerable body segments according the accident configuration.

It is necessary to have a more uniform way of data collection on different levels, first of all concerning the definitions and the data that is necessary to collect and secondly about the reliability of the collected data. The results obtained in the different countries and research projects could then be compared more easily.

Existing Restraint systems have been shown to be mostly effective, but have been designed to ensure a level of protection mainly in frontal impact. An important parameter in the protection of children in cars is that the correct use of an appropriate child restraint system should lead to the reduction in the number of severe injuries sustained by children as car passengers. In order to quantify this, it is necessary to have additional information detailing the exact rate of use of CRS and the proportion and types of misuse of these systems.

The different databases have shown that the head remains the most often injured body area. It is followed by the chest in frontal impacts and by the neck in side and rear impacts. This fact is true whatever the type of restraint system used.

Research programs are working on the subject, particularly the CHILD project in which an accident database is created containing data from the CREST project plus around 250 new accident cases. This will allow provision of severe cases for reconstructions and the definition of criteria based on child injuries. In addition, a report on the situation of appropriate use and misuse has been finalized at the end of the year 2003.

Information about child safety, provided for children, parents, teachers and the risks of injury has to be increased. This can be achieved through the development of new websites dedicated to that item and updated by specialists in child safety, information of pregnant women in clinics, public debates in nurseries, sensitization of children at school (at the age where restraint system use is decreasing).

ACCIDENTOLOGY IN COACHES AND BUSES

- [ToR: extended to include the situation in coaches and buses]

No European data is available, and IRTAD does not allow an analysis on child occupants of buses or coaches. Data from France, Germany, the United Kingdom and Italy have been analyzed. Very often this analysis is limited to the trends in the number of children killed yearly in buses and coaches. Sometimes it has been possible to have the distribution by age of children killed or injured. This has led to the conclusion that children are more involved in buses crashes due to a higher mobility. In addition, some children are using buses to go to school.
For protection in buses and coaches, specific legislation exists in some European countries, but there is no common position. The responsibility for children wearing seatbelt belongs to the driver of the bus in some countries but again, no common position exists.

Few detailed studies exist at this day in Europe:

ECBOS

ECBOS (Enhanced Coach and Buses Occupant Safety) is an European project which is studying bus and coach safety throughout Europe in general and although this research was valuable for the protection of adults, the project is not yet ready to make recommendations for the restraint of children of different ages in these vehicles.

Recommendations from the GDV (Gesamtverband der Deutschen Versicherungswirtschaft e.V.) study were that all buses should have three point belts for the protection of older children and adults; lateral windows should be laminated and deformable; roofs must be strengthened; recommendations were also made for emergency exits and for energy absorber interior trim.

CEESAR experience

From the early 80’s, CEESAR (Centre Européen d'Etudes de Sécurité, d'Analyse des Risques) makes an in-depth study for all bus and coach accidents which occurred in France. A new analysis of the database focused on children has been proposed and has been presented in October 2005 WG 18 meeting for discussion and validation in the WG18. Types of accidents or collisions, injury distribution, age and place of children, were studied. The study indicates benefits can be expected from seatbelt use in coaches for children.

- Recommendations from CEESAR for frontal impacts were:
    - Strengthen front structure of the coach;
    - Fit 3 point seatbelts in all seat; and
    - Eliminate hostess seat.
- For protecting occupants in roll over:
    - 3 points safety belts; and
    - Fit special lateral windows.

No information is available concerning the protection of young children, but the recommendation to limit the number of occupants to the number of seat has been made. A common practice in France up to now for the transportation of children was to allow to have three children in a row of two seats.

BUSBELT project:

This project (UK DfT) focused on child occupant protection in buses, minibuses and coaches, aimed at recommendations for restraint use for children of different ages traveling in these vehicles. Within the project, data are being gathered, according to age group to identify the exposure of child minibus, bus and coach passengers to traffic accident risk. Crash conditions will be established to identify those that are considered survivable, and to identify any circumstances where restraint induced injuries are or could be sustained by children.
The project plans to recommend and develop cost-effective measures of how to improve the safety of children of different ages in buses, minibuses and coaches including; various test protocols (dynamic and non-destructive), design solutions, numeric simulation, practicality of use and also a cost and benefit study. Some conclusions of this project are given below:

- The fit of adult belts is unacceptable for the majority of young children up to 8 years of age and some need CRS up to the age of 11.
- Poor fit is very likely to cause seatbelt induced injuries in accidents, by loading the neck and or soft abdomen.
- Appropriate CRS must be provided in minibuses and coaches.
- Many children will be unable to bend their knees due to the standard minibus and coach seat depth. Their feet foul the seat in front.
- This child group must be moved forwards in the seat or the seat base length must be adjustable.
- The use of PSVs by children and the numbers of fatal and seriously injured children in these vehicles are comparatively low.
- Rollover accidents have a higher rate of serious and fatal injuries, which are mostly linked to ejection. Retaining occupants through compulsory use of well fitting belts will be beneficial.

IDIADA research work:

IDIADA, funded by the Spanish Department of Road Transport, carried out a study based on the reconstruction of 8 severe accidents that occurred in Spain between 2000 and 2001 involving buses, which showed the reality of the protection offered to users. This study was the basis to identify problems and to propose efficient solutions. Occupant protection was studied in different positions within the vehicles.
The most relevant conclusion of the accident studies is a recommendation that adequate restraint systems for all occupants would reduce the severity of injuries and the number of fatalities in accidents (for adults and children). IDIADA presented a proposal for a system that could be compatible for adults and children from the age of 3 years. This was the result of work from a public funded project, where an integrated CRS for school transport was designed. The upper shoulder anchorage position of the 3 point belt was adjustable within the seat to enable use from the age of 3years to adult. When using the system for children between 3 and 12 years old, although it is intended to be used without any additional restraint system, an optimal protection could be achieved with the utilization of an additional booster seat.

Overall conclusions:

It is necessary to limit the number of children to the number of available seats in the vehicle.

The main impact types for buses and coaches are front impact and rollover:

- For the first type, energy absorption is necessary by the front structure of the vehicle. In addition, energy absorbing material should be used in the design of the interior of the vehicle in order to limit the risk of severe injuries when an impact between an occupant and one part of the vehicle occurs.

- The use of seatbelt should limit the projection of occupants inside of the vehicle. According the age of the occupant, the use of CRS should be required.
- For the rollover configuration, it is better, as the major risk to be injured is the ejection, to have all children (over an age to be further defined) restrained even with a two point belt than having them not restrained. For the younger ones, the use of an additional CRS should be required.
- Strengthening of the roof seems necessary for the rollover configuration.
- Lateral windows should be laminated in order to avoid ejection (partial or total) of occupants

Whatever the type of impact is seems that to have a restraint system properly used, retractor systems should be better than static systems.

As a summing up, it is accepted that it is essential to keep people inside buses and coaches in rollover accidents, so in general for older children and adults 3-point belts should be provided. At the same time buses and coaches should have lateral windows that can deform and are laminated, strengthened roofs, emergency exits and energy absorbing interior trim.
Recommendations cannot be made at this time for the restraint of young children as there is no currently a lack of knowledge in this area.
There is no requirement for ISOFIX in coaches, buses and minibuses. Further knowledge is needed in order to make recommendations for the restraint of younger children in buses, coaches and minibuses.
It has been proposed by this group to enhanced the knowledge of the kinematics of young children and the level of loads they have to face in coaches accidents according to the different restraint systems used and define what should be the best solution to be kept inside of the vehicle when a frontal crash occur (in the eventuality that it is followed by a tip-over or roll-over). For that a frontal crash test of a coach in a concrete barrier will be performed. It will be conducted with instrumented dummies in different restraint systems and on-board hi-speed cameras. It is possible that the results of this test are available before the end of 2005.

CHILD DUMMIES

The accidentology study as presented in first chapter describes the injury body segment repartition to the type of used CRS. In the same study, it also becomes clear that misuse is a serious threat for children in cars. To be able to improve the protection of children, several factors play a role. One of these factors is the child dummies. It is important that child dummies are good representatives of children with respect to anthropometry and biomechanics. The use of child dummies should give insight in misuse and provide measurements on dummy loadings in a dynamic test.

WG18 investigated the available child dummies with respect to misuse detection and if these dummies can reflect the loads as found in the field. This work has been done by reviewing research and regulations. Four specific subjects with respect to child dummies were considered as important for EEVC WG18 to report on. These subjects are:

- Shortcomings of selecting dummies for regulatory testing based on body weight only.
- Child dummy measurements.
- Injury criteria
- Common work with EEVC WG12.

Before the four subjects are described, first an introduction on the available child dummies is given, below.

Available child dummy families

Currently three child dummy families consist. The P-series and Q-series are developed in Europe. The CRABI dummies and the HIII child dummies are from US origin. In Europe the P-dummies are adopted in the regulation. In future, the Q-dummies may replace the P-dummies. The CRABI dummies and HIII child dummies are adopted in the US regulations. Below, each child dummy family is described.

The P-dummies were developed in the 1970's. The first versions became available around 1974 and a complete series consisting of a 9-month old (P¾), a 3-year old (P3), 6-year old (P6) and a 10-year old (P10) were available around 1976-1977. These dummies became official in 1981 when the European ECE-R44 [12] regulation came into force. Figure 12Figure 1 shows the P-dummy family.

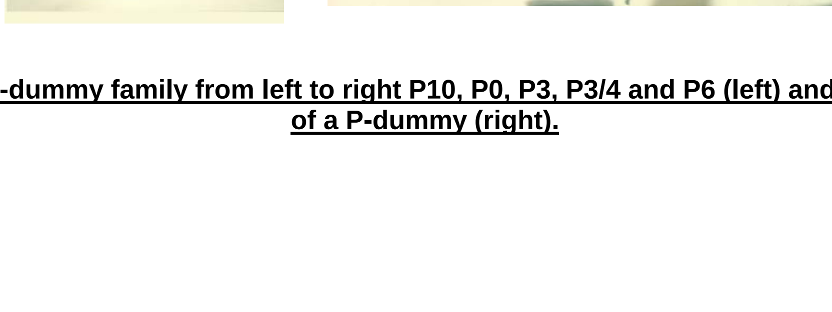

Figure 12: The P-dummy family from left to right P10, P0, P3, P3/4 and P6 (left) and the dummy parts of a P-dummy (right).

The P-dummy is essentially a loading device. It does have the correct body dimensions and total body mass. It doesn't meet current requirements for biofidelity, because it was developed before results of fundamental research on biofidelity and performance requirements for crash dummies had become available.
In 1988, a 5th dummy was added to the P-dummies representing a newborn child, the P0. Enhancements in CRS development and improved knowledge of occupant protection have led in 1995 to the addition of a 0+ group to ECE-R44. For the evaluation of this type of CRS, a 18-month old child dummy has been developed, it is called P1.5
The design of the P¾, P3, P6 and P10 is similar. These dummies consist mainly of steel covered with polyurethane. The design of P0 and P1.5 has a different design compared to the other child dummies. The P0 comprises a head, torso, arms and legs as a single unit. The head is polyurethane foam moulding covered by a PVC skin. The P1.5 consists of a plastic skeleton covered with flesh and skin simulating polymer. Unlike the other dummies in the P-series, the P1.5 dummy contains only few metal parts
The instrumentation of the P-dummies consists in tri-axial (or 3 uni-axial accelerometers) in the thorax, 3 and 6 channel load cells for the neck (except P6 and P10), 3 uni-axial accelerometers in upper spine and a modelling clay in the abdomen for evaluation of abdominal penetration.
Although rudimentary in design and limited in injury assessment capabilities, the present P-dummies have demonstrated realistic child like kinematics and good durability when used for ECE-R44 testing. Since 1982, manufacturers have used these dummies to develop and approve the child restraint systems for the European market.
However, now that more biomechanical data are available (based on adults) and more advanced test procedures are considered it is expected that the P-family soon no longer will meet current day needs. Therefore, in 1994 it was decided by TNO to develop a new series of dummies to replace the P-series.

The new child dummy series, called the Q-dummies, consists of five dummies: Q0, Q1, Q1.5, Q3 and Q6. They represent children in the age of 6 weeks, 12-month, 18-month, 3-year and 6-year old, respectively. Figure 13 shows the Q-dummy family.

Figure 13: The Q-dummy family: (from left to right) Q1.5, Q3, Q0, Q6, Q1, Q1 without suit, back of Q3.

The Q-dummies differ in many ways from the P- dummies that are used in regulation testing today. In particular, the Q-series is developed not only for front but also for side impacts. For their design, the latest biomechanical and anthropometrical data available on children is used. Specific design features of the Q-dummies are the anatomical representation of body regions, use of advanced materials, dummy-interchangeable instrumentation, multi-directional use (frontal & side impact) and easy handling properties (limited components, easy assembly/disassembly, and simple calibration). Full instrumentation options provided with the dummies have been based on a range of applications, notably R&D testing, airbag testing but foremost child restraint system certification.
The requirements for the dummies were set up by an international group of experts, working together in the Child Dummy Working group (CDWG). The group operated for a number of years, from 1993 to 1997 and monitored the development of the first dummy of the Q series, the Q3. With the start of the 4th framework CREST research programme, the group stopped its activities, as it was felt that the development and evaluation of the dummies could be addressed in the CREST program instead. Within the CREST project, three dummies were developed and used; these are the Q1, Q3 and Q6 dummy, which represent a 12-month, a 3-year, and 6-year old child. Although

the development of the Q3 was started before the CREST project, the experiences with the dummies in the tests performed by the CREST partners led to a number of improvements to the dummy. The Q6 dummy also profited from the experiences with the Q3 dummy in the CREST project. The Q1 arrived just before the end of the project. All these dummies will be used in the CHILD programme and even improved.
A QO has just been developed in the frame of the CHILD project and it will be highly evaluated in this project for full-scale reconstructions of actual accidents involving restrained newborns. The Q1.5 is the newest member of the Q-dummy family. It became available in 2003.
The segment masses and the main dimensions of the Q-series are slightly different from the manikins as defined in ECE-R44 which are based on the P-dummy anthropometry. The Q-dummy family, however, is based on a more recent anthropometric database (CANDAT). One of the objectives for the development of a new child dummy series was to extend the measurement possibilities. Therefore, the Q-dummies are provided with numerous instrumentation tools compared to the P-dummies. Their instrumentation is described in the Table 6.

Instrumentation		Dummy		
Type	**Position**	**Q0**	**Q1/Q1.5**	**Q3/Q6**
3-axis accelerometer	head	X	X	X
	chest	X	X	X
	pelvis	X	X	X
6-axis loadcell	upper neck	X	X	X
	lower neck			X
	lumbar spine		X	X
3-axis angular rate sensor	head		X	X
displacement sensor	chest		X	X

Table 6: Instrumentation of the Q-dummy family

The response of the current Q dummies in frontal and side impact is acceptable, but for each impact direction, not the optimal design solution. This means that some parts might have to be improved to make the dummy suitable for a different impact loading direction. In future, the Q-series could be world harmonised for child side impacts.

Besides these dummies, which are mainly used in Europe, there are other child dummy families, in US. These are the CRABI dummies and the HIII child dummy family. Figure 14 shows one of the CRABI dummies and one of the HIII child dummies.

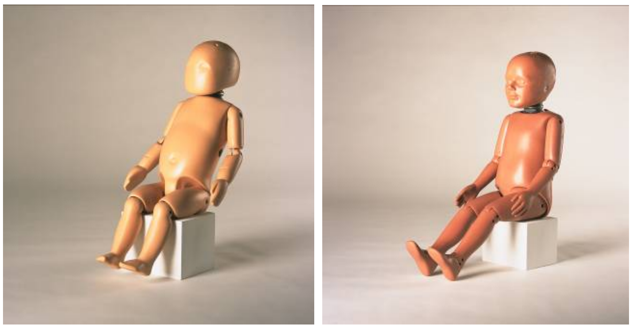

Figure 14: The CRABI 12 months old (left) and the HIII 3 yr old (right) dummies.

The CRABI dummies were developed to evaluate small child restraint systems in automotive crash environments, in all directions of impact, with or without air bag interaction. There are three dummies available: 6-month, 12-month and 18-month.
The 6-month allows measurement of tri-axial head acceleration, as well as angular head acceleration (1 channel) neck forces and moments for both upper and lower neck, chest tri-axial

acceleration, lumbar spine forces and moments (6 channels) and pelvic tri-axial acceleration. The 12-month and 18-month have the same instrumentation and, more, it is possible to measure shoulder forces (2 channels each) and pelvic (pubic) forces (2 channels).

The Hybrid III child dummy family consists of three dummies: a 3-year old, a 6-year and a 10-year old. The 3-year and 6-year old were originally developed in 1992 and they went through a complete upgrade in 1997, to enable to evaluate airbag aggressiveness when a child is close to a deploying airbag.
The OOP test procedures require the dummy to accurately measure neck loading, chest compression and the viscous criterion, while being durable and repeatable in these severe test conditions. They are equipped with tri-axial accelerometer pack in the head and one accelerometer for measurement of head rotation, Optional upper and lower axis neck load cells are available. Accelerometers are provided in the torso for measurement of viscous criterion in frontal impact. Bi-axial shoulder load cells are available. There is also an optional 6-axis lumbar load cell. A tri-axial accelerometer is mounted in the rear of the pelvis. For the 3-year old, a lateral neck has been developed.
The development of the 10-year old is more recent. It is designed to represent the population between the 6-year old and the small adult female for booster seats evaluation and airbag OOP testing, to evaluate the potential for injury from deploying airbags for those crashes while the airbag is not deactivated. A tri-axial accelerometer pack located at head centre of gravity enables the calculation of the HIC. Optional six-axis upper and lower neck cells are available. To measure chest deflection, the dummy is fitted with the rotary potentiometer and transducer arm as standard. Optional shoulder load cells can directly measure applied load cells. There is an optional six-axis lumbar load cell. A tri-axial accelerometer is mounted in the rear of the pelvis.
HIII child dummies will be used for frontal approval testing in US in the coming months.

In conclusion, none of the newest dummies is perfect. HIII child dummies are performing well in frontal impact but were developed for the US standard. The Q-series, which have been designed for both frontal and lateral impacts, is also performing well but have to be improved to be omni-directional.

Shortcomings of selecting dummies based on regulatory testing based on body weight

Child dummies are used for certification of the child restraint systems (CRS). In all certification test procedures, the CRS are classified into categories according to ranges of weight of the dummies. Table 7 shows the classification of CRS and dummies as defined in ECE-R44.

Mass group	Allowed weight of child	Test dummy	Max. weight of test dummy
0	< 10 kg	9 months	P¾, 9 kg
0+	< 13 kg	18 months	P1.5, 11 kg
I	9-18 kg	3 years	P3, 15 kg
II	15-25 kg	6 years	P6, 22 kg
III	22-36 kg	10 years	P10, 32 kg

Table 7: Classification of CRS and dummies as defined in ECE-R44.

For marketing reasons, it has become popular among manufacturers to have a very wide weight interval for child restraints. Unfortunately there is no need for the dummy to actually fit into the seat. The test regulations are such that the integral harness is allowed to disappear well beneath the shoulders and the centre of gravity of the head may be well above the seat back. The chest measurements are not affected and the product will pass the test. Today, it is not uncommon that the largest dummy used to test the seat does not fit according to the manual.

Figure 15: The P6 dummy doesn't fit into these group 2 seats. The P1 ½ doesn't fit into this group 0+ seat either.

The instructions manual requires a correct installation of the child into the child restraint. In practise a child will often have to be considerably overweight to actually reach the upper weight limit of the seat. Since the only information the parents have, when they buy the seat, is the weight limits, they will feel mislead when the seat is outgrown much earlier than expected. It is also important that the seat type reflects the needs of the child. A newborn baby needs a lot of support but a one year old prefers an upright position. Parents often have difficulties to foresee that their tiny frail little sleeping baby will be sitting without support half a year later. One of the basic ideas with the 0+ seats is to make sure that it is possible to have the child rearward facing during the first year. In practise, this is often not possible with a seat that only allows a baby inclination. The one-year-old toddler is simply too uncomfortable in the inclined position. A 0+ seat needs to be rather upright or have more than one possible inclination to be useful for the one year old.

Using the stature of the child rather than the weight will solve the problem that the seat is outgrown much earlier than expected. Children within the same age group also tend to vary less by length than by weight. The risk of misuse is also smaller if stature is used. The sizes of children's clothing are often given in centimetres (stature of the child). If the child restraints are marked with stature sizes it is very easy for the parents to make sure that they are using the restraint properly. Today parents must remember how much of the head is allowed to be over the seat back and how the integral harness should fit the shoulders. Since most children are fairly proportional, it is possible to give stature intervals for each pair of slots in the seat back as well as a maximum stature for the seat.

The dummies are representative for normal sized children both in length and weight. There is no need for new dummies if stature is used instead of weight. The diagrams show the size of various dummies (dots) vs. the size of children (lines). Unbroken lines represent the 50-percentile children and 5-percentile and 95-percentile are represented by dotted lines. Girls are drawn in red and boys in blue colour. The length is a good measurement also because most children will follow their "curve" rather well after a few months. This is not entirely true for babies that are premature (born early) or born very small (multiple births for example). In most cases, however, the parents will have a good prediction from early on if they need a seat for a tall child or not. Since a high rearward-facing seat can be more difficult to fit into a car the larger seat will not automatically suit all families.

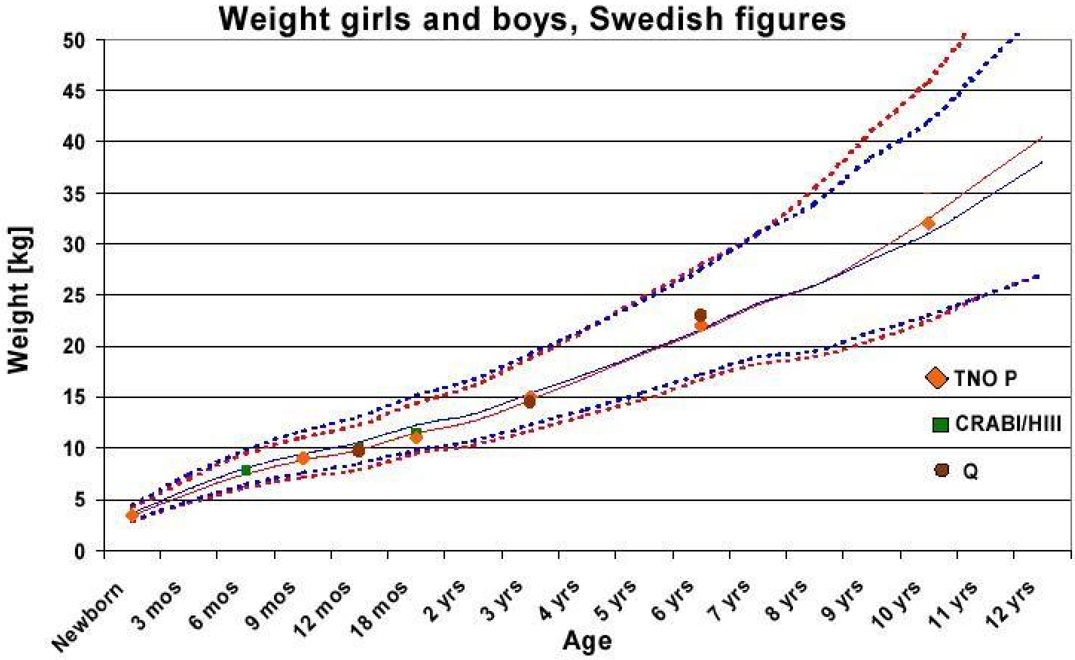

Figure 16: The weight of Swedish children compared to international dummies. The Swedish figures do not vary much from international figures. The 5- and 95-percentiles are the dotted lines. Note that the weight span is relatively large compared to the length span (Figure 17).

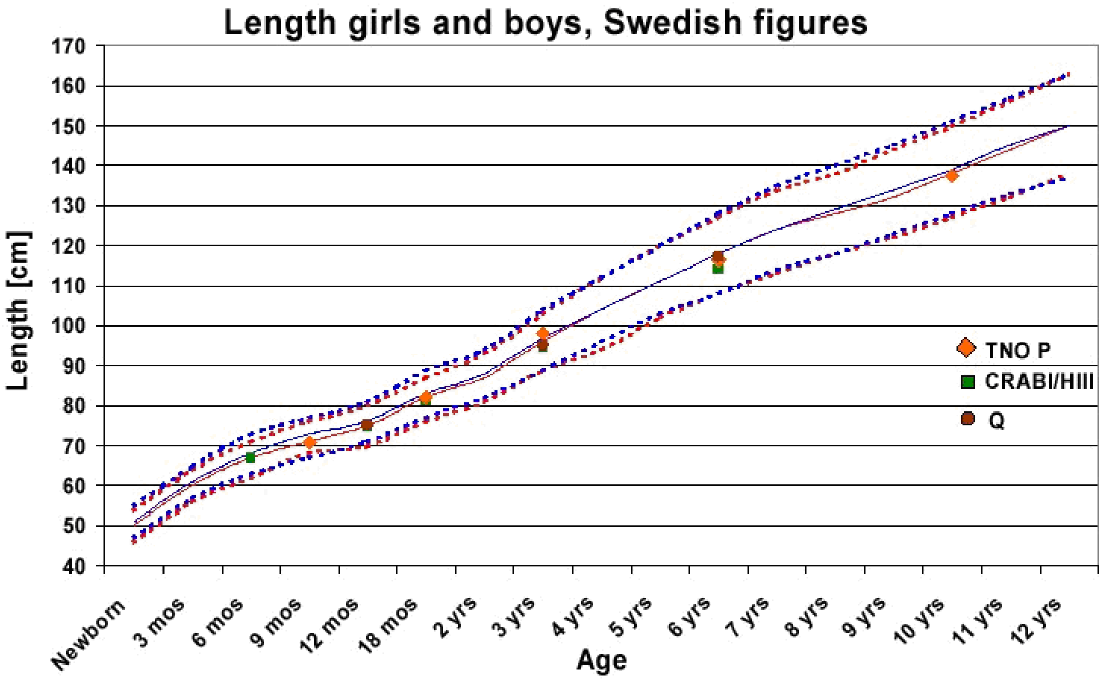

Figure 17: The length of Swedish children compared to international dummies. The Swedish figures do not vary much from international figures.

In the test procedures, It is required that the tallest allowed child will fit the seat. There are two major limitations that can make a restraint too small for a child: the top of the head and the height of the shoulder. If either the integral harness or adult belt guiding drops below the shoulders or the top of the head is too far above the seat back the seat doesn't fit the child. From a sitting position, there is a good correlation both between the height of the shoulder and the top of the head to the stature. That is, we can measure the seat and calculate a stature.
Once the statures are defined the dummies needs to be chosen. If we allow the same weights and dummies as today, Table 7 can be replaced by a stature table as shown in Table 8.

Mass group	Allowed max. stature of child	Max. weight/length of test dummy	Corresponding age to max. sized child
0	75 cm	9 kg / 71 cm	11 months
0+	87 cm	11 kg / 82 cm	2 years
I	107 cm	15 kg / 98 cm	4,5 years
II	126 cm	22 kg / 117 cm	7 years
III	138 cm	32 kg / 138 cm	11 years

Table 8: Classification of CRS and dummies using stature

Conclusions
Stature is more relevant than weight for the parents as they buy clothing for the children with length sizes. To increase safety even further, the stature intervals can be written between the slots for a seat with an integral harness or guiding for the adult belt. The seat can easily be measured to check that the stature intervals recommended by the manufacturer are correct. There is no need for new dummies if we choose to use stature instead of weight intervals. There is no obvious need for groups but it is important to emphasise that the seat must meet the needs of the children it is intended for. E.g. a newborn can't sit 90º upright whereas the one-year-old toddler prefers the upright position.
Taking into account the fact that there is no need to change either the dummies or any part of the test set up, it should be fairly easy to implement this amendment.

Dummy Instrumentation

All the dummies offer measurement capabilities more or less extensive according to the time where they were developed and the range of applications in which they are intended to be used. The priority is obviously to get measurements on the body parts that are the most frequently and seriously injured in actual accidents.

The first part of the report, which describes the state of the art of European accidentology, indicates that whatever the impact direction considered, the head remains the body area the most injured. This is followed by the chest in frontal impacts (often slight injuries, resulting of the interaction of the restraint t system itself and the child) and by the neck in side and rear impacts. Also severe neck injuries are found for small children in forward facing CRS in frontal impacts.
When comparing the injuries occurring to children using a booster cushion and a seatbelt to those using only the adult seatbelt, a lot of abdominal injuries were observed in the cases without booster cushion. In addition, there were more severe chest injuries sustained by children using only the adult seat belt.
With all kinds of CRS, limbs fractures (upper and lower) were observed.

On the basis of these data, it is clear that there are priorities for the body segments that have to be instrumented both for frontal and lateral impact configurations:

- the head with at least a tri-axial accelerometer, (or three uni-axial accelerometers attached orthogonally on a common mounting block) to measure linear acceleration of the head (though there is no requirement in terms of acceleration or HIC in the actual European regulation),
- the neck with load cells allowing measurements of forces and moments, at the upper and lower neck positions,
- the thorax, which must provide at least acceleration measurement, as there is a requirement in the European regulation. Most pertinent could be the measurement of deflection of the thorax, which is now available on the new series of Q dummies,
- the abdomen, severely injured in case of submarining of the child, should be equipped with a transducer measuring either the penetration in the abdomen or the pressure. Until now sensors were developed but they were used for research purposes only. New sensors are being developed in the frame of the European CHILD project for the Q dummies.

As described in the first paragraph, the Q-dummy family has the most extensive set of instrumentation which covers the needs as expressed above. Only the abdominal sensor is under development. The HIII child dummies almost meet the priorities as given above. These dummies are limited in measuring chest deflection and an abdominal sensor is not yet under development. The P-dummies are very limited in their measurement capabilities. Mainly accelerations can be measured and some of these dummies can be equipped with a neck load cell.

Injury Criteria For Child Dummies

In the actual regulations, there is few injury criteria required in order to assess the child restraint systems.
In the ECE R44, there is only a limitation on the resultant thoracic acceleration and on the vertical component of this acceleration. No injury criteria for the head, the only requirement is on the head displacement.
It is the same in the US FMWSS 213, with however also a limitation on the HIC value, head and knees excursions. Last evolutions of this regulation took place in August 2005.

The ISO/TC22/SC12/WG6 edited a technical report (ISO/PDTR 7861) that gives injury risk curves to evaluate occupant protection in frontal impact, for both adult and child. These curves can be used by regulatory authorities, as well as car manufacturers to set occupant protection levels based on the injury risk which they believe are acceptable for the frontal collision being simulated. However, no limits are given because it is ISO TC22 position that the setting of performance levels is the responsibility of the regulatory authorities, and not of ISO.
There is no risk curve for the child head. As regards the neck, three normalised risk curves for AIS 3+neck injury based on measurements made at the occipital condylar joint for tension-extension neck loading are given for CRABI and HIII dummy families. Scaling, taking into account geometrical factors as well as failure stress allowed establishing them. Corrections are available for the HIII family for muscle activation, based on static strength tests. An example of such curve is given in Figure 18.

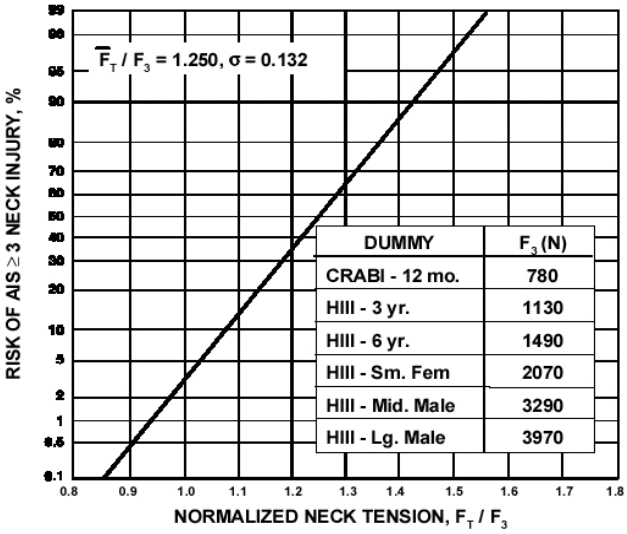

Figure 18: Risk of AIS> 3 neck injury for CRABI and Hybrid III dummy families as a function of the peak normalized neck tension.

For the thorax, there are two types of thoracic loadings for which injury risk curves have been developed: shoulder belt loading with and without airbags, and distributed thoracic loading such as produced by airbags without belt. The risk of AIS>4 thoracic injuries are given for these child dummies as a function of the peak viscous criterion, the sternal compression and the peak rate of sternal compression.
The other risk curves (lower limbs) are given only for adult.

In the frame of the European CREST programme, preliminary risk curves were established for some body segments, for the Q dummies, in frontal impacts.
An in-depth analysis of the full scale reconstructions compared to the corresponding actual accidents made possible to associate the pertinent measurements to the levels of observed injuries in the actual accidents, in order to constitute injury risk curves.

For head, thorax and pelvis, the analysis was done directly by comparing AIS levels of injuries with measurements (for instance head accelerations or HIC in relation with head AIS). For the neck, a more detailed analysis of injury mechanisms was made in order to associate the good physical parameters to each kind of injury. For instance, a dens fracture was associated to flexion or shearing, whereas spinal cord damage was associated to flexion and traction.

All results of reconstructions and sled tests were analysed and used to construct injury risk curves. Since accident cases concern several ages, data were scaled to 3 years old, using geometrical and material failure factors.

Figure 19 gives the level of AIS in relation with the HIC (36 ms) value corrected for 3 years old for frontal impact. Only results with Q dummies (and P1 ½, which is closer to Q than to P dummies) were used for the definition of injury risk curves. The curve was constructed using the certainty method and is shown on Figure 19 for AIS 3+.

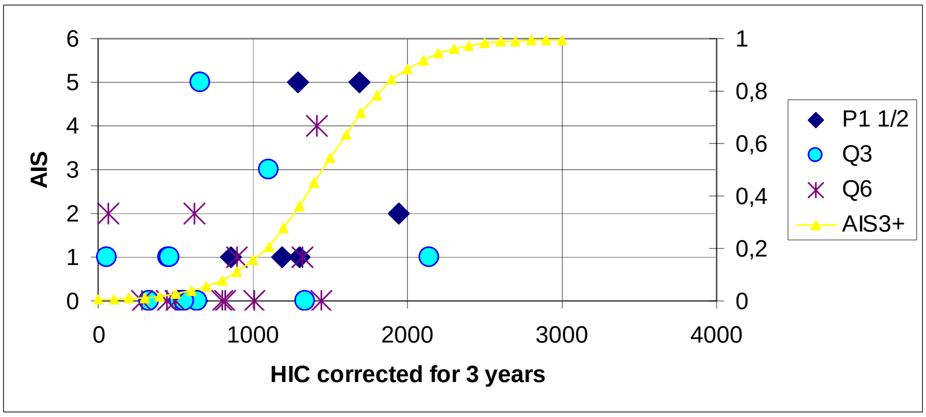

Figure 19: AIS 3+ Injury risk curve for HIC (3 years old)

For the neck some data were available, but it is clear that we are still missing results for the definition on injury risk curves, in particular cases with injuries.
For the thorax, an injury risk curve was established for AIS 2+ injuries, using a logistic regression with all dummies.

As regards side impacts, there were no sufficient data to establish confidently risk curves.
Complementary data are necessary for both frontal and lateral impacts, for the segments the most often and the most severely injured. This should be obtained in the frame of the new European CHILD project, which started in September 2002.

Common work with EEVC WG12

The European Enhanced Vehicle-safety Committee (EEVC) wants to promote the use of more biofidelic child dummies and biomechanical based tolerance limits in regulatory and consumer testing. It initiates the assessment of new child dummies and criteria for child occupant protection in frontal impact. Therefore, EEVC WG12 and WG18 carried out collaborative research following four basic steps: (i) identification of child injury causation in frontal impacts based on real world data, (ii) completion and consolidation of the specifications of the Q-series of advanced child dummies, (iii) recommendation for new injury criteria and tolerance limits for frontal impact, and (iv) a validation test program based on ECE R.44 test conditions, comparing P and Q dummy performance in frontal CRS tests. For the latter part, eleven European organizations including OEMs, research institutes and child restraint manufacturers performed 300 tests covering 30 available child seats. These seats represent the majority of existing child seat categories on the European market.
EEVC WG18 is responsible for the first step, the child injury causation. The second and third steps are covered by EEVC WG12. Both WG's contribute to the validation programme. The first two steps, the validation programme and a first analysis are presented at the ESV conference in 2005 [14].

The main conclusions of the common work with respect to the dummies are that the Q-dummy biofidelity results are good, except for the (linear scaled) thorax requirement. The Q-measurements show good repeatability and the Q-dummies are durable for ECE-R44 and EuroNCAP test conditions. After the first analysis of the validation tests, it is concluded that the P- and Q-dummies show similar results with respect to ECE-R44 requirements. For CRS evaluation, the potential merits of the Q-dummy family lie in the extra measurement capabilities.

CONCLUSION

- The main priority to reduce the number of children killed or severely injured is to get them properly restrained in an appropriate CRS, and to limit misuses. A significant step could be done using education, public information, in combination with law enforcement.

- The review of child occupant injuries in cars related to CRS systems used in frontal impact has demonstrated that the whole priority should lie on protecting the head and neck from injury for infants and toddlers (Group 0/1), shifting to head, chest and abdomen as children grow up and starting to become taller (Group 2/3/adult belt).

- To reduce misuse and to solve the problem that the seat is outgrown much earlier than expected it is proposed to use the stature of the child rather than the weight. Changes to the ECE-R44 CRS classification table are suggested in this report.

- For Europe, the Q-dummy family can become the successor of the P-dummies in regulations. The Q-dummies have shown their biofidelity, repeatability and durability in the common work of EEVC WG12 and WG18. For CRS evaluation, their potential merits lie in the measurement capabilities.

- The work on injury criteria for Q-dummies and further analysis of the validation test programme are required before final conclusions can be drawn.

FUTURE WORK

Finalization of the common work on frontal impact:

- Establish injury criteria for Q-dummies
- Further analysis on validation tests
- Reporting to SC

Continue the co-operation between WG12 and WG18 focusing on side impact:

- Investigation of all available data for side impact.
- Share the work as for frontal part between WG 18 & WG 12,
- Proposition of a final draft of EEVC Steering Committee.

EEVC WG 18 members want to underline

It is necessary to continue the work on the following points:

- In the field of accident studies, special attention should be paid to new members from Eastern Europe, for which the situation of children in car accidents could be significantly different. A common methodology for collecting child accidents could also be proposed, in order to harmonize data sets and to enable better comparisons. A harmonized accident data collection in Europe could result in a significant database, usable, reliable, and statistically representative.
- The incidence of misuse and its effects on injury mechanisms should be better investigated, as well as the impact of the introduction of ISOFIX devices.
- The specific knowledge in accident research in coaches and buses must be improved
- The specific situation of the transport of handicapped children should be taken into account.
- The effects of the evolution of adult protection devices on the children protection should be taken into account.

REFERENCES

1. Tarrière C., Trosseille X., Ardoino P.L., Brun-Cassan F., Lesire P., Dejeammes M. CREST - Child Restraint Systems for Cars, Conference on Child Occupant Protection 2nd Symposium Proceedings, SAE P-316, Orlando, Florida, USA, November 12th, 1997 - Poster.

2. Brun-Cassan F., Lesire P., Brutel G., Trosseille X., Le Coz J.Y. Reconstructions of Actual Accidents Involving Restrained Children: The European « CREST » programme, in Proceedings of the 16th ESV Conference, Windsor, Canada, June 1st-4th, 1998, Paper N° 98-S7-P-15.

3. Schrooten M, Cassan F, Trosseille X, Child restraint system for children in cars - CREST results, Proceedings ESV, 17th International Technical Conference on Enhanced Safety of Vehicles, Amsterdam, The Netherlands, June 4-7, 2001, Paper No. 294.

4. Cuny S., Got C., Forêt-Bruno J.Y., Le Coz J.Y., Brun-Cassan F., Brutel G. The Effectiveness of Child Restraint Systems in France, Child Occupant Protection Symposium, SAE P-316, Orlando, Florida, USA, November 12th, 1997 - Poster.

5. EEVC WG 18, Child safety, Steering Committee report, London, December 2003.

6. Cassan F, Lesire P, Results of the EU-CREST Program & Aims of the new EU-CHILD Project, 1st international Conference “Protection of children in cars”, Koln, July 2003.

7. Grant R, Lesire P, Cassan F, Gehre C, CHILD Project, 2nd international Conference “Protection of children in cars”, Koln, September 2004.

8. Cassan F, Overview of present results of the ongoing EC-project CHILD, Child Safety APSN Workshop, Berlin, November 2004.

9. Cassan F, Lesire P, Gehre C, Grant R, Increased Knowledge of accidents in Europe and resulting safety measures, 3rd international Conference “Protection of children in cars”, Munich, 1st - 2nd December 2005.

10. Aldman B, Gustafsson H, Nygren Å, Tingvall C. Child restraints. A prospective study of children as car passengers in road traffic accidents with respect to restraint effectiveness. Acta Paediatr. Scand 1987; Suppl. 339: II:1-22

11. ISO /TR 13214 "Road vehicles - Child restraint systems - Compilation of safety regulation and standards"

12. R44 – 03, Uniform Provisions concerning the Approval of Restraining Devices for Child Occupants of Power-Driven Vehicles (“Child Restraint System”).

13. Bell Robert, Burleigh David, "An Empirical Comparison of the FMVSS213 and ECE 44.03 Standards for Child Restraints", Proceedings of the 2nd Symposium on Child Occupant Protection, 1997, SAE paper 973312.

14. De Jager K, Van Ratingen M, Lesire P, Guillemot H, Assessing New Child Dummies and Criteria for Child Occupant Protection in Frontal Crashes, ESV Conference, Washington, Jun 2005.