SEVENTH FRAMEWORK PROGRAMME

PROJECT DELIVERABLE

CASPER

CHILD ADVANCED SAFETY PROJECT FOR EUROPEAN ROADS

Grant Agreement number: 218564

Date of latest version of Annex I against which the assessment will be made: 31/12/2011

Deliverable No.	D.3.2.3
Deliverable Name	Report on Accident Analysis
Dissemination level	Public
Written By	Alan KIRK (Loughborough University, UK) Philippe LESIRE (GIE RE PR, France)
Checked by	Philippe LESIRE (GIE RE PR, France)
Approved by	Philippe LESIRE (GIE RE PR, France)
Issue date	16 October 2012

Please refer to this report as follows:

Kirk, A., Lesire, P., Report on Accident Analysis, Deliverable 3.2.3 of the EC FP7 Project CASPER (2012).

Keywords: Child occupant road accidents, Child restraint systems, Frontal impact, Lateral impact, Injury analysis

Left intentionally blank

EXECUTIVE SUMMARY

This document reports on work undertaken in subtasks 3.2.2 (Focussed accident data collection) and 3.2.4 (Data analysis and reporting) of the EC CASPER (Child Advanced Safety Project for European Roads) project.

There are two main objectives, to describe the information available from the road accident data collection activity of the CASPER project and its predecessors, CREST and CHILD, and to provide an analysis of the child accident data – within the constraints of the case selection criteria used. This work would not be possible without the contributions made to the road accident database by the participants in all three EC projects (CREST, CHILD and CASPER) – the data collection teams and sponsors of the data collection activities.

After an introduction to the work in **Chapter 1**, in **Chapter 2** the methodology behind the collection, review and recording of the accident data is presented. Importantly the case sampling plan that has been used during data collection is given. The real world accident cases are collected to ensure that information on child kinematics, injury causation, injury criteria and CRS performance (including misuse where understood) is available to the project in order to further activities in injury criteria, dummy/model development and the understanding of misuse. This has an implication for how the analysis should be interpreted as the database is not representative of the overall child car passenger crash population. However, the database does give an indication of which body regions are being injured in different CRS types or for different ages of children and gives insights into restraint conditions that lead to injury.

Chapter 3 presents the status and overall contents of the database indicting the number of data available from the three EC child occupant safety projects, CREST, CHILD and CASPER. The combined dataset is one of the largest collections of in-depth road accident data focused on restrained child occupants. Overall there are 1301 restrained children in the combined database, 954 in frontal impacts, 341 in lateral impacts and 6 in rear impacts. Of these restrained children, 30% have a maximum abbreviated injury score (MAIS) of 3 or above, or have fatal injuries.

In **Chapter 4** an analysis for frontal impacts is carried out using the more recent CHILD and CASPER cases, considering 483 restrained children, 37% using the adult seat belt only and 63% in additional CRS. When injuries are known, 45% have an overall MAIS ≥ 2 and 25% have a MAIS ≥ 3. Injury severity levels by body region for each CRS type are examined. Head injuries are important to consider for all CRS types in frontal impacts but the relative importance decreases from rear facing CRS through to children using just the adult seat belt. Neck injuries feature in this dataset only for forward facing harness systems, especially at the AIS ≥ 3 level. Thoracic and abdominal injuries are present for all forward facing restraints but particularly for booster systems, followed by just the adult seat belt. Likewise extremity injuries follow a similar pattern although upper extremity injuries fall away at the AIS ≥ 3 level. A relationship is observed between cases where misuse has been identified and higher rates of serious injury.

In **Chapter 5** an analysis for lateral impacts is carried out, also using the combined CHILD and CASPER database, considering 148 restrained children, 35% using the adult seat belt only and 65% in additional CRS. When injuries are known, 46% have a MAIS ≥ 2 and 34% have a MAIS ≥ 3. Struck side children have greater proportions of serious injury or fatality than non-struck side children. For these struck side children the rates of higher injury levels are much higher when there is direct

intrusion to the area in which they are seated. At over 300 mm of maximum intrusion, 68% of the 41 restrained children on the struck side are MAIS ≥ 2, 44% are MAIS ≥ 4 or have fatal injuries. Injury severity levels by body region for each CRS type are examined. For struck side children the head is the most important body region for all restraint types. At the AIS ≥ 3 level thoracic and lower extremity injury also feature for all restraint types except lower extremity for rear facing CRS. For the non-struck side the number of injured children is low but a similar pattern to struck side children is evident with head, thoracic and lower extremity injuries.

In **Chapter 6** the status of safety technologies in the database is reported. With the majority of children seated in the rear passenger compartment and most technologies focused in the front seats it continues to be difficult to collect a significant number of data regarding new safety technologies across all ages, restraint conditions and crash types/severities. There are still only 7 children using an ISOfix system in the database, 3 of them in the same vehicle. Eight cases are available of deployed passenger airbags and rear facing infant carriers. Whilst 5 of the children are reported as having survived, the children are very young and the brain injuries are likely to be important at a critical time of development.

The previous CREST and CHILD projects used the AAAM Abbreviated Injury Scale 1990 system for recording injuries. For CASPER all previous cases were changed from AIS90 to AIS98, and AIS98 became the primary injury recording system for new cases. Additionally, when possible, all new CASPER cases were also recorded using AIS2005 (updated 2008) for child occupants. In **Chapter 7** evaluations of the level of changes in injury severity between these recording systems are given. For the child sample the only substantial injury severity change from AIS90 to AIS98 has been an increase for femur fractures form AIS 2 to AIS 3. A comparison between the AIS98 and AIS2005 systems shows much larger differences with an overall shift towards lower injury severity for AIS2005. It is recommended that any future activities are coded with both AIS98 and AIS2005, to ensure consistency with previous biomechanics work and enable injuries in new road accident cases to be recorded as accurately as possible.

Chapter 7 is a discussion/conclusions section which includes directions for future work.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

The CASPER Project (Grant Agreement 218564) is partly funded by the European Commission under the EC 7th Framework Programme. This publication solely reflects the author's views. The European Community is not liable for any use that may be made of the information contained herein.

The authors would like to acknowledge the contribution made to the road accident database by the participants in all three EC projects (CREST, CHILD and CASPER) – the data collection teams and sponsors of the data collection activities.

Chalmers University, Sweden (represented by SAAB)	CHILD
FIAT, Italy (represented by ELASIS)	CREST, CHILD and CASPER
Applus+ IDIADA, Spain	CHILD and CASPER
Transport Safety Research Centre, Loughborough University, UK	CREST, CHILD and CASPER
Medical University of Hanover (MUH), Germany	CREST, CHILD and CASPER
PSA, France	CREST, CHILD and CASPER
RENAULT, France	CREST, CHILD and CASPER
GDV, Germany	CREST and CHILD
Ludwig-Maximilians-Universität München (LMU), Germany	CASPER
VFSB, Germany	CASPER

UK Loughborough cases, collected during the EC CREST/CHILD projects, include accident data from the United Kingdom Co-operative Crash Injury Study, collected up to 2006. CCIS was managed by TRL Ltd on behalf of the Department for Transport (Transport Technology and Standards Division) who funded the project with Autoliv, Ford Motor Company, Nissan Motor Europe and Toyota Motor Europe. The data were collected by teams from the Birmingham Automotive Safety Centre of the University of Birmingham, the Vehicle Safety Research Centre at Loughborough University, and the Vehicle & Operator Services Agency of the Department for Transport. The views expressed in this work are those of the authors and not necessarily those of the UK CCIS sponsors.

ABBREVIATIONS, TERMS AND DEFINITIONS

Definitions of the technical measures and terms used are given in the Methodology Chapter, Section 2.4.

AIS	Abbreviated Injury Scale
CASPER	Child Advanced Safety Project For European Roads (EC Research Project 2009 - 2012)
CDC	Collision Deformation Classification
CHILD	Child Injury Led Design (EC Research Project 2002 - 2006)
CREST	Child Restraint System for Cars (EC Research Project 1996 - 2000)
CRS	Child restraint system
EC	European Commission
EES	Equivalent Energy Speed
FF	Forward facing
HGV	Heavy Goods Vehicle
LGV	Light Goods Vehicle
MAIS	Maximum Abbreviated Injury Score
NFS	Not further specified
RF	Rearward facing
Shell system	Rear or forward facing CRS with harness

1. INTRODUCTION

1.1. Overall Background – WP3 and Task 3.2

It is important that the work of the CASPER project is both set in the context of the real world and is scientifically driven by real world data. This is generally the purpose of Work Package 3, but more specifically Task 3.2 concentrates on children in road accidents.

Task 3.2 makes studies at different levels for the protection of children transported in cars:

- the size of the issue,
- determining the main injury and fatality reasons,
- the restraint conditions,
- and crash configurations.

Injury mechanisms for restrained children are studied and reported.

1.2. Objectives of Sub tasks 3.2.2 and 3.2.4 - Road Accident Data Collection and Analysis

The primary **objective of subtask 3.2.2** is to collect road accident cases involving restrained child car occupants, with a good detailed understanding of crash severity and configuration and quality of restraint use. These cases are selected in order to provide real-world data that are essential to improve or to develop crash test dummies and models and to obtain injury criteria (WP1 and WP2). Accident data are used to validate injury mechanisms (physical and numerical).

The review of car accident investigations leads to proposed test procedures that are closer to the real travelling conditions of children than the test conditions currently used for the approval of CRS (integrated in the WP4 solutions). Also misuse situations observed in the road accident cases further the understanding of the effect of misuse on injury outcome and provide real world situations to feed into the misuse testing activities of CASPER. This data are integrated by WP4 in the proposed solutions.

The primary **objectives of subtask 3.2.4** are to analyse and to report main results by crash configuration and restraint type for restrained in the accident database.

2. METHODOLOGY

2.1. Process

Review

Rather than cases just being added to the database, CASPER has a process of review to ensure that cases are suitable to the scientific aims of the project and of sufficient quality. Importantly the combined experience of the group during case review adds to the quality of each case. Comments are made and discussions held regarding injury mechanisms, child restraint type, misuse situations and crash severity. If required, additional information has to be provided before deciding to include an accident in the database or to reject it.

Crash Conditions / Severity

In particular, during case review, consideration is made of vehicle structure engagement and involvement to understand the effect that crash circumstance (direction, intrusion, impact area) and severity has had on the injury outcome of the occupants. This is considered in parallel with occupant age, restraint conditions and restraint quality.

In particular the following are considered;

- Engagement of the crash energy management structures (frontal and side) and stiff structure involvement
- Comparison of injuries across occupants of vehicle
- EES and Delta V

Consideration of Misuse - Identification during Investigation

Misuse (use of CRS not according to user manual instructions) can be difficult to find in investigations – the priority is to remove the child from the vehicle for medical treatment as soon as possible. Certainly low severity misuse (for example, small level of seat belt or harness slack) is more difficult to assess after an accident than severe misuse as the evidence is less likely to present itself in terms of injury or physical damage to the CRS or vehicle. As CASPER is the third project to utilise a review process as described above a good level of experience has been established in the group in identifying severe misuse injury patterns and real world circumstances that can lead to misuse.

Examination of the CRS or evidence from photographs can indicate many misuse situations including; belt routing is incorrect, CRS is incorrectly in a position with a frontal airbag, harness strap height is incorrect, slack is present (both CRS to car and belts restrained children) and unexpected belt routing marks (if CRS is not still attached in the car) or for booster systems that are not necessarily directly fixed to the car.

Projection and excursion that is not in keeping with crash conditions can indicate poor restraint of either the CRS or the child. If the child restraint is reported as being ejected or found loose in the vehicle (by those immediately at the scene) it could be possible that belt routing for the CRS attachment to the vehicle is incorrect. Marks or damage to the door could indicate only attachment on one side. Extreme projection of the head (for example reaching the B pillar) with low or moderate crash severity can show problems with CRS or child restraint.

Unusual injury patterns that do not relate to expected restraint routing can show problems. For example, if detailed injury records mention thoracic bruising under the arm but nothing to the shoulder it could be possible that the seat belt is under the arm rather than over the shoulder.

Information from parents/carers (when appropriate and possible) regarding common travelling conditions can provide insight into misuse situations. For example, some parents will admit that the child typically repositions the seat belt away from the neck by putting it under the arm. Also background into the overall family situation can be informative. For example, an older sibling may have recently moved up from a group 1 harness seat to a booster seat, making the group 1 seat available to a younger sibling. This can be a reason for the harness straps being too high for the younger sibling, if the parents have forgotten to make the adjustment for the younger, smaller, child.

Even so the levels of misuse that are recorded in the database are lower than the actual levels (found during misuse field surveys) and it likely that at best the database is considering severe misuse, rather than being able to highlight slight misuse.

CHILD & CASPER children:	14% misuse positively identified
CASPER children:	20% misuse positively identified

Consideration of Inappropriate use

Inappropriate use is considered to occur when the restraint system used by the child is not approved for their weight / height (or age if height and weight are unknown).

The CRS type being used or just the use of the adult seat belt can clearly be identified as being appropriate, or not, if data is available regarding weight, height and age. Appropriate use can be more difficult to record if only age is available. In particular, whether it is appropriate for a 3 year old to be in a booster seat, as some children would not yet be 15 kg at that age whilst others would be exceeding 18 kg. Likewise, for older children, for example of 10 years old, it is not possible to be sure if the chid exceeds 36 kg or is above the height criteria for an adult seat belt only to be appropriate. Further information on how inappropriate use is considered is given in the table given in Section 2.4 (Definitions).

2.2. Sampling Criteria

The cases found in the CASPER dataset are not proportionally representative of the accident situation across Europe, or in individual countries.

The real world accident cases are collected to ensure that information on child kinematics, injury causation, injury criteria and CRS performance (including misuse where understood) is available to the project in order to further activities in injury criteria, dummy/model development and the understanding of misuse. To achieve this case selection, criteria are used that generally favour more severe cases, in terms of both injury severity and impact severity. To also provide a full range of data for injury criteria and an understanding across the injury severity spectrum, cases of high crash severity but low injury severity are also included.

Summary of selection criteria:

- At least one child up to and including the age of 13 years old in a passenger car designed for up to 9 occupants (case vehicle). Car-to-vehicle or car-to-fixed-obstacle accidents are considered.
- The child should be correctly restrained in a child restraint system (CRS) or adult seat belt. Cases with misuse can be included if the conditions of the misuse are well defined and possible to reproduce in a sled test or reconstruction.
- Frontal, lateral or rear impact (not just rollover)
- Rollover only crashes not considered. If rollover has occurred in combination with a frontal, lateral or rear impact, then the injuries must be clearly attributed to the frontal, lateral or rear impact.
- The child or another restrained occupant in the case car has at least an AIS 2 injury (AIS 2 concussion not included). If not:
    - a frontal impact must have a Delta V of at least 40 km/h
    - a lateral impact must have at least 200mm of intrusion with the child on the struck side
    - rear impacts reviewed on a case by case basis

Other than the inclusion of 12 and 13 year olds and rear impacts, the same set of criteria was used in the previous EC projects (CREST and CHILD).

Due to this selection process, the cases are generally more severe in terms of both injury and crash severity than would be seen in the overall child car passenger crash population. As an example of crash severity, 82% of restrained children in frontal impacts are in an impact with an Energy Equivalent Speed (EES – Definitions Section 2.4) over 40 km/h. For the overall child car passenger crash population in frontal crashes the crash severity would be lower. Similarly, in the general child crash population involved in lateral impact crashes, average passenger compartment intrusion would be much lower than the cases selected for the database.

The database does give an indication of which body regions are being injured in different CRS types or for different ages of children and gives insights into restraint conditions that lead to injury. It is important that any analysis carried out is set in the context of the selection criteria presented above.

2.3. Limitations of the Data

Although all teams follow up cases as thoroughly as possible it is not always possible to gather as much data as would be preferable. For example, for the restrained children with known injury severity the following is recorded:

Type of restraint:	99%	
Age:	100%	
Height or weight of child:	43%	of cases

Without contact with the parents, or if in a fatality this information is not recorded in the medical notes, it can be difficult to get height and weight of children and therefore there is a reliance on age in many cases for selecting testing dummies for further CASPER activities and suggesting if CRS use is appropriate.

2.4. Definitions and Procedure

Adult seat belt: When the restraint type is referred to as the adult seat belt the only restraint is the adult seat belt with no additional child restraint system

CDC: Collision Deformation Classification, an alphanumeric code to describe the nature and location of direct contact to a vehicle. Devised by SAE (Recommended Practice J224b).

Child: Occupant of car up to and including 13 years of age

CRS: Child restraint system (additional to the vehicle or integrated)

Restrained: Using a child restraint system or adult seat belt (includes inappropriate use or misuse)

Appropriate use: Restraint system used by child is approved for their weight / height (or age if height and weight are unknown). Table 1 gives the rules used to code children on the database as being appropriately or not appropriately restrained

CRS type group	Approved weight (kg)	Height (cm)	Age (expert)
Rearward facing infant carrier group 0	<10	-	up to 12 m
Rearward facing infant carrier group 0+	<13	-	up to 18 m
Carrycot group 0	<10	-	up to 12 m
Forward facing group 1	9 to 18	-	from 9 m up to 47 m
Rearward facing group 1	9 to 18	-	from 9 m up to 47 m
Booster group 123	9 to 36	-	from 9 m up to 11 y
Booster group 23	15 to 36	<140 cm	from 3 y to 11 y
Booster group 3	22 to 36	<140 cm	from 5 y to 11 y
Group 2	15 to 25	<140 cm	from 3 y to 6 y
Adult seat belt	>36	>140 cm	from 12 y and more

Table 1: Rules for the coding of appropriate use

Misuse: Use of CRS not according to user manual instructions

Shell system: CRS designed to be used with a harness or a shield to restrain its occupant, rearward facing or forward facing

Struck side: The side of the vehicle on which the main impact occurred during the crash

Direct intrusion: The occupant is in the area in which the car sustained deformations due to a contact with an external object/obstacle or another vehicle

AIS: All Injuries are coded according to the Abbreviated Injury Scale (AIS) (AAAM, 1998) and in CASPER are doubly coded to AIS 2005 (updated 2008)

MAIS: Maximum Abbreviated Injury Score, the highest injury score for the occupant to any body region. Can also be connected to a particular body region to give the highest injury score for that body region - for example, MAIS (thorax)

EES: Energy Equivalent Speed, the equivalent speed at which a particular vehicle would need to contact any fixed rigid object in order to dissipate the deformation energy corresponding to the observed residual crush. (ISO/DIS 12353-1:1996(E))

Sample Size: The sample sizes in the analyses presented may differ slightly from overview statistics. This is due to different filtering and different focuses in each analysis. For instance, a case may be filtered out if a variable pertinent to that investigation is not available (e.g. side structure intrusion)

3. OVERALL OVERVIEW OF DATABASE

3.1. Introduction

The CASPER accident database includes cases from the previous EC child safety studies CREST and CHILD. The fundamental case selection criteria are the same for all three projects (see Section 2.2), the only changes for CASPER being the inclusion of 12 and 13 year olds and rear impacts (although the rear impact numbers are low).

Rather than an analysis of any particular area this chapter is a statement of the data that are available in the accident database regarding overall numbers, source of the data and overall injury levels. Further chapters will focus on frontal and lateral impacts.

3.2. Overall Case and Occupant Numbers

Table 2 gives an overview of the case numbers and number of restrained child occupants from each project (children who are not restrained appear on the database when they are in the same vehicle as a child who does fit the sampling criteria but are not considered here). Restrained children are up to and including 13 years old.

EC Project	Cases	Vehicles	Overall Occupants	Restrained children	Vehicles with restrained children
CREST	405	746	1832	645	432
CHILD	264	465	1146	431	279
CASPER	137	251	611	225	152
Total	806	1462	3589	1301	863

Table 2: Overall Case Numbers – All Impacts

Table 3 shows the number of restrained children distributed by impact type and the general restraint type used – child restraint system or adult seat belt only.

EC Project	All Impacts		Frontal		Lateral		Rear	
	Seatbelt Only	CRS	Seatbelt Only	CRS	Seatbelt Only	CRS	Seatbelt Only	CRS
CREST	220	425	165	306	55	119	0	0
CHILD	166	265	117	196	49	68	0	1
CASPER	74	151	61	109	10	40	3	2
Total	460	841	343	611	114	227	3	3

Table 3: Restrained children by impact type n=1301

If the CHILD and CASPER cases are combined, 34% of the 656 restrained children in the resulting dataset are from cases collected in the CASPER project and 66% from the CHILD project.

Table 4 shows the same information but for restrained children where the MAIS is known to be 3 or above or injuries are fatal.

EC Project	All Impacts		Frontal		Lateral		Rear	
	Seatbelt Only	CRS	Seatbelt Only	CRS	Seatbelt Only	CRS	Seatbelt Only	CRS
CREST	71	110	51	73	20	37	-	-
CHILD	34	78	16	51	18	26	0	1
CASPER	20	71	14	53	5	16	1	2
Total	125	259	81	177	43	79	1	3

Table 4: Restrained children by impact type – MAIS ≥ 3 or fatality n=384

If the CHILD and CASPER cases are combined, 45% of the 203 MAIS ≥ 3 or fatality injured restrained children in the resulting dataset are from cases collected in the CASPER project and 55% from the CHILD project.

3.3. Type of Impact (Restrained Children)

Figure 1 gives an overview of the type of impact for the restrained children in each project. The impact used for analysis is the one that had the most influence on the injury outcome of the children in the vehicle. This is judged during case review of the accident, where the effect of multiple impacts or any rollover on injury outcome is also evaluated.

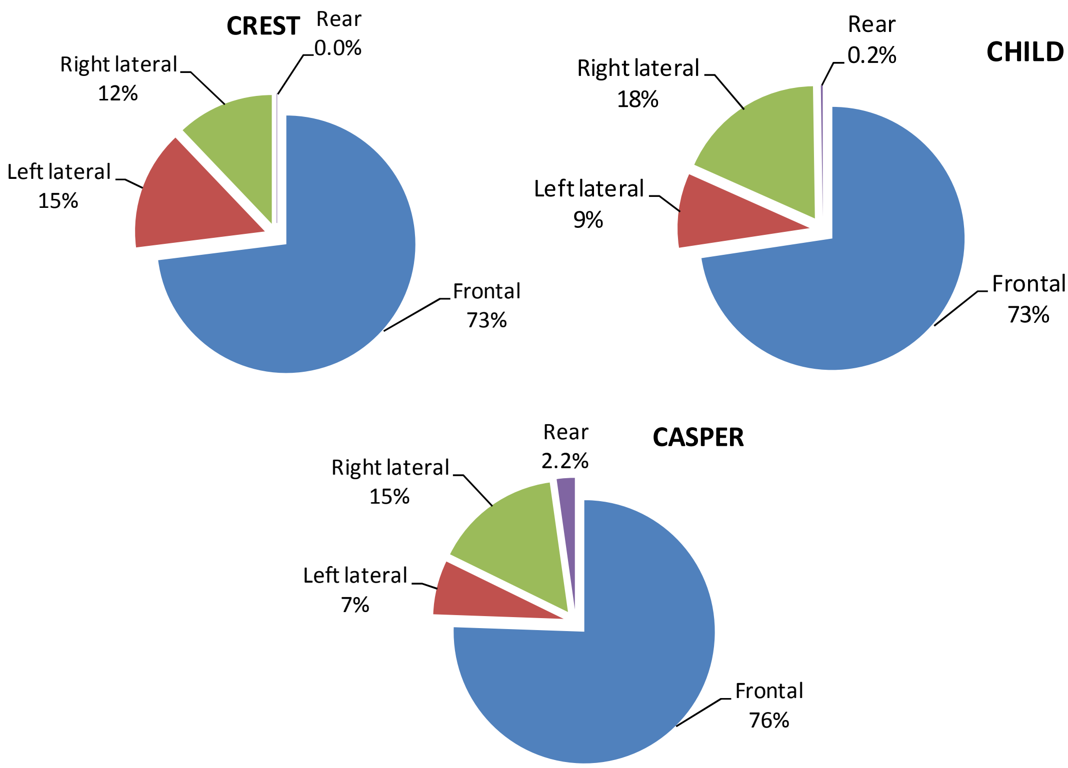


Figure 1: Type of Impact – CREST, CHILD and CASPER Datasets

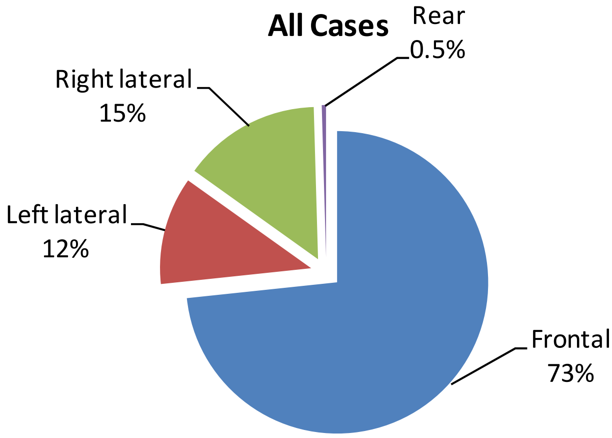


Figure 2: Type of Impact – All cases n=1301 (restrained children)

Overall, around one quarter of restrained children are in lateral impacts for each project dataset. In the CHILD and CASPER projects twice as many restrained children are in right side lateral impacts than left side lateral impacts.

4. FRONTAL IMPACTS

4.1. Introduction

The accident database has available the cases of the combined CREST, CHILD and CASPER datasets to inform the development of injury criteria and the understanding of injury causation. Crashworthiness in frontal impacts has improved due to new testing programs. For the analysis of frontal impacts in this section the CHILD and CASPER data, which is more recent than CREST data, are utilised to investigate the most injured body regions. Whilst it is recognised that CHILD cases are not particularly recent – the project ran from 2002 to 2006, with cases that occurred before this being entered as well – it is considered by the authors that the majority of cars are of a 'EuroNCAP' generation with vehicle structures and core restraint systems that are recognisable in more modern cars. Likewise, the CRS designs in the CHILD dataset are generally of designs that are recognisable today. Although improvements have of course been made in CRS designs and materials there has not been a step change in design that makes the CRS present in the CHILD dataset look particularly out of date. Although it is recognised that individual products have of course introduced novel features.

Of the combined CHILD and CASPER database, 483 restrained children are in frontal impacts, 73.6% of the total (656).

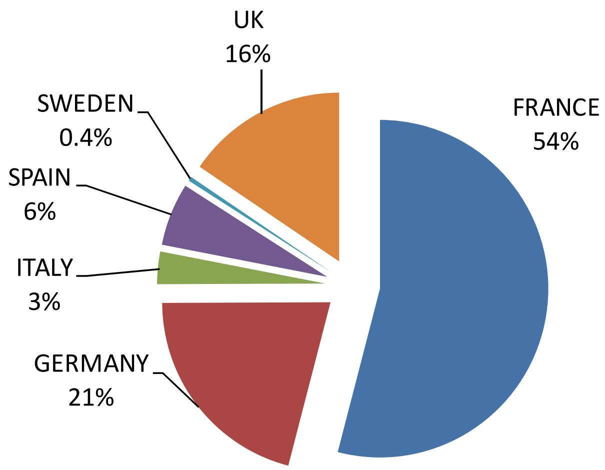


Figure 3: Distribution of restrained children by country of origin – Frontal impacts n=483

Figure 3 shows the country of case origin for the 483 restrained children in frontal impacts.

4.2. Crash and Restraint Parameters

Crash Opponent

Figure 4 and Figure 5 show the distributions of crash opponent for restrained children in frontal impacts, the first for all restrained children and the second for MAIS ≥ 3 restrained children or those with fatal injuries, sometimes with injuries not known (Section 4.3 for more detail).

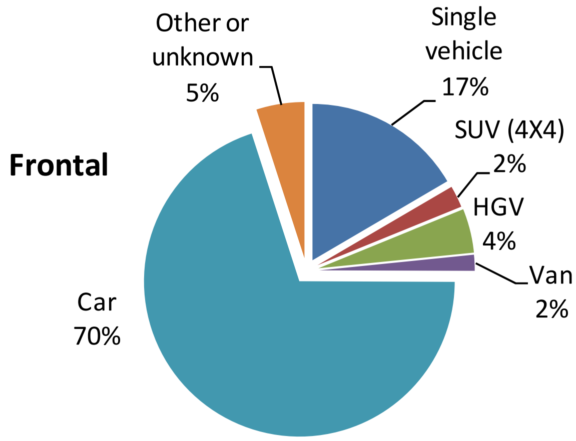


Figure 4: Distribution of crash partner – Restrained children n=483

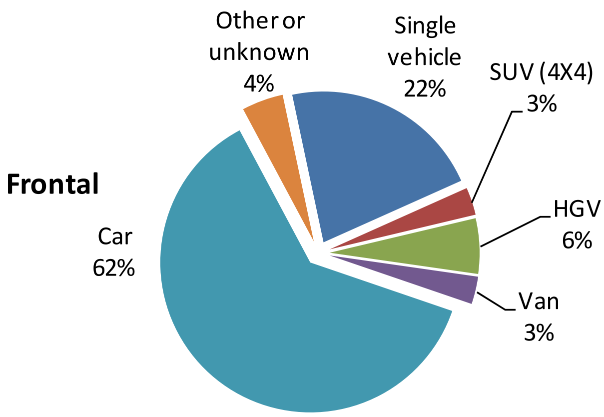


Figure 5: Distribution of crash partner – Restrained children, MAIS ≥ 3 or fatality n=134

Whilst in both figures another car is the most often struck opponent when the sample is shifted to serious and fatal injury the proportion of cars reduces, with an increase in the second most frequent category of single vehicle impact (with obstacle). When the crash opponent is not another vehicle, 76% of the children are in a car that has an impact with a tree/pole (same for MAIS ≥ 3 or fatal).

The MAIS distributions for the main crash partner categories are given in Figure 6.

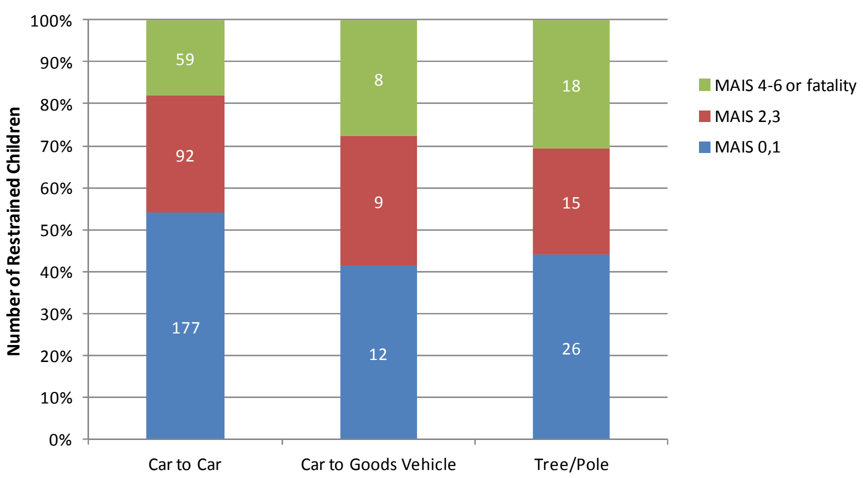


Figure 6: Distribution of MAIS by crash opponent – Frontal impacts n=416

There is a shift to a greater proportion of MAIS ≥ 2 restrained children for crashes involving goods vehicles and trees/poles.

Seating Position (Restrained Children)

Seat position distribution can have an effect on injury outcome due to intrusion - especially for lateral impacts (struck or non-struck side) but also for frontal impacts - or restraint design - traditionally front seats have more advanced restraint systems (e.g. airbags, pretensioners and load limiters). The top figure (Figure 7) shows all restrained children, the bottom figure (Figure 8) shows MAIS ≥ 3 restrained children with injuries known or those with fatal injuries.

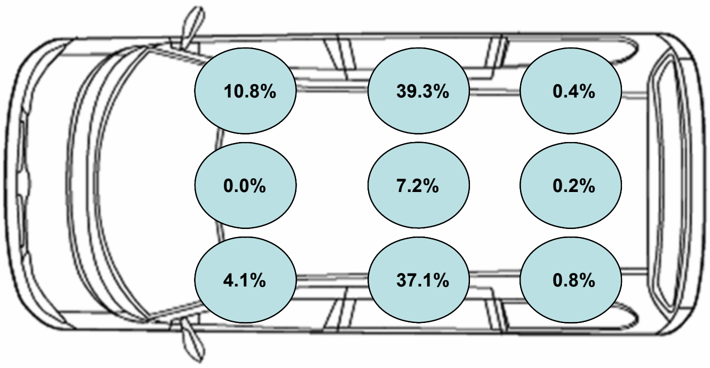


Figure 7: Distribution of seating position – Frontal impacts n=483

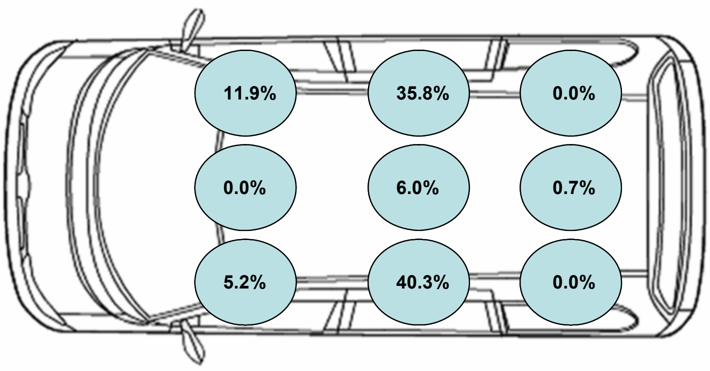


Figure 8: Distribution of seating position – Frontal impacts, MAIS ≥ 3 or fatality n=134

For both injury samples the majority of restrained children are in the second row of seats. Of the severely or fatally injured group, 17% are seated in the front row of the car.

Age

The following figure (Figure 9) illustrates the distribution of age for the restrained children.

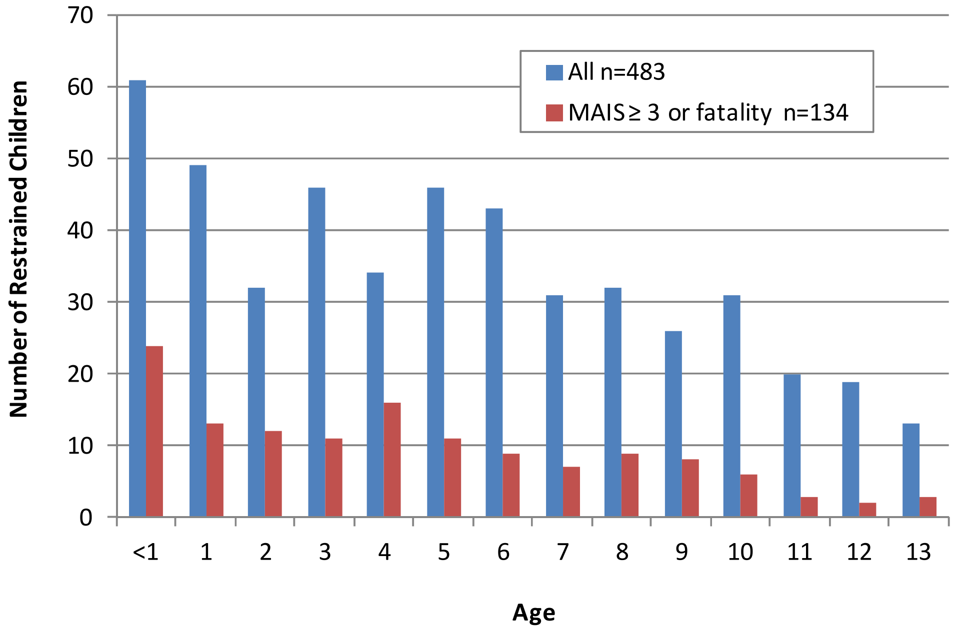


Figure 9: Restrained children by age – Frontal impacts

Figure 9 shows there is generally a good spread of ages across the frontal impact sample although there is a fall in number towards higher age. This may be a feature of the case sampling, resistance to injury as age increases, population or exposure (distance travelled). Also, 12 and 13 year old children were not in the inclusion criteria of the previous research projects, so some occupants of that age were present in vehicles, but cases with only children of that age were not presented/accepted.

Restraint Type by Age

Figure 10 shows the type of restraint being used at the time of impact for all restrained children in the combined database in frontal impacts. This is only an indication of appropriate use as age is used. The ideal situation would be to have weight, height and age available for each child.

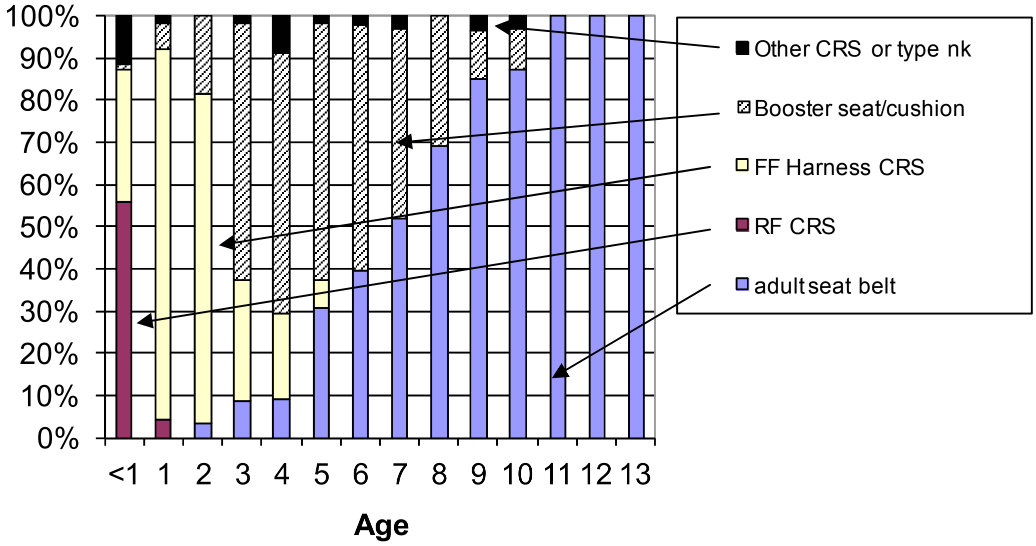


Figure 10: Restraint condition by age – Frontal impacts n=483

The majority of the inappropriately restrained children are in adult seat belts rather than dedicated child restraint systems. At the age of 7 years old the majority of restrained children are using just the adult seat belt when at this age most should be restrained by booster systems. As the database is a sample biased towards higher severity injuries and impact severity it could be expected that the level of inappropriate use, if inappropriate use is expected to increase injury risk, may be higher than in the crash population as a whole. There is an overall picture of the use of rearward facing to forward facing to booster CRS and then just the adult seat belt towards greater age.

4.3. Overall Injury Situation in Frontal Impacts

There are 450 restrained children in the dataset in frontal impacts with type of restraint and injuries known (or it is known that no injury has occurred). Of these children, 45% have a MAIS ≥ 2 and 25% have a MAIS ≥ 3.

There are a further 19 restrained children with fatal injuries but the actual injuries by AIS and body region are not known.

Fatalities

Of the 483 restrained children in frontal impacts, there are 55 fatalities. The distribution of MAIS for restrained children with fatal injuries is given in Figure 11. MAIS (Maximum Abbreviated Injury Score) is used to indicate the highest injury severity that an occupant has received to any body region.

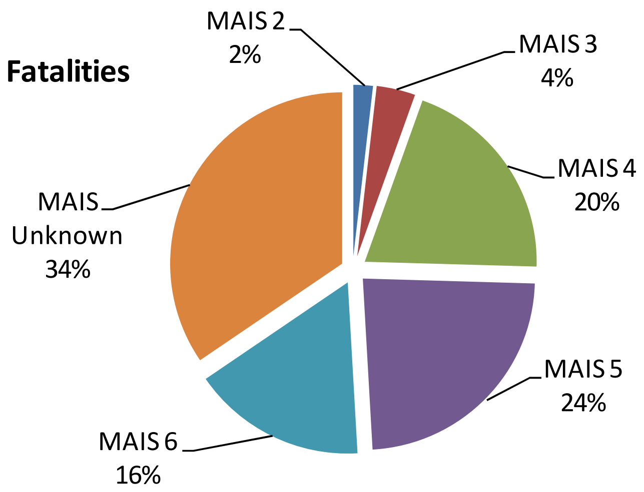


Figure 11: MAIS for fatalities – Frontal impacts n=55

Unfortunately detailed injuries are not available for some of these fatalities (19 out of 55), with the MAIS recorded as unknown.

MAIS Distribution – Overall and by Restraint Type

The overall distribution of MAIS for restrained children in frontal impacts is given in Table 5.

	Restrained children	
MAIS	Frequency	Percentage
0	59	12.2%
1	187	38.7%
2	90	18.6%
3	38	7.9%
4	48	9.9%
5	19	3.9%
6	9	1.9%
Unknown MAIS (but known to be fatality)	19	3.9%
Unknown MAIS (not fatality)	14	2.9%
Total	483	100%

Table 5: MAIS distribution restrained children frontal impact n=483

Of the children with known MAIS, 13% are not injured, 45% have a MAIS ≥ 2 and 25% have a MAIS ≥ 3.

The type of restraint that the child is using can be recorded in the database to a detailed level. For the analysis here the CRS types have been grouped into the common ECE group classifications; Rearward facing CRS (Group 0, 0+ or Group 1), Forward facing with harness (Group 1), Booster seats or cushions (Group 2, 3). There are 3 shield systems (two Group 1 and one Group 2) in the CHILD/CASPER dataset and they have been placed in the ‘other’ category. Other examples of CRS in the other group are carrycots, belt guides and CRS type unknown. Unknown was recorded if, for example, the child was taken to hospital in the CRS but the type was not recorded.

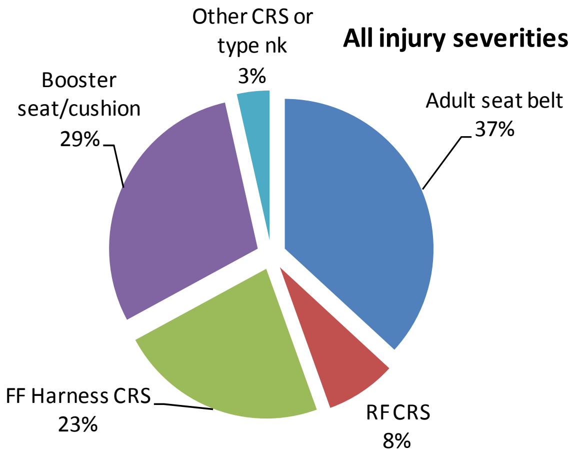


Figure 12: Restraint type distribution – Frontal impacts – all injury severities n=483

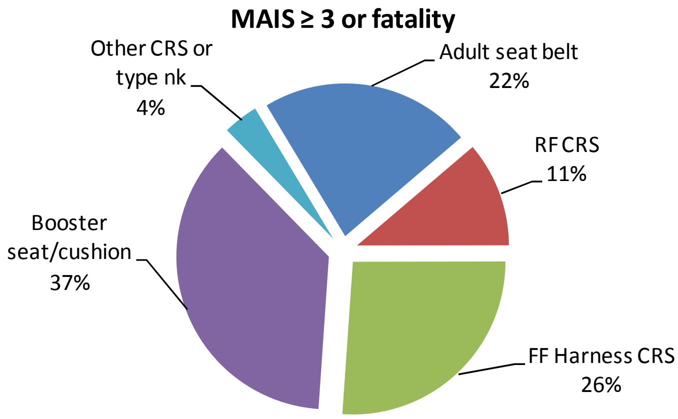


Figure 13: Restraint type distribution – Frontal impacts MAIS ≥ 3 or fatality n=134

Comparing all injury severities to the serious and fatal injury sample, the proportion of restrained children using dedicated child restraint systems increases with a corresponding drop in the use of just adult seat belts.

Figure 14 is a statement of the situation found in the accident database for frontal impacts regarding restraint type use – those with known MAIS or known to have fatal injuries are selected. Comparisons cannot be made across the child restraint types as appropriateness must be taken into account and crash parameters (in simple terms 'average' crash severity) are not necessarily comparable.

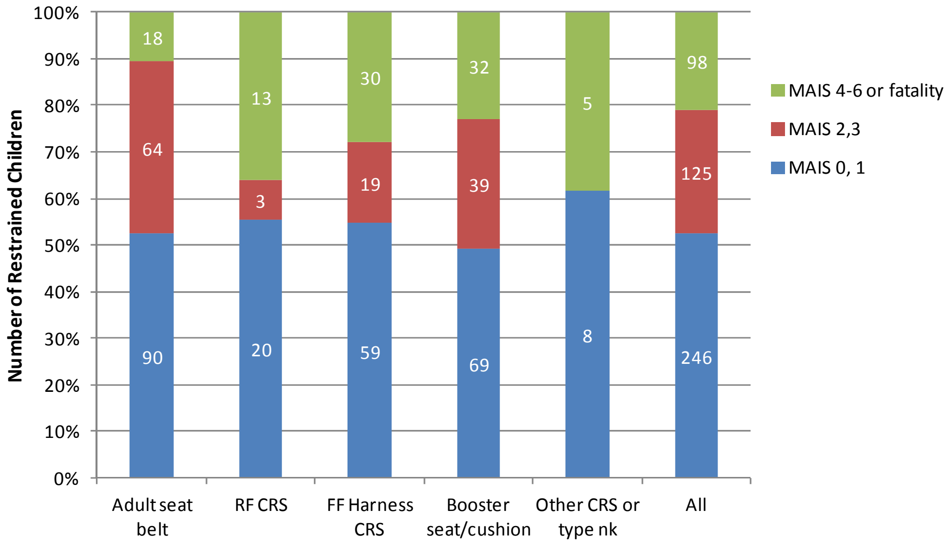


Figure 14: Overall Injury by CRS Type – Frontal impacts n=469

In the sample, the highest proportion of serious and fatal cases are for children restrained in booster systems and the lowest proportion (of the known CRS types) are restrained in rearward facing CRS. At the MAIS ≥ 2 level there is little difference though. The highest proportion of MAIS ≥ 4 and fatalities is for rearward facing children and the lowest for just adult seat belt restrained children.

Quality of Restraint Use

It is possible to record if misuse is present and the type of misuse. For analysis just two categories are used 'Misuse identified' and 'No misuse identified'. Misuse is a complex issue and it is important to understand that sometimes it is not possible from the available evidence to identify misuse, especially if injury levels are low or not known or it has not been possible to examine the CRS. Therefore the definition of 'No misuse identified' should be read as 'No misuse identified with the evidence available'.

Restraint type	Misuse identified	No misuse identified
Adult seat belt	7.6%	92.4%
RF CRS	36.1%	63.9%
FF Harness CRS	29.6%	70.4%
Booster seat/cushion	12.1%	87.9%
Other CRS or type not known	15.4%	84.6%
Total n=469	16.4%	83.6%

Table 6: Distribution of misuse identification by restraint type – Frontal impacts n=469

The overall rate of misuse identified (16%) is lower than figures found in misuse field studies (surveys and checking days). It is likely that at best the database is considering severe misuse, rather than being able to highlight slight misuse. Further discussion is given in Section 2.1 and Section 8.

Figure 15 shows banded injury severity by appropriate use and misuse. It is important to note that in the analysis below, appropriateness is often a judgement - as outlined in Section 2.4 - as often weight and/or height are not known. Misuse has been positively identified in the misuse cases and not identified or unknown in the 'no misuse identified' category.

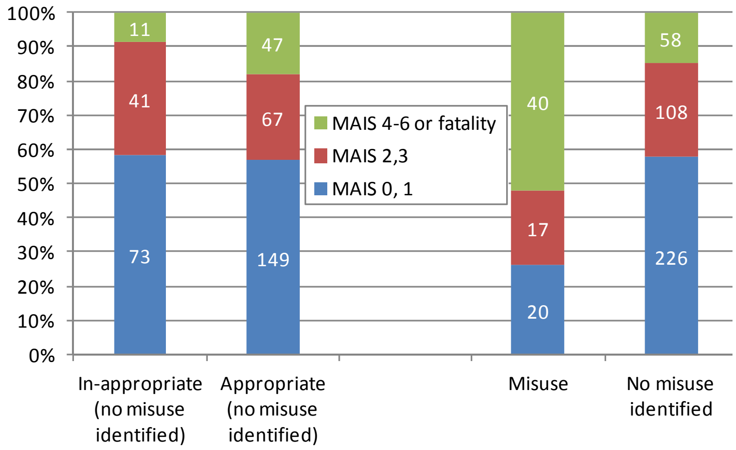


Figure 15: Quality of restraint – Overall injury levels

A relationship between misuse and injury level is apparent in Figure 15 with higher MAIS ≥ 2 injury levels for restrained children in the sample where it has been possible to identify misuse, compared to those restrained children with misuse not identified. There is no control for crash parameters (the cases with misuse may be of overall higher crash severity).

The same relationship is not apparent for appropriate use. This may be due to the definitions of inappropriate injury used, especially when weight and/or height are not known. In particular the recording of restrained child up to and including 11 years old being inappropriately restrained in just the adult seat belt (where otherwise no information is known regarding weight and/or height) is quite strict. Also there is no control for crash parameters - the cases with inappropriate use may simply be of overall higher crash severity.

Parameters for Frontal Impacts – Crash Severity

It is important to not suggest that one CRS type is worse than another in terms of injury risk as this sample is not representative, crash parameters are not necessarily comparable across CRS and quality of restraint use and airbag deployment must be taken into account. Also overall practical considerations must be projected onto the data that take into account the changes in child anatomy, physiology, strength and therefore injury tolerances as they get older. And, although it would afford them the best protection, children over the age of 4 are not likely to be agreeable to travelling rearward facing or have the space to do so.

Confounding factors in using general measures of crash severity for child occupants, compared to adult occupants, are, in particular, quality of restraint use (appropriateness, misuse and pre-crash positioning) and airbag deployment (especially for rear facing restrained children). Also seen during case review is the influence of intrusion in sideswipes or narrow frontal impacts.

The direction of force (DOF) for an impact is available from the CDC code. For the frontal impacts the distribution of direction of force for restrained children is given in Table 7.

Direction of force	MAIS known or fatality n=469	MAIS ≥ 3 or fatality n=134
10 o'clock	0.4%	1.5%
11 o'clock	19.8%	19.4%
12 o'clock	67.4%	73.1%
1 o'clock	12.4%	6.0%
2 o'clock	0.0%	0.0%

Table 7: Distribution of direction of force – Frontal impacts

The largest proportion of children can be seen to be injured in 12 o'clock impacts, followed by 11 o'clock impacts. This doesn't change a large amount when selecting only MAIS ≥ 3 children or fatalities.

To quantify the crash severity in frontal impact, EES (Equivalent Energy Speed) has been used. EES is a translation of the energy absorbed by the car during the crash (based on structural deformation) into an impact speed against a rigid object to obtain equivalent deformations in a crash test. Different methods are used by different collection teams;

1. Estimation method based on comparing structural deformations of the case car to deformations sustained during crash tests
2. Calculation of energy from crush measures
3. PC Crash scene dynamics impact and rest points

The distribution of crash severity (EES) (when available) is given in Figure 16 for restrained child with known MAIS injury level or it is known that injuries are fatal. If the impact is narrow or a sideswipe, intrusion is seen in certain cases to be a large problem leading to severe injury. Here there is no selection for intrusion, direction of force or appropriate use.

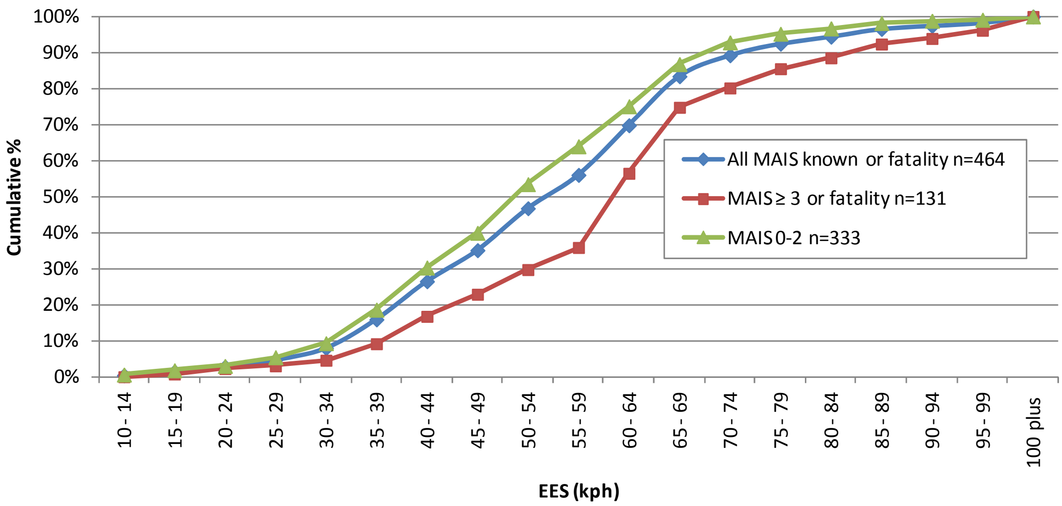


Figure 16: Distribution of crash severity (EES) in frontal impacts

As would be expected there is a general trend for a shift in the cumulative % graph towards higher EES for higher overall injury level. Of the MAIS ≥ 3 children or those with fatal injuries, approximately half are in a vehicle for which the EES is over 60 km/h and approximately 25% over 70 km/h, exceeding the design criteria of cars and CRS (ECE R44 frontal impact test conditions).

Figure 17 shows the distribution of crash severity (EES) (when available) for restrained child with known MAIS ≥ 3 injury level or fatalities. Selection for misuse is introduced compared to Figure 16. It is worth noting again that ‘No misuse identified’ should be understood to be ‘No misuse identified with the evidence available’.

Including severe injury and misuse in this analysis does introduce complexities, in particular the identification of misuse. For 19 of the fatalities injury details are not known (shown in Figure 11). Injury patterns are one of the main ways of identifying misuse so it is more likely that misuse will not be positively identified for such fatalities.

It is expected here that larger differences in EES are observed in the figure for lower severities than higher, if the hypothesis is that misuse is causing serious injury or fatalities at otherwise low crash severities. The effect of misuse is likely to be more masked at higher severity as the natural effects of higher severity - higher loads on the body and intrusion - play a larger role.

There are 3 cases where the child is identified as being ‘out of position’ pre-crash. This is not necessarily misuse but has an effect on injury outcome. These three cases have been included in the misuse identified category for the purposes of Figure 17. Further cases identify the child as ‘sleeping’ or ‘relaxed’ but this does not necessarily imply a poor restraint condition and in this analysis these cases have not been assigned as ‘misuse identified’, unless misuse has also been recorded separately in the case, for example slack being introduced into the seat belt.

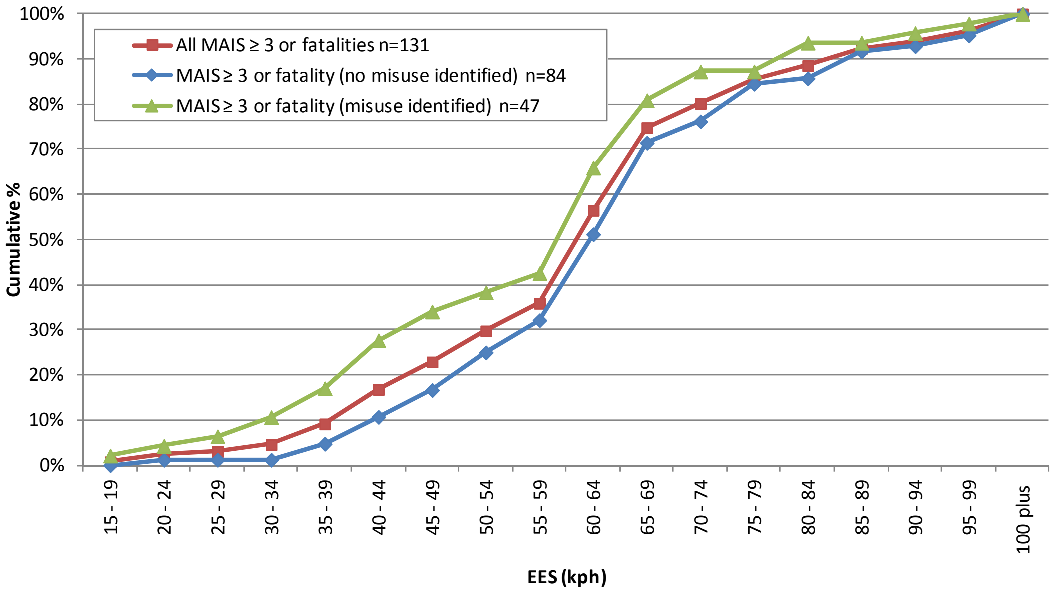


Figure 17: Distribution of crash severity (EES) in frontal impacts – MAIS ≥ 3 and fatalities

Figure 17 indicates that at lower crash severities misuse is a factor when MAIS ≥ 3 and fatalities occur, with separation of the misuse and no misuse identified category lines on the figure.

A confounding factor is the actual type of frontal impact. Cases are apparent that are not side swipes (the direct contact overlap is more than 10 cm) but the frontal overlap is such that the particularly stiff frontal structures of the vehicle have not been engaged, for instance the longitudinal beam can be seen not to have been loaded. These cases can lead to high levels of deformation along the side of the car, especially if the opposite vehicle is a goods vehicle but also in car to car impacts. Intrusion can reach child occupants causing serious injury and in some cases damage to restraint systems. In order to only include cases where children have been in a frontal impact with the likelihood of deformation of the car's primary stiff frontal structure, Figure 18 excludes cars with an overlap of only 20% or less.

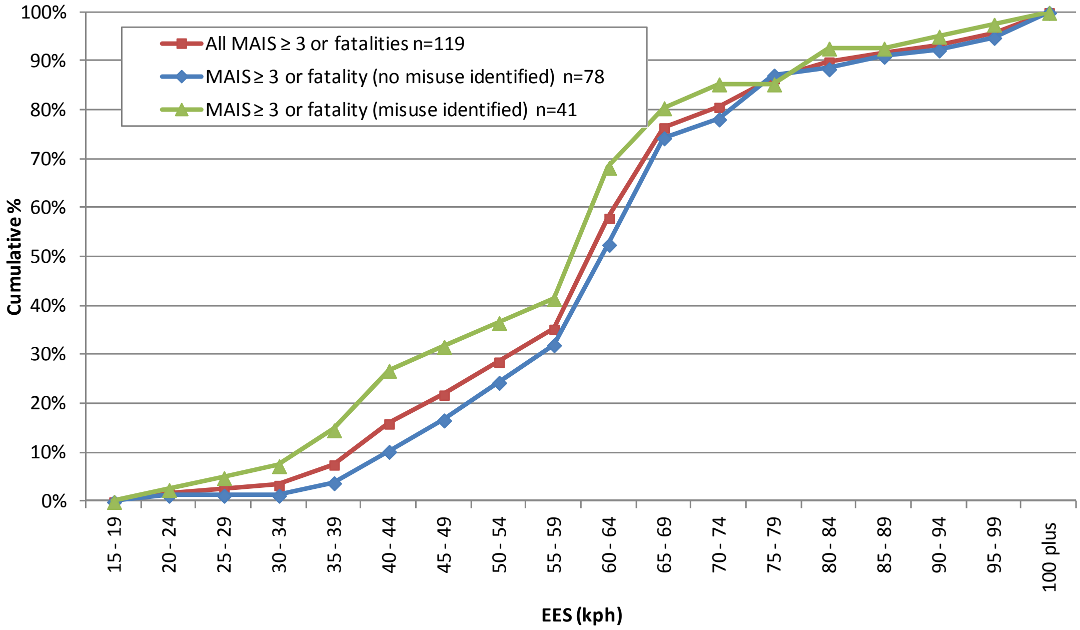


Figure 18: Distribution of crash severity (EES) in frontal impacts – MAIS ≥ 3 and fatalities – Only cars with more than 20% frontal overlap

Whilst controlling for frontal overlap the pattern for EES distribution in Figure 18 is similar to Figure 17.

4.4. Maximum Injury Severity by Restraint Type

As this section addresses injury by body region and restraint type, restrained children with injuries not known or restraint type not known are excluded.

Figure 19 gives the proportions of restrained children by restraint type that have an injury to each body region at the MAIS ≥ 2 level (body region). For example, of the 33 children in the dataset restrained rearward facing 36% have a head injury of AIS 2 or above. The MAIS ≥ 2 (head) rate is therefore 36%. Likewise Figure 20 addresses MAIS ≥ 3 injury rates. It is important to remember that this sample is not representative. An extreme example of this would be to note the high levels of head injury to rear facing restrained children. For each frontal impact that a child in a rearward facing child is involved in across Europe, there is not such a high chance (36%) of a head AIS ≥ 2 injury in every impact.

This analysis shows the general patterns of injury across the different restraint types. The neck, thorax and abdominal regions include the relevant region of the spine. 'Head' does not include the face. The MAIS ≥ 2 (external) rate is zero for all and not shown on the figures.

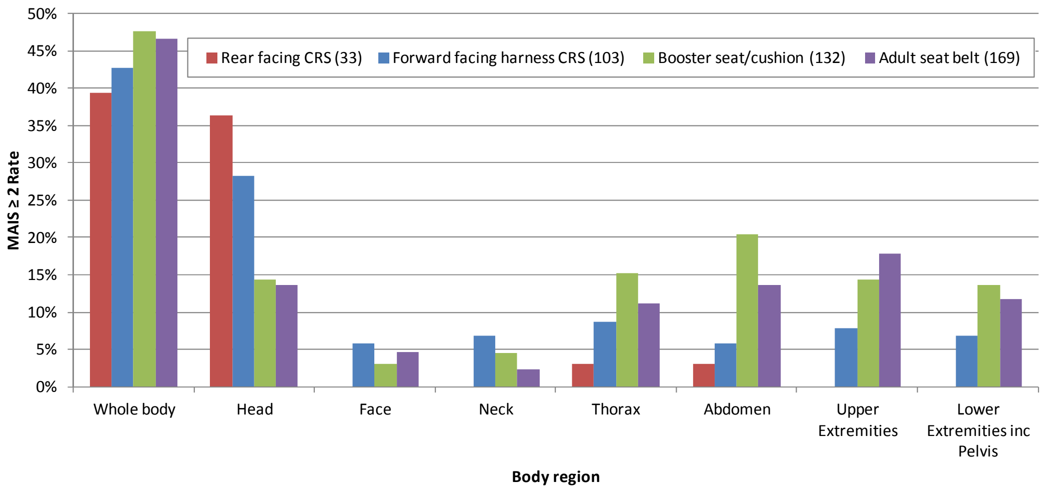


Figure 19: Proportion of restrained children with an AIS ≥ 2 injury by body region and restraint type – Frontal impact n=437

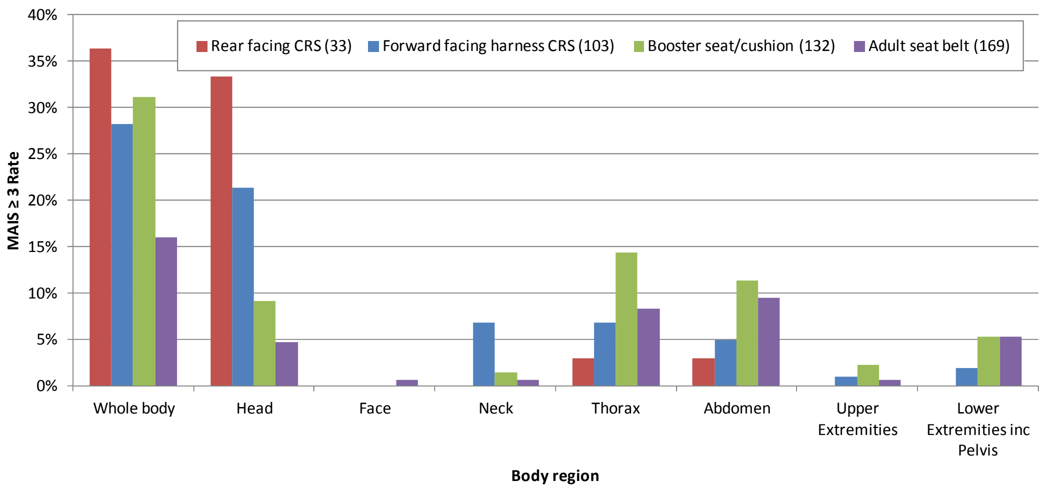


Figure 20: Proportion of restrained children with an AIS ≥ 3 injury by body region and restraint type – Frontal impact n=437

Rear facing CRS Even though case numbers are small it is clear that the head is the most seriously injured body region, this is a good example of how this data can identify areas to consider in severe crashes, but is not representative of the whole injury population.

Forward facing harness CRS Again, as for rearward facing systems, it is clear that the head is the most seriously injured body region with 28% of the 103 children in this sample receiving an AIS ≥ 2 injury head injury. At the AIS ≥ 2 level, the other body regions start to feature equally but increasing the AIS to ≥ 3 shows the neck, abdomen and thorax are more prominent than the face and extremities.

Booster seat/cushion Serious injuries are more distributed across the body regions than for harness shell systems with both upper (14%) and lower extremity (14%) regions, the abdomen (21%) and the thorax (15%) featuring strongly at the AIS ≥ 2 level, along with the head (14%). At the AIS ≥ 3 level the thorax features as the most injured body region with 14% of the children in this sample having such an injury. The abdominal and head regions are also evident at 11% and 9% respectively.

Adult seat belts For children just restrained by the adult seat belt the extremities, upper extremities (18%) and lower extremities and pelvis (12%), feature strongly at the AIS ≥ 2 level, along with the head (14%) and abdomen (14%), followed by the thorax (11%). At the AIS ≥ 3 level the abdomen has an AIS ≥ 3 injury for 10% of the 169 children, followed by the thorax (8%) and then the head and lower extremities are equally prevalent at 5%.

The following sections look at each restraint type individually at an injury level rather than the maximum injury level for each body region.

4.5. Injury to Body Regions by Restraint Type

Rearward Facing CRS

There are 33 children using rearward facing child restraint systems, of which 13 are not injured. Multidirectional ('convertible'), 2 way child restraints, are included when they are being used rearward facing. 94% are below 1 year old and 6% are 1 year old.

There are 20 injured children in rearward facing CRS, sustaining 47 injuries of all severities. Of these children, 13 have AIS ≥ 2 injury(ies) with 28 AIS ≥ 2 injuries in total.

Figure 21 shows how the 28 individual AIS ≥ 2 injuries for rearward restrained children are distributed across the body regions. For example, 93% of all the individual AIS ≥ 2 injuries for this sample are to the head.

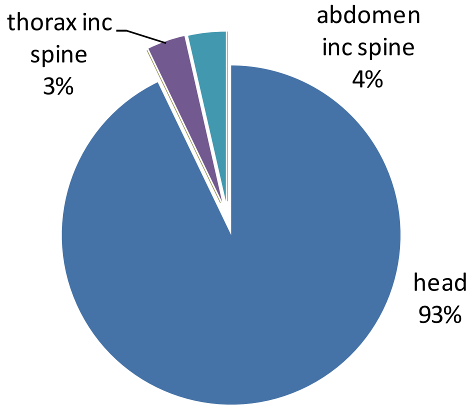


Figure 21: AIS ≥ 2 Injury distribution for rearward facing CRS - Frontal impacts known injuries - 28 AIS ≥ 2 injuries in total

As in Figure 19 and Figure 20 it is clear that the head is by far the most injured body region for the children in this sample, with 26 (93%) of the 28 AIS ≥ 2 injuries being to the head. Of these AIS ≥ 2 injuries 18 are brain injuries and 8 are fractures, with no crush or penetration injuries.

This is a small sample but of the 12 casualties with AIS ≥ 2 cranium injury, 11 are in the front passenger seat. In 3 cases contact with the dashboard is recorded and in another 7 there is a deployed frontal airbag. The casualty in the rear sustained brain haemorrhage due to excessive slack in the harness allowing contact with the carrying handle.

Fracture is present for 7 casualties along with brain injury, whilst 4 casualties have just brain injury and 1 casualty having just fracture. This skull fracture (which was AIS 2) was caused by a wooden toy mounted on the carrying handle of the CRS.

The only child without head injury sustained a thoracic crush injury with the centre console when the strap between the legs failed during the crash.

Forward Facing Harness CRS

There are 103 children using forward facing child restraint systems with a harness, of which 21 are not injured. Convertible, two-way child restraints are included when they are being used forward facing with a harness. The simple distribution of age is given in Figure 22, showing that most are 1 year old.

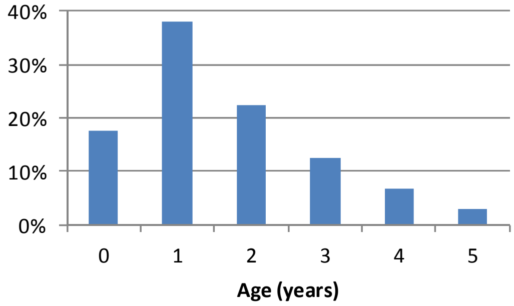


Figure 22: Restrained child age distribution for Forward Facing CRS Harness – Frontal impacts known injuries

There are 82 injured children using forward facing child restraint systems with a harness, with a total of 228 injuries of all severities. Of these children 44 have AIS ≥ 2 injury(ies) with 116 AIS ≥ 2 injuries in total.

Figure 23 shows how the 116 individual AIS ≥ 2 injuries for forward facing restrained children are distributed across the body regions. For example, 51% of all the individual AIS ≥ 2 injuries for this sample are to the head.

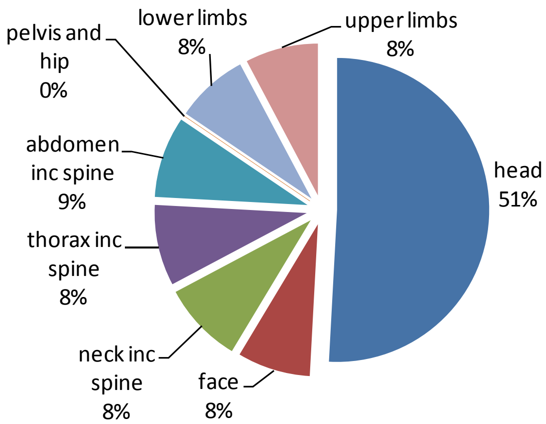


Figure 23: AIS ≥ 2 Injury Distribution for Forward Facing CRS – Frontal impacts known injuries - 116 AIS ≥ 2 injuries in total

As in Figure 21 it is clear that the head is by the most injured body region for the children in this sample, with 51% of the 116 AIS ≥ 2 injuries being to the head. The distribution of AIS ≥ 2 injuries between remaining body regions is then very similar (except for the pelvis and hip where there are no AIS ≥ 2 injuries). Of the 44 MAIS ≥ 2 casualties, 3 are in the front passenger seat, the rest in the middle rear row.

Of the casualties with AIS ≥ 2 head injuries, when a contact is identified (75% of cases), it is to the seat back in front in 48% of cases and to the B pillar in 18%. Combining the own kinematics and deceleration fields gives 23%. 46 of the AIS ≥ 2 head injuries are to the brain, 12 are fractures and 1 is a crush or penetrating injury. 17 children have just a brain injury, 5 just a fracture and 6 both types of injury.

The injury causes to the extremities can be difficult to attribute but the seatback and the dashboard are given as possible causes.

Booster Systems

There are 132 children using booster child restraint systems either with or without backrests, of which 13 are not injured. The simple distribution of age is given in Figure 22, showing that the peak is at 3 years old - often the changeover point for children from harness to booster.

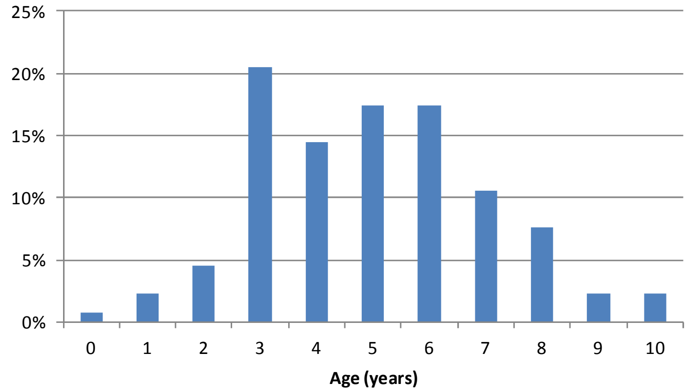


Figure 24: Restrained child age distribution for booster systems – Frontal impacts known injuries

There are 119 injured children using a booster system, with a total of 358 injuries of all severities. Of these children, 63 have AIS ≥ 2 injury(ies) with 184 AIS ≥ 2 injuries in total. Figure 25 shows how the 184 individual AIS ≥ 2 injuries for booster system restrained children are distributed across the body regions. For example, 20% of all the individual AIS ≥ 2 injuries for this sample are to the head.

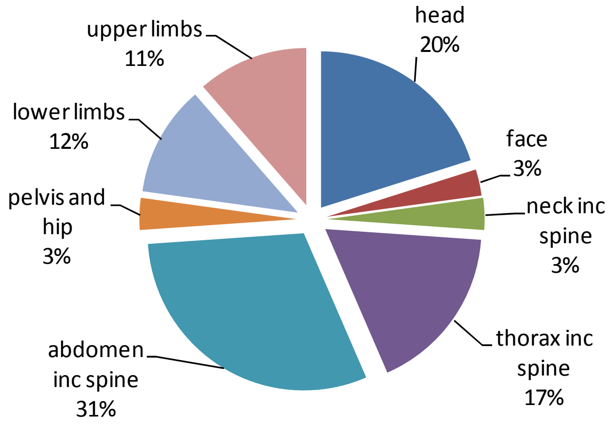


Figure 25: AIS ≥ 2 Injury distribution for booster systems – Frontal impacts known injuries - 184 AIS ≥ 2 Injuries in total

Figure 25 shows that the abdomen region accounts for just under a third of all AIS ≥ 2 injuries for this sample of children. The head accounts for 20% of all AIS ≥ 2 injuries followed by the thoracic region at 17%. The extremities added together cover 23% of the 184 AIS ≥ 2 injuries. Of the 132 MAIS ≥ 2 casualties, 10 are in the front passenger seat, 121 in the middle rear row and 1 in the third row (rear).

Of the casualties with AIS ≥ 2 abdominal region injuries, when a contact is identified (96% of cases), it is to the seat belt in all cases. The same is found for thoracic AIS ≥ 2 injuries.

The injury causes to the extremities can be difficult to attribute and show a higher use of ‘unknown’ for probable injury cause than for other body regions.

Only Adult Seat Belt

There are 169 children using just the adult seat belt, of which only 10 are not injured. The simple distribution of age is given in Figure 22, showing an expected rise starting at 5 years old.

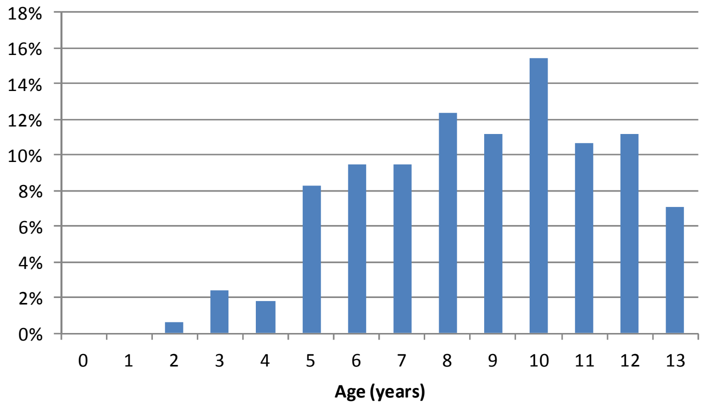


Figure 26: Restrained child age distribution for adult seat belts – Frontal impacts known injuries

There are 159 injured children using just the adult seat belt, with a total of 560 injuries of all severities. Of these children, 79 children have AIS ≥ 2 injury(ies) with 189 AIS ≥ 2 injuries in total. Figure 27 shows how the 189 individual AIS ≥ 2 injuries for only adult seat belt restrained children are distributed across the body regions. For example, 17% of all the individual AIS ≥ 2 injuries for this sample are to the head.

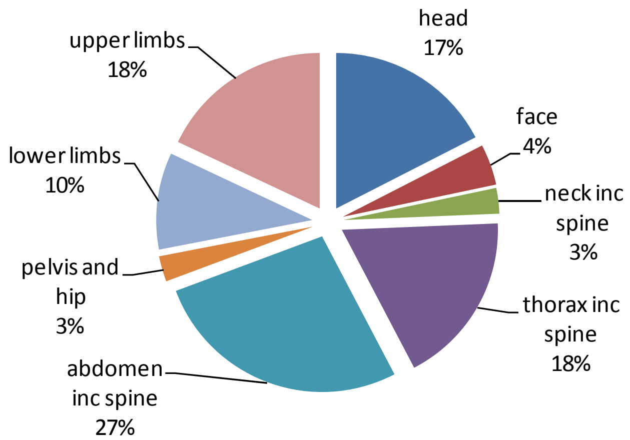


Figure 27: AIS ≥ 2 Injury distribution for adult seat belts – Frontal impacts known injuries - 189 AIS ≥ 2 injuries in total

Figure 27 shows that AIS ≥ 2 extremity injuries account for 28% of all the AIS ≥ 2 injuries for this sample of children and then the abdominal region features strongly at 27%, followed by the thorax and head with similar proportions (18% and 17%).

Children restrained with the adult seat belt only are more spread around in terms of seating position than those with dedicated CRS. Of the 169 MAIS ≥ 2 casualties, 33 are in the front passenger seat, 131 in the middle rear row and 5 in the third row (rear).

As with booster systems, abdominal injuries are mainly attributed to the seat belt, as are the thoracic injuries.

5. LATERAL IMPACTS

5.1. Introduction

The same dataset (CHILD and CASPER) is used for lateral impacts as in the frontal impact analysis. It is important to consider that the data is sampled against certain criteria and is not representative of the child crash population. However, as with frontal impacts, it can be used to give an indication of which body regions are being injured in different CRS types.

Of the combined CHILD and CASPER database, 167 restrained children are in lateral impacts, 25.5% of the total (656).

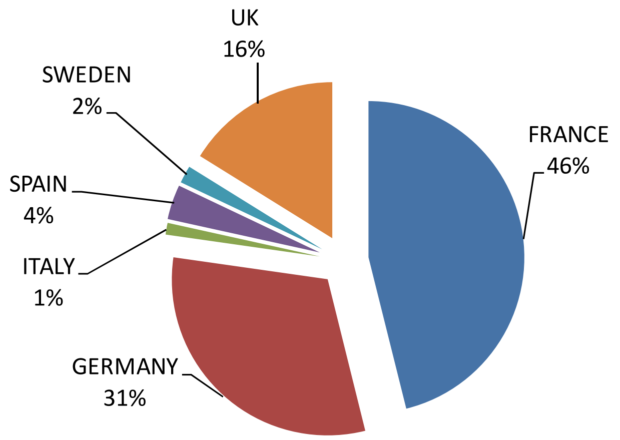


Figure 28: Distribution of restrained children by country of origin – Lateral impacts N=167

Figure 28 shows the country of case origin for these 167 children.

5.2. Crash and Restraint Parameters

Crash Opponent

Figure 29 and Figure 30 show the distribution of crash opponent for restrained children in lateral impacts.

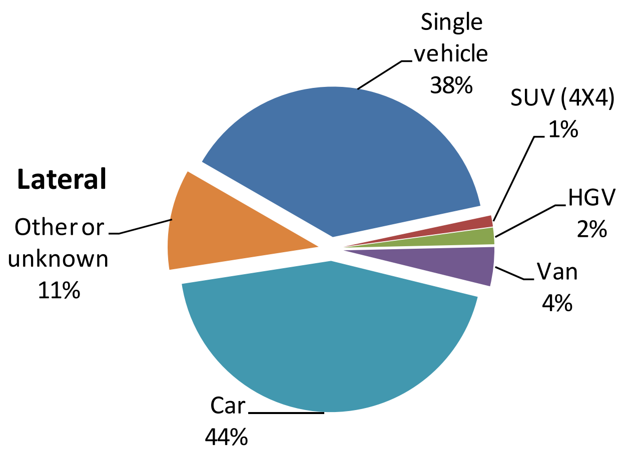


Figure 29: Distribution of crash partner – Restrained children n=167

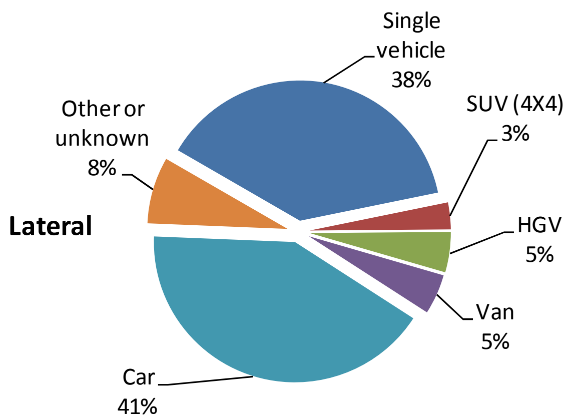


Figure 30: Distribution of crash partner – Restrained children, MAIS ≥ 3 or fatality n=65

The division between car to car impacts and single vehicle impacts is similar, for both injury selections. When the crash opponent is not another vehicle, 83% of the children are in a car that has an impact with a tree/pole (80% for MAIS ≥ 3 or fatal).

The MAIS distributions for the main crash partner categories are given in Figure 31.

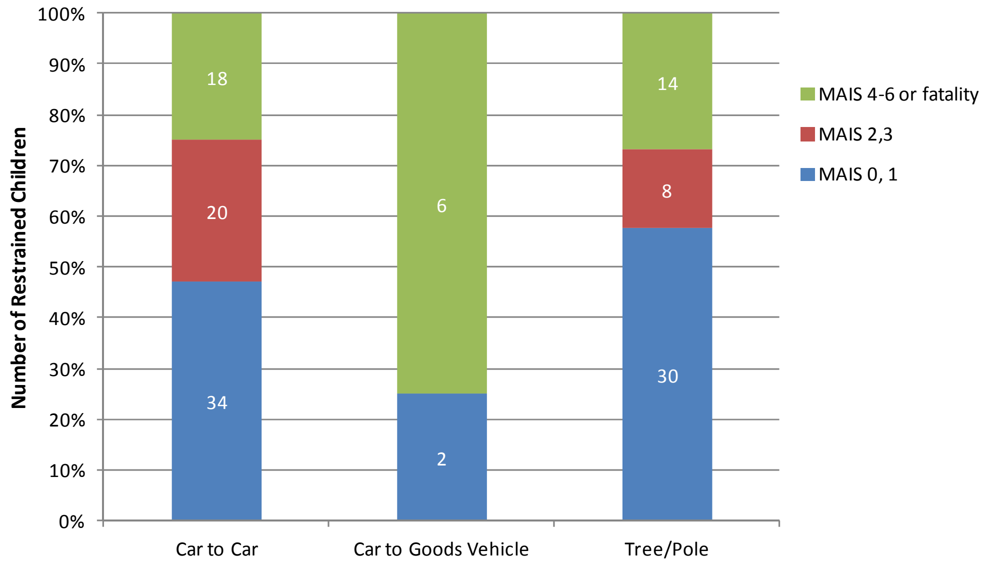


Figure 31: Distribution of MAIS by crash opponent – Lateral impacts n=132

In the lateral impact sample the rate of serious injury is highest for restrained children involved in crashes with goods vehicles, although overall they form a small proportion of the sample.

Seating Position (Restrained Children)

Seat position distribution can have an effect on injury outcome due to intrusion - especially for lateral impacts (struck or non-struck side) but also for frontal impacts - or restraint design - traditionally front seats have more advanced restraint systems (e.g. airbags, pretensioners and load limiters). The top figure is all restrained children, the bottom figure MAIS ≥ 3 restrained children with injuries known or those with fatal injuries.

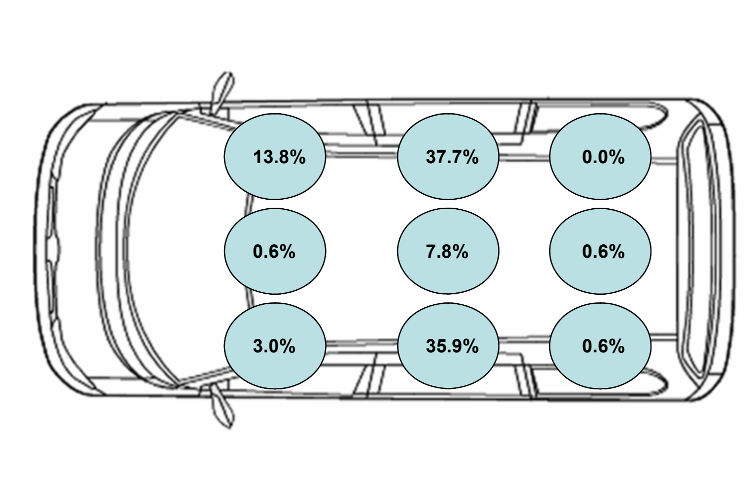


Figure 32: Distribution of seating position – Lateral Impacts n=167

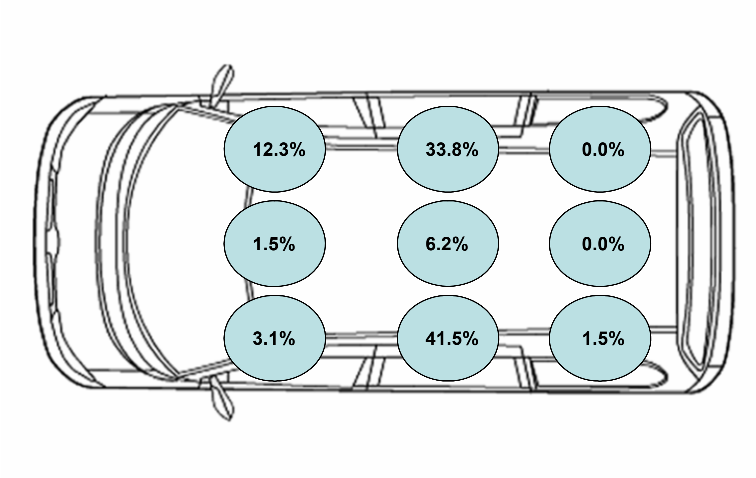


Figure 33: Distribution of seating position – Lateral Impacts, MAIS ≥ 3 or fatality n=65

For both injury samples the majority of restrained children are in the second row of seats. Of the severely or fatally injured group, 17% are seated in the front row of the car and when in the second row more are sat on the left side than the right.

Age

The following figure (Figure 34) illustrates the distribution of age for the restrained children.

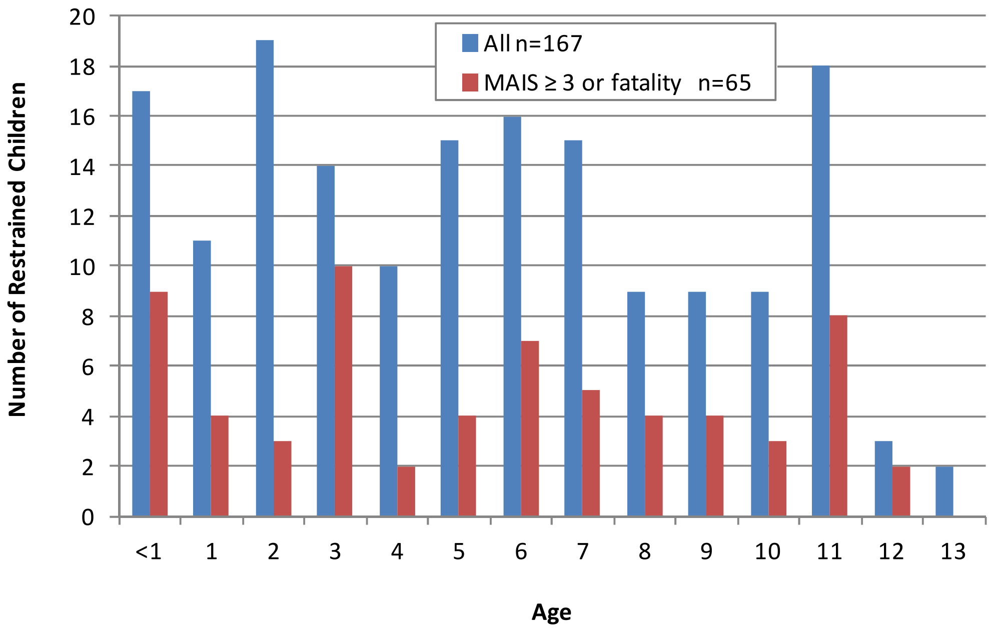


Figure 34: Restrained children by age – Lateral impacts

Figure 34 shows that the distribution of age across the lateral impact sample is not uniform but each part of the age spectrum reflecting the CRS grouping system is represented. As with frontal impacts there is a fall in number for 12 and 13 year olds. This may be a feature of the case sampling combined with resistance to injury as age increases and the inclusion of older children mainly for CASPER cases.

Restraint Type by Age

Figure 10 shows the type of restraint being used at the time of impact for all restrained children in the combined database in lateral impacts. This is only an indication of appropriate use as age is used. The ideal situation would be to have weight, height and age available for each child.

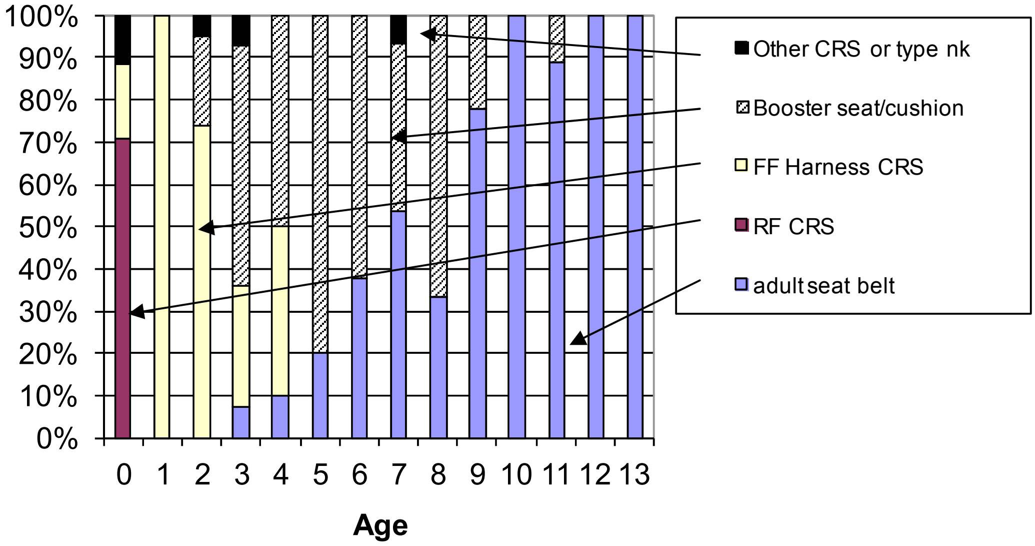


Figure 35: Restraint condition by age – Lateral impacts n=167

The majority of the inappropriately restrained children are in adult seat belts rather than dedicated child restraint systems. At the age of 7 years old the majority of restrained children are using just the adult seat belt when at this age most should be restrained by booster systems – although there is then a reduction in just adult seat belt use for 8 years old. As the database is a sample biased towards higher severity injuries and impact severity it could be expected that the level of inappropriate use, if inappropriate use is expected to increase injury risk, may be higher than in the crash population as a whole. There is an overall picture of the use of rearward facing to forward facing to booster CRS and then just the adult seat belt towards greater age.

5.3. Overall Injury Situation in Lateral Impacts

There are 148 restrained children in the dataset in lateral impacts with type of restraint and injuries known (or it is known that no injury has occurred). Of these children, 46% have a MAIS ≥ 2 and 34% have a MAIS ≥ 3.

There are a further 15 restrained children with fatal injuries but the actual injuries by AIS and body region are not known.

Fatalities

Of the 167 restrained children in lateral impacts, there are 34 fatalities. The distribution of MAIS for restrained children with fatal injuries is given in Figure 36. MAIS (Maximum Abbreviated Injury Score) is used to indicate the highest injury severity that an occupant has received to any body region.

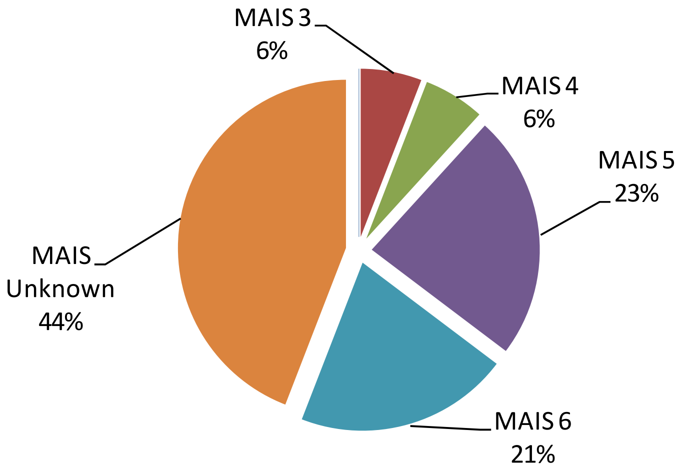


Figure 36: MAIS for fatalities – Lateral impacts n=34

Unfortunately detailed injuries are not available for some of these fatalities (15 out of 34), with the MAIS recorded as unknown.

MAIS Distribution – Overall and by Restraint Type

The overall distribution of MAIS for restrained children in lateral impacts is given in Table 8.

	Restrained children	
MAIS	Frequency	Percentage
0	25	15.0%
1	55	32.9%
2	18	10.8%
3	19	11.4%
4	12	7.2%
5	12	7.2%
6	7	4.2%
Unknown MAIS (but known to be fatality)	15	9.0%
Unknown MAIS (not fatality)	4	2.4%
Total	167	100.0%

Table 8: MAIS distribution restrained children - Lateral impact n=167

Of the children with known MAIS (n=148), 17% are not injured, 46% have a MAIS ≥ 2 and 34% have a MAIS ≥ 3.

The type of restraint that the child is using can be recorded in the database to a detailed level. For the analysis here the CRS types have been grouped into the common ECE group classifications; Rearward facing CRS (Group 0, 0+ or Group 1), Forward facing with harness (Group 1), Booster seats or cushions (Group 2, 3). There are 3 shield systems (two Group 1 and one Group 2) in the CHILD/CASPER dataset and they have been placed in the ‘other’ category. Other examples of CRS in the other group are carrycots, belt guides and CRS type unknown. Unknown was recorded if, for example, the child was taken to hospital in the CRS but the type was not recorded.

The following figures include only restrained children with known injuries.

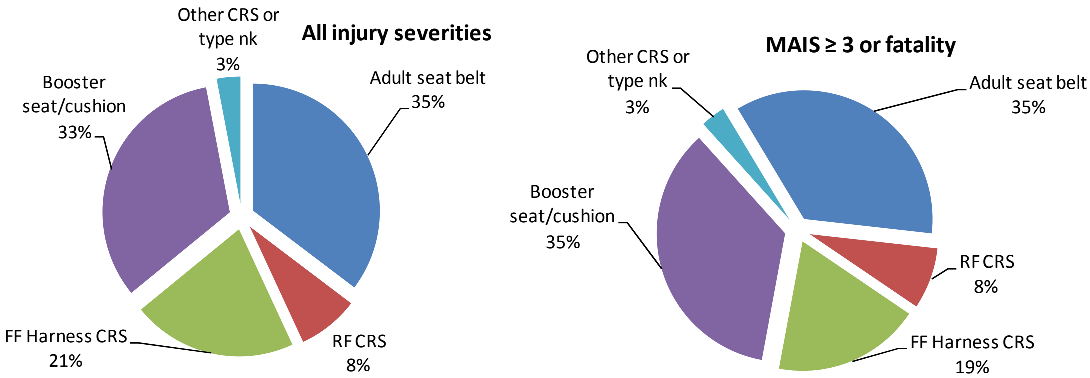


Figure 37: Restraint type distribution – Lateral impacts

Comparing all injury severities to the serious and fatal injury sample the restraint type distribution is very similar.

Figure 38 is a statement of the situation found in the accident database for lateral impacts. Comparisons cannot be made across the child restraint types as appropriateness of restraint type for each age must be taken into account and crash parameters (in simple terms ‘average’ crash severity) are not necessarily comparable. Figure 38 includes restrained children with known MAIS or known to have fatal injuries in lateral impact.

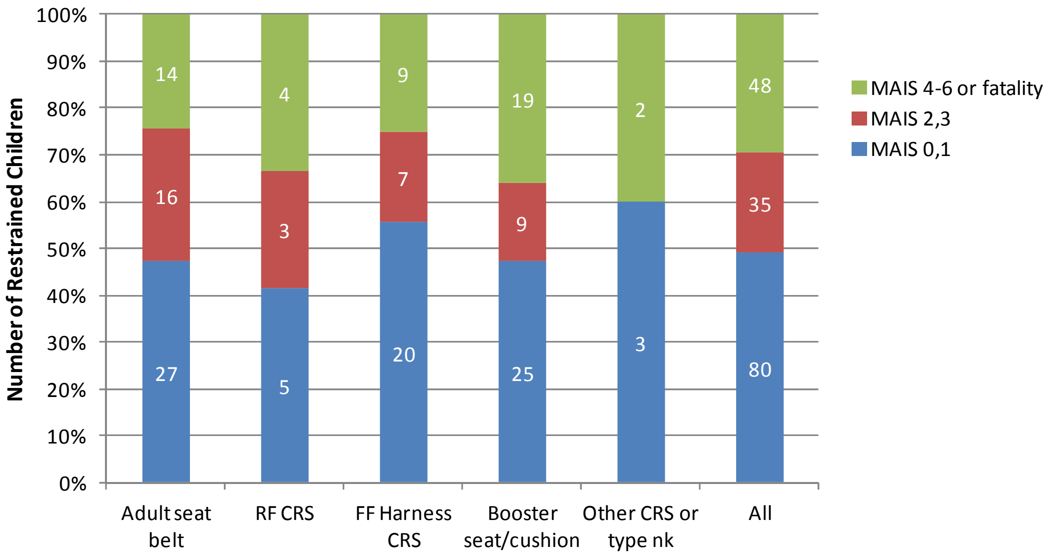


Figure 38: Overall Injury by CRS Type – Lateral impacts n=163

In the sample, the highest proportion of serious and fatal cases are for children restrained in rear facing child restraints and the lowest proportion (of the known CRS types) are restrained in forward facing harness CRS. The highest proportion of MAIS ≥ 4 and fatalities (of the known CRS types) is for children using booster systems and the lowest equally for children using just the adult seat belt and forward facing harness systems.

Quality of Use

It is possible to record if misuse is present and the type of misuse. For analysis just two categories are used ‘Misuse identified’ and ‘No misuse identified’. Misuse is a complex issue and it is important to understand that sometimes it is not possible from the available evidence to identify misuse, especially if injury levels are low or not known or it has not been possible to examine the CRS. Therefore the definition of ‘No misuse identified’ should be read as ‘No misuse identified with the evidence available’.

Restraint type	Misuse identified	No misuse identified
Adult seat belt	-	100.0%
RF CRS	8.3%	91.7%
FF Harness CRS	16.7%	83.3%
Booster seat/cushion	11.3%	88.7%
Other CRS or type nk	20.0%	80.0%
Total	8.6%	91.4%

Table 9: Distribution of misuse identification by restraint type – Lateral impacts n=163

Overall the rate of identified misuse in lateral impact (8.6%) is approximately half the rate in frontal impacts (16.4%). Injury mechanisms that identify misuse can be more obvious in frontal impacts than in lateral impact. For example, in a frontal impact head projection of a sizeable distance can indicate poor restraint condition, such as slack in the harness or seat belt, but in lateral impact on the struck side the distance before head contact is smaller so does not necessarily identify slack in harness or seat belt.

Figure 39 shows banded injury severity by appropriate use and misuse. It is important to note that in the analysis below, appropriateness is often a judgement - as outlined in Section 2.4 - as often weight and/or height are not known. Misuse has been positively identified in the misuse cases and not identified or unknown in the 'no misuse identified' category.

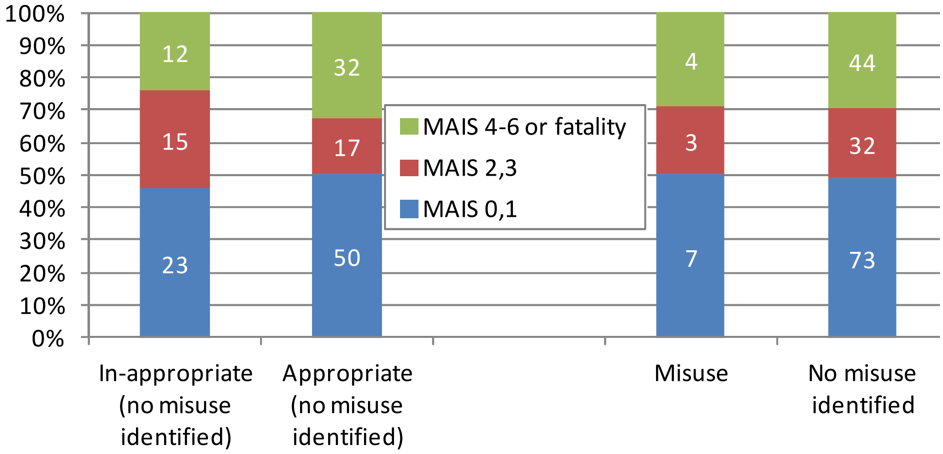


Figure 39: Quality of restraint – Overall injury levels – Lateral impacts

A relationship between misuse and higher injury levels is not apparent in Figure 39 for lateral impacts, as it was for frontal impacts in Figure 15. In fact as discussed above the number of cases where misuse has been identified is very low at only 11. There is no control for crash parameters (the cases with misuse may be of overall higher crash severity).

The proportion of children defined as appropriately restrained with no or minor injuries is higher than the in-appropriately restrained group, but the difference is small and does not hold for MAIS 4 to 6 and fatally injured children. This may be due to the definitions of inappropriate injury used, especially when weight and/or height are not known. In particular the recording of restrained child up to and including 11 years old being inappropriately restrained in just the adult seat belt (where otherwise no information is known regarding weight and/or height) is quite strict. Also there is no control for crash parameters - the cases with inappropriate use may be of overall higher crash severity.

Parameters for Lateral Impacts

The direction of force (DOF) for an impact is available from the CDC code and is shown in relevant groups in Table 10.

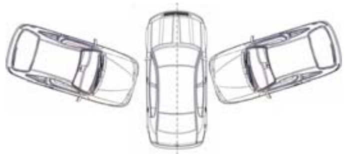
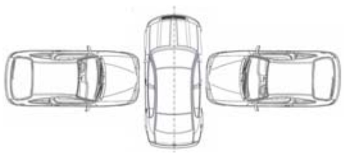
DOF		Distribution - All injury severities	Proportion with MAIS ≥ 2 or fatality
Lateral from rear 07 08 04 05 o'clock		17 10.4%	41.2%
Lateral from front 01 02 10 11 o'clock		84 51.5%	50.0%
Pure lateral 09 03 o'clock		61 36.8%	54.1%
Other	-	2 1.2%	50.0%
All		100%	-

Table 10: Direction of force for lateral impacts

'Lateral from front' and 'pure lateral' together are the impacts experienced the by large proportion of restrained children in lateral impacts. The proportion of children with MAIS ≥ 2 or fatal injuries is highest for purely lateral impacts (54%), followed by lateral from front (50%) and then lateral from rear (41%).

5.4. Lateral Impact by Struck Side

It is known whether the occupant is on the struck side or non-struck side of the car. Being in the centre is considered to be non-struck side.

Injury Severity

There are 92 restrained children sitting on the struck side in a lateral impact and 71 are non-struck side. Figure 40 shows the distribution of MAIS by struck/non-struck side and by direct intrusion for struck side occupants.

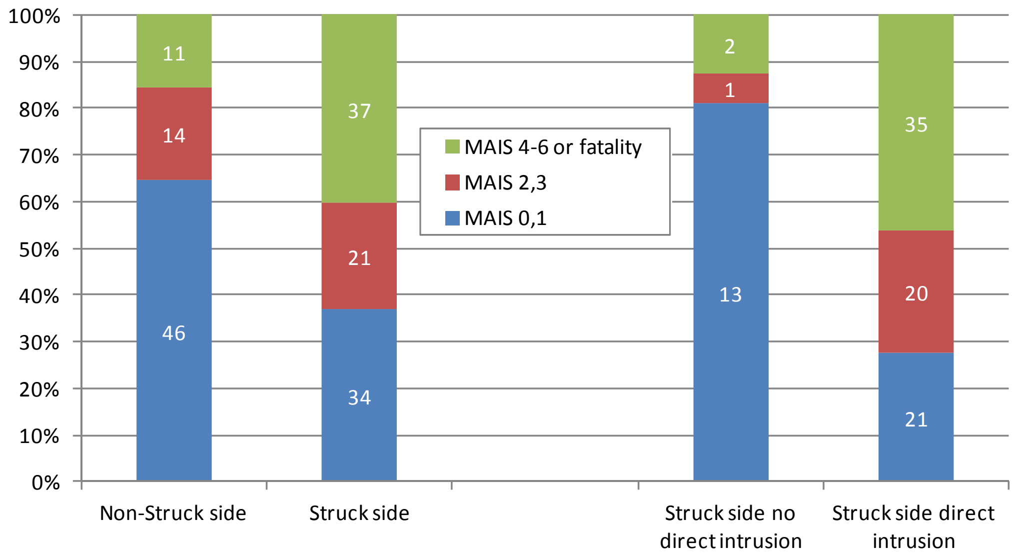


Figure 40: MAIS – Non / Struck side and direct intrusion – Lateral impacts restrained children n=163

Figure 40 shows that the distribution of MAIS for restrained children sitting on the struck side is different than for the non-struck side. There are more children on the struck side and they have a higher rate of MAIS ≥ 2 and a greater proportion of MAIS 4-6 and fatal injury. This indicates that children seated on the struck side in lateral impacts have a more serious injury outcome in the sample than those on the non-struck side. But it also shows that serious and fatal injury is present for non-struck side passengers, often when high levels of intrusion effectively put them on to the struck side or poor restraint conditions project them across the car.

Figure 40 also shows that being on the struck side is not the sole parameter influencing the severity of injury outcome and it is visible that having direct intrusion (on the struck side) gives a higher proportion of serious injury than no direct intrusion. The sample of children on the struck side but not in the area of intrusion is small but it shows the best proportion of not injured or slightly injured children. Therefore to make significant progress for the protection of children in side impact, it is important that the side impact test procedure used for CRS approval simulates the intruding parts of the vehicle.

Injury Severity Distribution by Maximum Intrusion – Struck Side Restrained Children

Figure 41 shows the maximum intrusion for struck side restrained children by overall injury severity (MAIS). The intrusion value is the highest value recorded for the general area that the child is seated. For children in the front seat that is the B pillar and forwards. For children in the rear, the B pillar and rearwards. Therefore it is possible to have intrusion (especially from a tree or pole) at the B pillar and not necessarily at the child's head position.

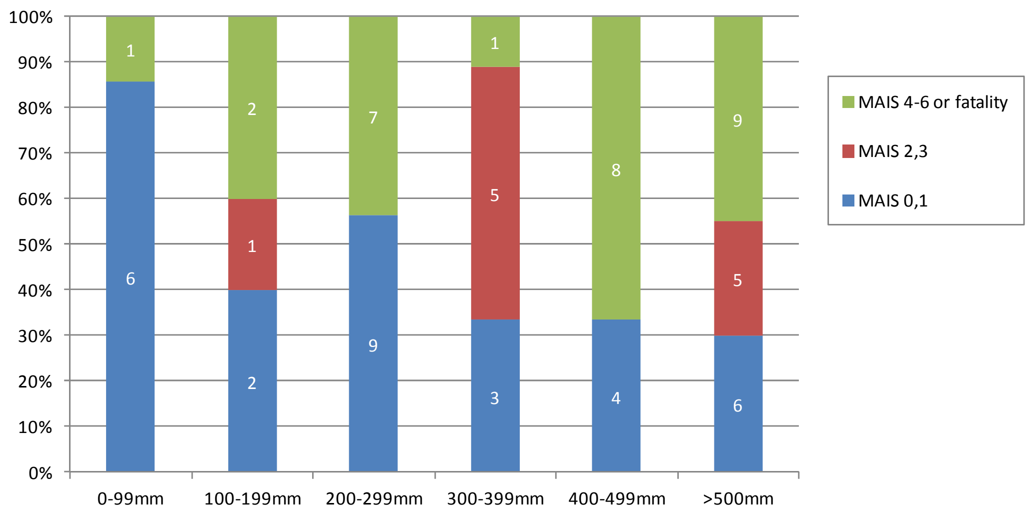


Figure 41: Injury severity distribution by maximum intrusion – Struck side restrained children n=69

Examining the MAIS 0,1 children with >500mm of intrusion some are in shell CRS and the intrusion is on the B pillar but not necessarily high at the children's actual position, especially if the child is young and the impact is purely lateral. Conversely if the impact has a forward component the head excursion can put the head into the area of B pillar intrusion leading to high levels of injury.

The amount of maximum intrusion around the child's position has a link with the level of injury severity for children on the struck side in the area of the intrusion (direct intrusion), with an overall increase in maximum injury severity towards higher intrusion. Although it should be noted that the 100-199mm band has more serious injury than might be expected. This is mainly linked to case inclusion criteria that are in lateral impact more than 200mm of intrusion on the compartment of the vehicle or MAIS ≥ 2 for at least one occupant. Lateral impact cases present in the CASPER database with less than 200mm of intrusion must have at least one MAIS ≥ 2 occupant which can be the child. Another explanation can be that if the intrusion occurs on the engine block (stiff structure – often low deformation) the level of deceleration for occupants is high and the risk of projection is increased, very often such impacts are combined with a large rotation of the vehicle as the impact occurs away from its centre of gravity, leading to other possibilities of impact location in the vehicle. In addition, the sample in the category of less than 200 mm of intrusion is low.

At over 300 mm of maximum intrusion, 68% of the 41 restrained children on the struck side are MAIS ≥ 2 children, 44% are MAIS ≥ 4 or have fatal injuries.

5.5. Maximum Injury Severity by Restraint Type – Struck Side

As this section addresses injury by body region and restraint type, restrained children with injuries not known or restraint type not known are excluded.

Figure 42 gives the proportions of restrained children (lateral impact – struck side) by restraint type that have an injury to each body region at the MAIS ≥ 2 level (body region). For example, of the 29 children in the dataset restrained in a shell system, 35% have a head injury of AIS 2 or above. The MAIS ≥ 2 (head) rate is therefore 35%. Likewise Figure 43 addresses MAIS ≥ 3 injury rates. Shell systems are rear and forward facing harness systems (including multidirectional 'convertible', 2 way child restraints). It is important to remember that this sample is not representative and that the sample size when broken down into categories is not very large for each group. An extreme example of this unrepresentativeness would be to note the high levels of head injury to shell system restrained children. For each lateral impact that a child in a rearward facing child is involved in across Europe in a struck side position, there is not such a high chance (35%) of a head AIS ≥ 2 injury in every impact.

This analysis shows the general patterns of injury across the different restraint types. The neck, thorax and abdominal regions include the relevant region of the spine. 'Head' does not include the face. The MAIS ≥ 2 (external) rate is zero for all and not shown on the figures.

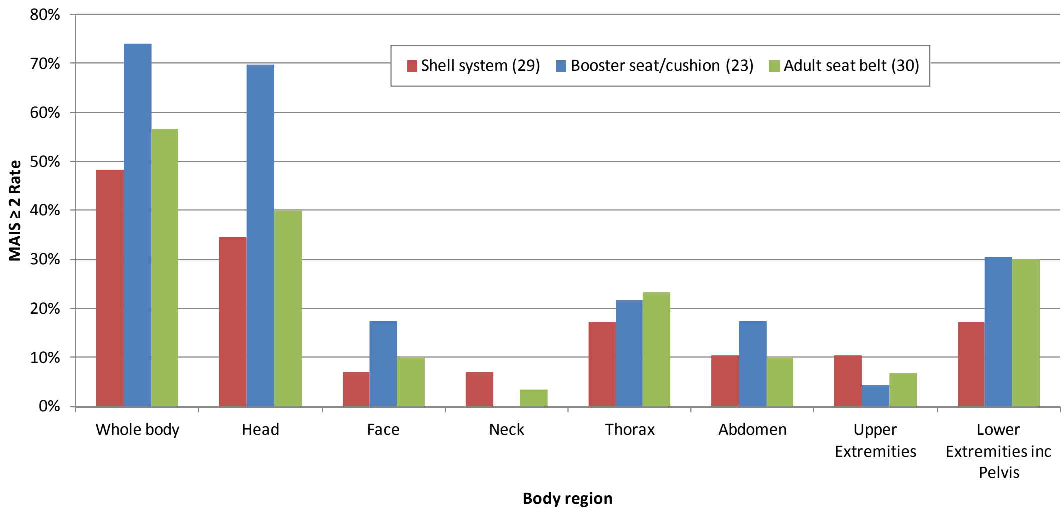


Figure 42: Proportion of restrained children with an AIS ≥ 2 injury by body region and restraint type – Lateral impact, struck side n=82

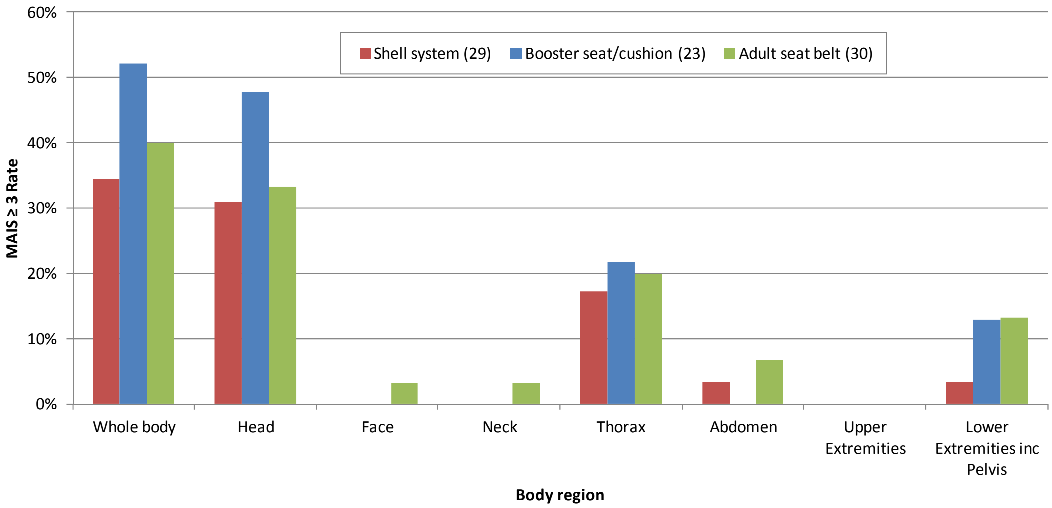


Figure 43: Proportion of restrained children with an AIS ≥ 3 injury by body region and restraint type – Lateral impact, struck side n=82

Shell System CRS The head is the most seriously injured body region, followed equally by the thorax and lower extremities at the AIS ≥ 2 level and strongly by the thorax at the AIS ≥ 3 level.

Booster seat/cushion The rate of serious injury to the head is very high, in itself and compared to the shell system and adult seat belt restrained children. Abdominal injuries do feature at the AIS ≥ 2 level but at a lower rate than lower extremities and the thorax and equal to the face. At the AIS ≥ 3 level, injuries are only seen for the head, then thorax and lower extremities.

Adult seat belts The rate of serious injury to the head is slightly higher than for shell systems. At the AIS ≥ 2 level, lower extremity injuries have the second highest injury rate, followed by the thorax. This relationship between the lower extremities and the thorax is reversed at the AIS ≥ 3 level.

Globally, it can be said that shell systems seem to have lower rates of AIS ≥ 3 injuries than other systems and that the repartition of severe injuries across the body segments is similar for the different types of restraint systems: head, thorax and lower extremities.

The following sections look at each restraint type individually at an injury level rather than the maximum injury level for each body region.

5.6. Injury to Body Regions by Restraint Type

Shell Systems – Struck Side

There are 29 children using shell systems with a harness, of which 4 are not injured. The simple distribution of age is given in Figure 44, showing a spread from new born to 4 years old.

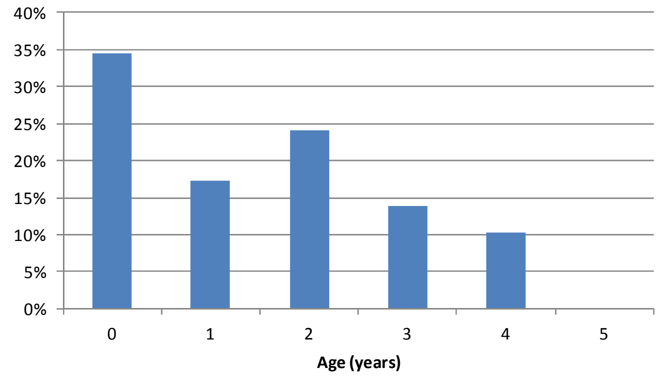


Figure 44: Restrained child age distribution for shell systems – Lateral impacts, struck side, known injuries

There are 25 injured children in shell systems with harness, sustaining 103 injuries of all severities. Of these children, 14 have AIS ≥ 2 injury(ies) with 46 AIS ≥ 2 injuries in total.

Figure 45 shows how the 46 individual AIS ≥ 2 injuries for shell system restrained children are distributed across the body regions. For example, 48% of all the AIS ≥ 2 individual injuries for this sample are to the head.

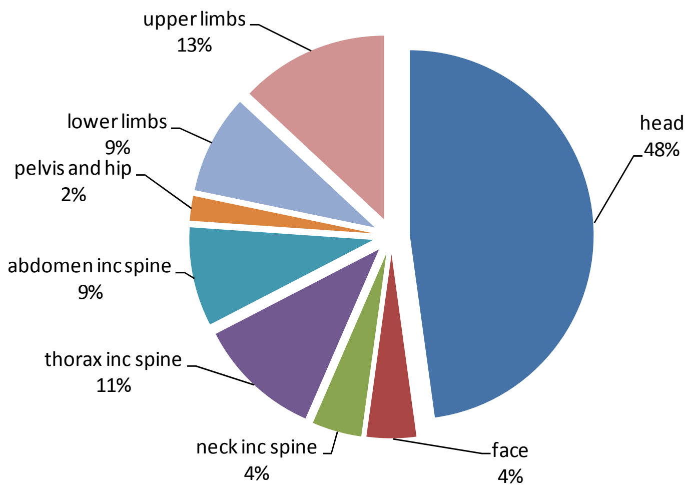


Figure 45: AIS ≥ 2 Injury distribution – Non-struck side restrained children – Shell systems - 46 AIS ≥ 2 injuries in total

As in Figure 42 and Figure 43 it is clear that the head is by far the most injured body region for the children in this sample, with 22 (48%) of the 46 AIS ≥ 2 injuries being to the head. Of these AIS ≥ 2 injuries 12 are brain injuries, 7 are fractures and 3 are crush or penetration injuries. Skull fracture is present for 3 casualties along with brain injury, whilst 6 casualties have just brain injury. Upper limbs represent the second body region with the most AIS ≥ 2 injuries, followed by the thorax and the lower limbs and abdomen equally. Of the 5 AIS ≥ 2 thoracic injuries, all involve lung contusion, there are no fractures.

All of the 10 casualties with AIS ≥ 2 head injury are sat in the rear of the car (5 on the left, 5 on the right). Regarding injury causation, known contacts are varied: window lateral (3), pillar B (1), object external to the vehicle (2), door panel (2), own kinematics (1).

Booster Systems – Struck Side

There are 23 children using booster systems, of which 2 are not injured. The simple distribution of age is given in Figure 46, showing a spread from 2 to 11 years old.

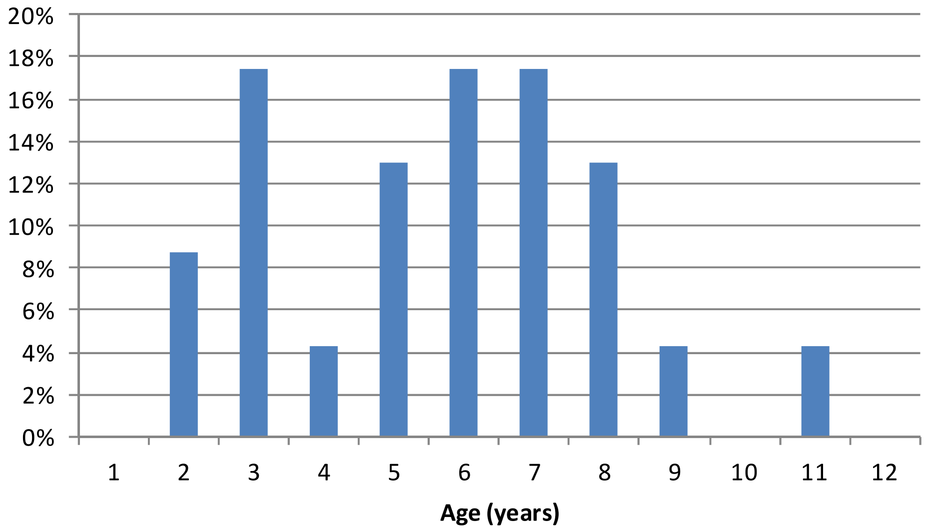


Figure 46: Restrained child age distribution for booster systems – Lateral impacts, struck side, known injuries

There are 21 injured children in booster systems, sustaining 130 injuries of all severities. Of these children, 17 have AIS ≥ 2 injury(ies) with 59 AIS ≥ 2 injuries in total.

Figure 47 shows how the 59 individual AIS ≥ 2 injuries for booster system restrained children are distributed across the body regions. For example, 54% of all the individual AIS ≥ 2 injuries for this sample are to the head.

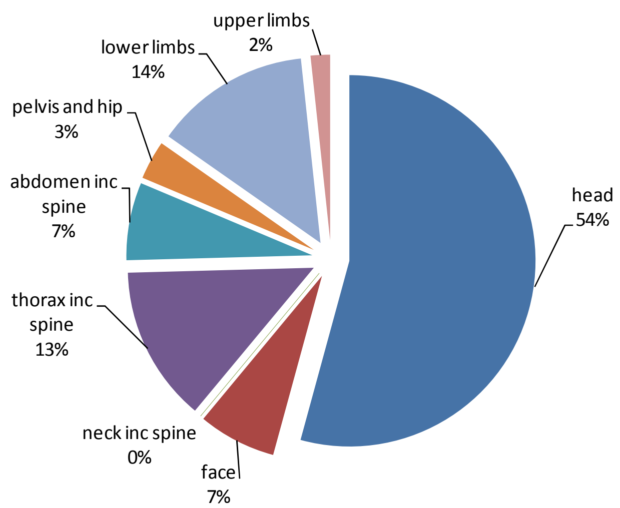


Figure 47: AIS ≥ 2 Injury distribution for booster systems – Lateral impact restrained children - 59 AIS ≥ 2 injuries in total

The head is by far the most injured body region for the children in this sample, with 32 (54%) of the 59 AIS ≥ 2 injuries being to the head. Of these AIS ≥ 2 injuries 23 are brain injuries, 8 are fractures and 1 is a crush or penetration injury. Skull fracture is present for 5 casualties along with brain injury, whilst 10 casualties have just brain injury. Compared with shell systems upper limb injuries decrease whilst lower limb increase.

Of the 16 casualties with AIS ≥ 2 head injury, 14 are sat in the rear of the car and 2 are front seat passengers. Regarding injury causation, known contacts are varied: window lateral (5), B pillar (1), C pillar (4), object external to the vehicle (1), door panel (2), own side (2).

The 5 casualties with AIS ≥ 2 thoracic injuries have those injuries attributed to the door panel in 3 cases and CRS in one case (1 unknown). Of the 8 AIS ≥ 2 thoracic injuries, 1 is a rib fracture and 1 is a crush injury. For the lower limbs the most frequent contact is with the door panel.

Only Adult Seat Belt – Struck Side

There are 30 children using only the adult seat belt, of which 3 are not injured. The simple distribution of age is given in Figure 48, showing a spread from 4 to 13 years old, although ages are concentrated in the 6 to 11 year old range, with a dip for 8 year olds.

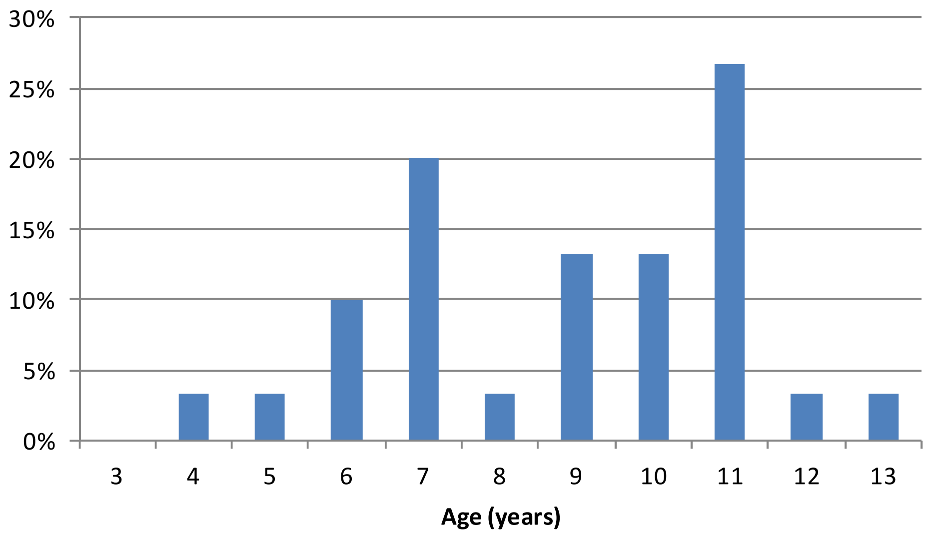


Figure 48: Restrained child age distribution for just adult seat belts – Lateral impacts, struck side, known injuries

There are 27 injured children using just adult seat belts, sustaining 149 injuries of all severities. Of these children, 17 have AIS ≥ 2 injury(ies) with 79 AIS ≥ 2 injuries in total.

Figure 49 shows how the 79 individual injuries for restrained children using just the adult seat belt are distributed across the body regions. For example, 49% of all the individual AIS ≥ 2 injuries for this sample are to the head.

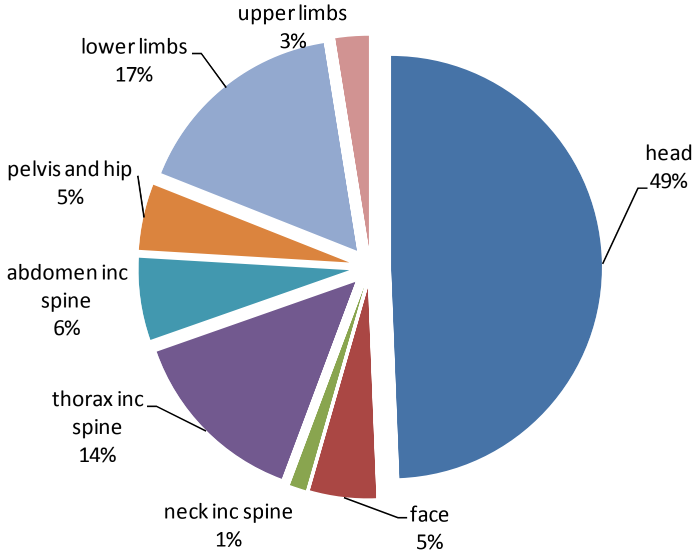


Figure 49: AIS ≥ 2 Injury distribution for just adult seat belts – Lateral impact restrained children - 79 AIS ≥ 2 injuries in total

Compared to frontal impacts, where for children just using the adult seat belt the injured body regions become more distributed than for the dedicated CRS, a similar pattern is seen in Figure 49 to booster systems for lateral struck side impacts, with half the AIS ≥ 2 being to the head and lower limb injuries being prominent. Compared with shell systems upper limb injuries decrease whilst lower limb increase (as with booster systems).

Of the 39 AIS ≥ 2 head injuries 32 are brain injuries and 7 are fractures. Skull fracture is present for 5 casualties along with brain injury, whilst 7 casualties have just brain injury.

Of the 12 casualties with AIS ≥ 2 head injury, 6 are sat in the rear of the car and 6 are front seat passengers. Regarding injury causation, known contacts are varied: window lateral (1), roof (1), object external to the vehicle (4), door panel (1). For the lower limbs the most frequent contact is with the door panel although contacts for limbs are also often unknown. The 7 casualties with AIS ≥ 2 thoracic injuries have those injuries attributed to the door panel in 4 cases and own side in 1 case (2 unknown). Of the 11 AIS ≥ 2 thoracic injuries, 3 are fractures.

5.7. Maximum Injury Severity by Restraint Type – Non-Struck Side

As this section addresses injury by body region and restraint type, restrained children with injuries not known or restraint type not known are excluded.

Figure 50 gives the proportions of restrained children (lateral impact – non-struck side) by restraint type that have an injury to each body region at the MAIS ≥ 2 level (body region). For example, of the 14 children in the dataset restrained in a shell system, 14% have a head injury of AIS 2 or above. The MAIS ≥ 2 (head) rate is therefore 14%. Likewise Figure 51 addresses MAIS ≥ 3 injury rates. Shell systems are rear and forward facing harness systems (including multidirectional ‘convertible’, 2 way child restraints).

It is important to remember that this sample is not representative. An extreme example of this would be to note the high levels of head injury to shell system restrained children. For each lateral impact that a child in a rearward facing child is involved in across Europe in a non-struck side position, there is not such a high chance (14%) of a head AIS ≥ 2 injury in every impact.

This analysis shows the general patterns of injury across the different restraint types. The neck, thorax and abdominal regions include the relevant region of the spine. ‘Head’ does not include the face. The MAIS ≥ 2 (external) rate is zero for all and not shown on the figures.

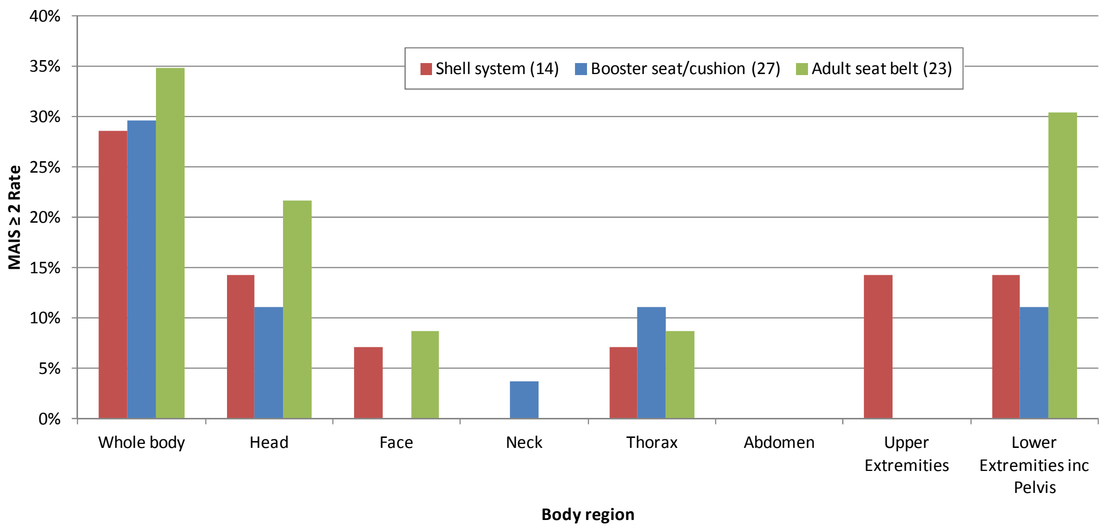


Figure 50: Proportion of restrained children with an AIS ≥ 2 injury by body region and restraint type – Lateral impact, non-struck side n=64

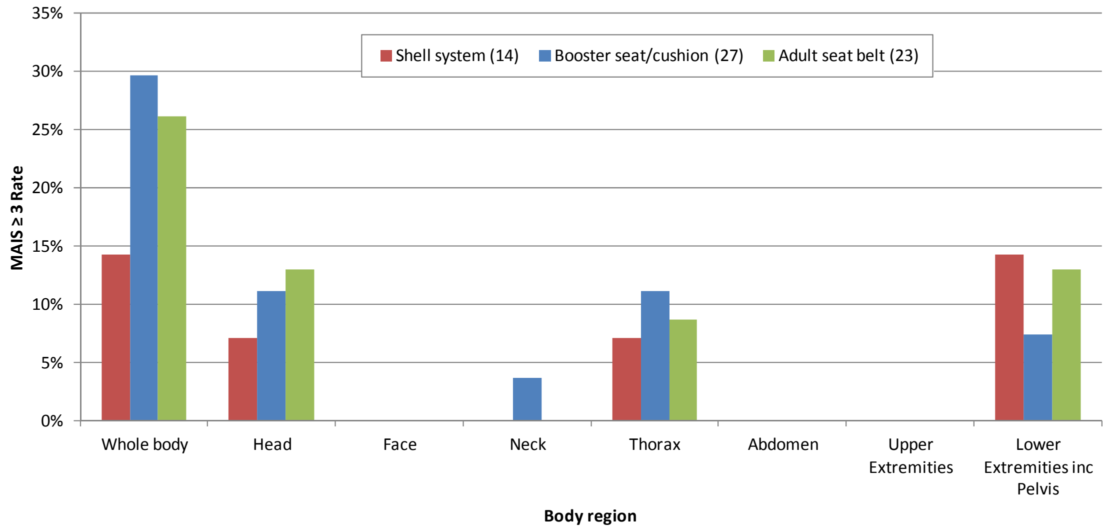


Figure 51: Proportion of restrained children with an AIS ≥ 3 injury by body region and restraint type – Lateral impact, non-struck side n=64

Shell System CRS The number of children is low with only 14 in the sample. The rate of AIS ≥ 2 injury to both the lower and upper extremities is equivalent to that for the head. At the AIS ≥ 3 level, upper extremity injuries fall away leaving the highest rate for lower extremity injuries.

Booster seat/cushion The rate of AIS ≥ 2 injury to both the lower extremities and thorax is equivalent to that for the head. At the AIS ≥ 3 level, thoracic and the head give the highest rate of injury.

Adult seat belts In this sample, the rates of head and lower extremity injuries are high at both AIS ≥ 2 and AIS ≥ 3 levels, followed by thoracic injuries.

The following sections look at each restraint type individually at an injury level rather than the maximum injury level for each body region.

5.8. Injury to Body Regions by Restraint Type

Shell Systems – Non-Struck Side

There are 14 children using shell systems with a harness, of which 4 are not injured. The simple distribution of age is given in Figure 44, showing mainly children under 1 year old to 2 years old.

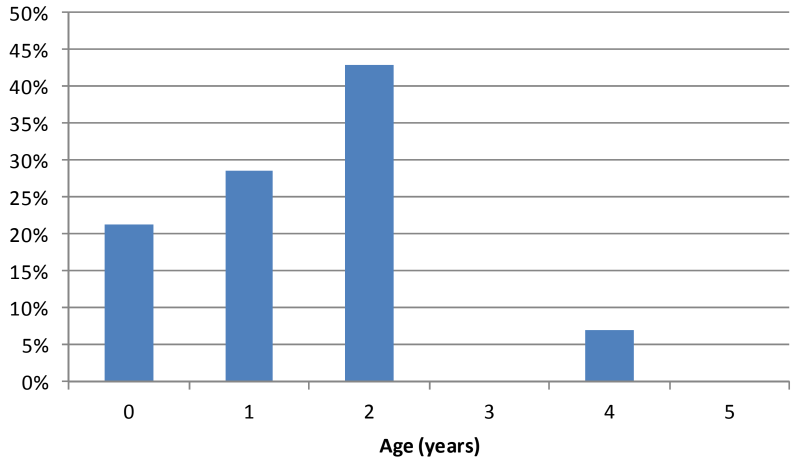


Figure 52: Restrained child age distribution for shell systems – Lateral impacts, non-struck side, known injuries

There are 10 injured children in shell systems with harness, sustaining 22 injuries of all severities. Of these children, 4 have AIS ≥ 2 injury(ies) with 9 AIS ≥ 2 injuries in total. Figure 45 shows how the 9 individual AIS ≥ 2 injuries for shell system restrained children are distributed across the body regions. For example, 22% of all the AIS ≥ 2 individual injuries for this sample are to the head.

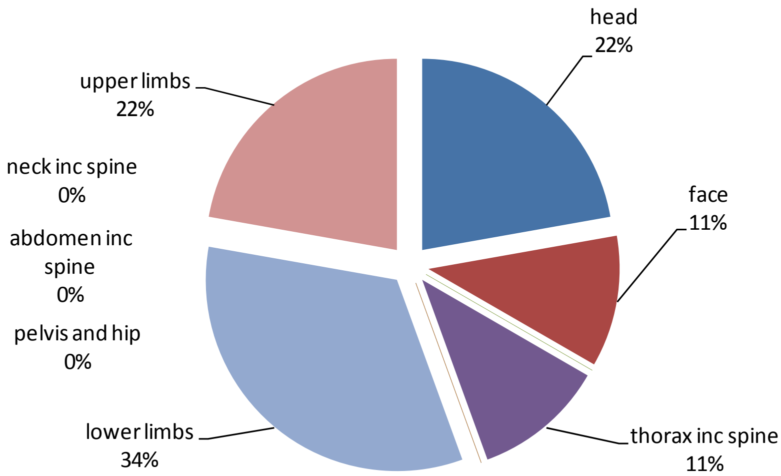


Figure 53: AIS ≥ 2 Injury distribution – Non-struck side restrained children – Shell systems - 9 AIS ≥ 2 injuries in total

The number of individual AIS ≥ 2 injuries is small and only applies to 4 children. In this sample the injuries are distributed five body regions, with extremities combined at the highest number.

Booster Systems – Non-Struck Side

There are 27 children using booster systems, of which 6 are not injured. The simple distribution of age is given in Figure 46, showing a spread from 2 to 11 years old.

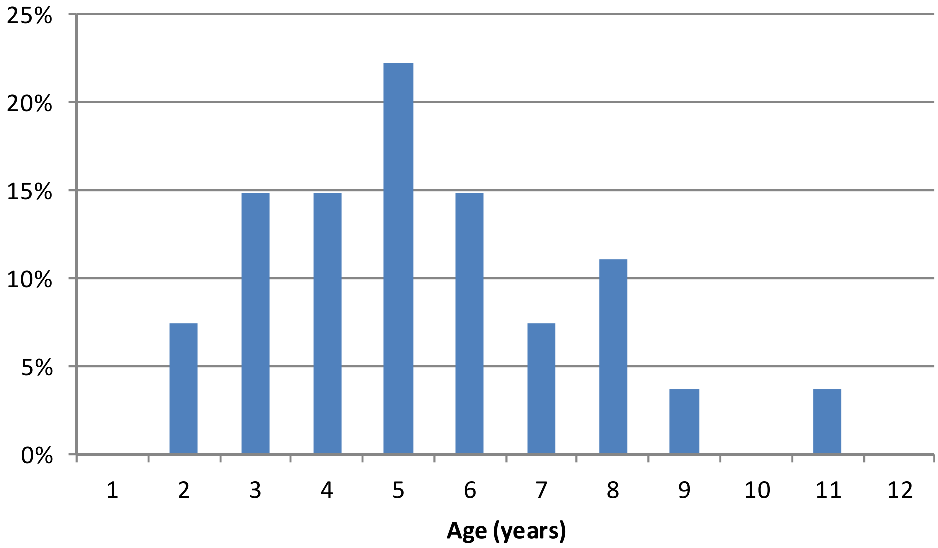


Figure 54: Restrained child age distribution for booster systems – Lateral impacts, non-struck side, known injuries

There are 21 injured children in booster systems, sustaining 51 injuries of all severities. Of these children, 8 have AIS ≥ 2 injury(ies) with 13 AIS ≥ 2 injuries in total.

Figure 47 shows how the 13 individual AIS ≥ 2 injuries for booster system restrained children are distributed across the body regions. For example, 46% of all the individual AIS ≥ 2 injuries for this sample are to the head.

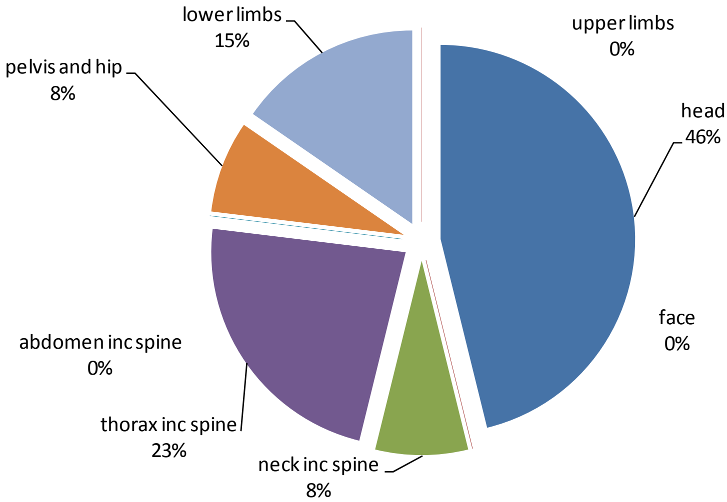


Figure 55: AIS ≥ 2 Injury distribution – Non-struck side restrained children – Booster systems - 13 AIS ≥ 2 injuries in total

The number of individual AIS ≥ 2 injuries is small and only applies to 8 children. In this sample the injuries are distributed across the body regions, with the head having the highest number.

Only Adult Seat Belt – Non-Struck Side

There are 23 children using only the adult seat belt, of which 6 are not injured. The simple distribution of age is given in Figure 56, showing a spread from 3 to 13 years old, although ages there are peaks at 10 and 11 years olds.

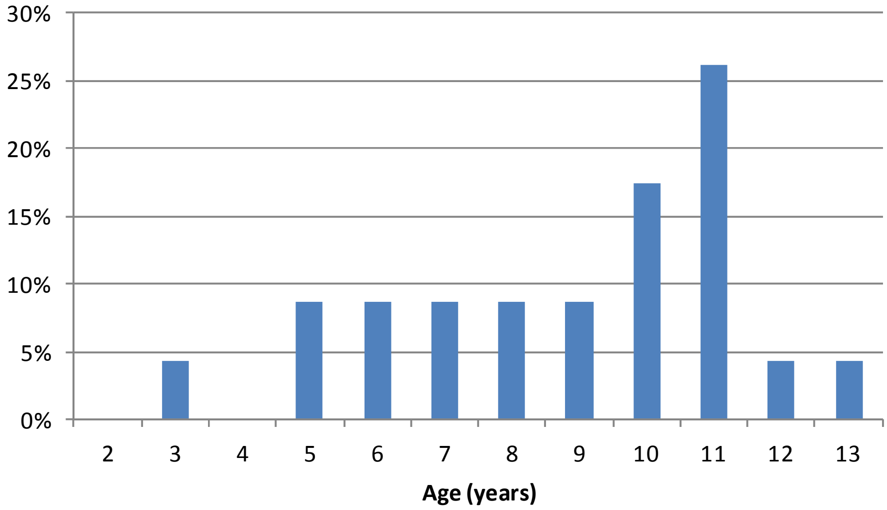


Figure 56: Restrained child age distribution for just adult seat belts – Lateral impacts, non-struck side, known injuries

There are 17 injured children using just adult seat belts, sustaining 49 injuries of all severities. Of these children, 8 have AIS ≥ 2 injury(ies) with 22 AIS ≥ 2 injuries in total.

Figure 57 shows how the 22 individual injuries for restrained children using just the adult seat belt are distributed across the body regions. For example, 45% of all the individual AIS ≥ 2 injuries for this sample are to the head.

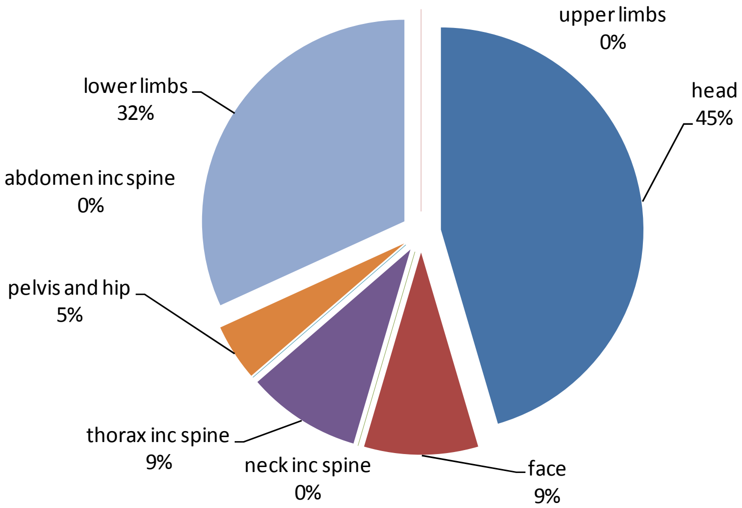


Figure 57: AIS ≥ 2 Injury distribution for just adult seat belts – Lateral impact restrained children - 22 AIS ≥ 2 injuries in total

The number of individual injuries is small and only applies to 8 children. In this sample the injuries to the head are the most numerous, followed by the lower limbs.

Non-Struck Side - Injury Causation

Examining the whole non-struck side sample. The 10 children with AIS ≥ 2 head injuries have the following known contacts; B pillar (1), object internal to the vehicle (1), door panel (2) and seat backrest (1). The 10 children with lower extremity AIS ≥ 2 injuries have the following known contacts: luggage (1), other occupant (1), door panel (1) and seat backrest (4). Of the 6 AIS ≥ 2 thoracic injuries, 5 involve lung contusion and 1 is a spinal injury, cord contusion with dislocation due to own kinematics. Contacts for the lung contusions are various: Safety belt, CRS, other occupant (twice) and CRS.

Looking at the injury distribution through the different types of restraint systems in Figure 51, it is seen that the head that is better protected in shell systems than with other systems on the non-struck side. This is likely to be due to children in such systems being linked to the CRS with a harness and that the CRS movement is limited when the seatbelt route is correct. The scenario with boosters and only adult seat belt can be an escape from the restraint system of the upper part of the child. This can lead to a higher displacement and then more risk for sustaining a head impact again a rigid part of the car or be place into the area where the intrusion is occurring.

6. SAFETY TECHNOLOGIES

To maximise the data regarding safety technologies the CREST, CHILD and CASPER are used in this Section.

Whilst it would be beneficial to be able to indicate the effectiveness of safety technologies such as pretensioners, load limiters and airbags in reducing injury the numbers in the database when spread across crash situation (type and severity), presence of misuse, child age and restraint type make it is difficult. Here a statement is made regarding the information in the accident database regarding safety technologies. It is more likely that experiences here can be put with reconstruction or misuse testing results to start to form a more complete picture of the effectiveness of safety technologies (car or CRS) for restrained children.

No evaluation of primary safety systems has been made or is possible with the road accident database. Also no causation analysis is undertaken. The main focus of the road accident database is to collect information on secondary (passive) safety aspects for restrained children.

Safety technologies are often introduced primarily to protect adult occupants and the benefit or problems for children travelling in these seating positions equipped with these safety functions is not one of the first considerations. This can lead to the following situations;

- safety benefit also for children,
- no benefit for children, but also no danger,
- dangerous situation due to the safety function.

6.1. Seat Belt Technologies

Front and Rear Passenger Compartments

As part of the introduction of airbags and associated crash structures (EuroNCAP era) restraint systems often also incorporate pretensioners and load limiters - but often only in the front seats. This is shown in Figure 58. Side airbags refer to door or (more often) seat mounted side airbags. Head airbags refer to side mounted airbags in the roof rail (tube or curtain).

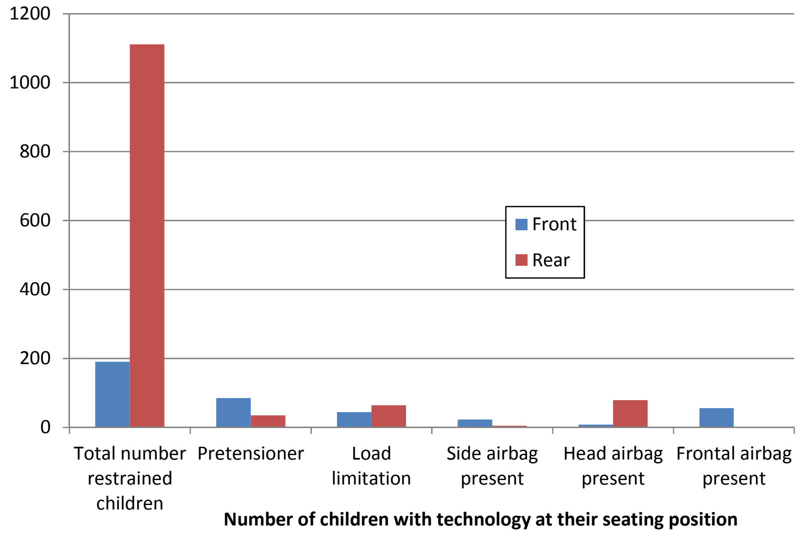


Figure 58: Number of restrained children with certain technologies present at their seating position

Although the majority of children are in the rear rows of seats (85%) this proportion is not reflected in the technologies present at children's seating positions.

6.2. Airbags

Disabled Frontal Airbags

In the database it has been recorded that frontal airbags (all in the front seats) have been disabled for 6 child occupants, in all cases with rear facing CRS. There are 15 occasions recorded in the database of a frontal airbag and a rear facing CRS. In 8 cases the frontal airbag has deployed, in 1 case it did not deploy as the impact was lateral rather than frontal and it has been disabled in 6 cases.

There is one example of CPOD transponder technology (Child Seat Presence and Orientation Detection) in the accident database. It has proved effective in disabling the passenger frontal airbag in a 50 km/h (EES) frontal impact where a rear facing infant carrier was present. There were no injuries to the child.

Deployed Frontal Airbags and Rear Facing CRS

There are 8 cases with a deployed frontal airbag and a rear facing CRS, with all children in the front passenger position. In 7 of the cases the EES is below 45 km/h with no intrusion of the passenger compartment. In the other case (number 4 in Table 11) the EES was 72 km/h but with no intrusion to the front passenger area.

The eldest being 8 months old, 3 of the children died and 5 survived. Table 11 gives a summary of the highest head injury severities recorded for these 8 children.

	Highest AIS severity	
Child	Brain injury	Skull fracture
1 - killed	6	2
2 - survived	4	-
3 - survived	4	2
4 - survived	4	-
5 - survived	4	3
6 - killed	4	3
7 - killed	5	4
8 - survived	3	2

Table 11: Injury summary – rear facing children with deployed frontal airbag

Table 11 shows that each child had injury or injuries to the brain, 6 of them also reported as having skull fracture. Like the general rear facing sample injuries are characterised by a lack of injury to other body regions away from the head. All these injuries are attributed to contact with the deploying frontal airbag.

Deployed Frontal Airbags and Forward Facing Children

There are 35 instances of a deployed frontal airbag and a known forward facing restrained child. Of these, 27 occurred in frontal impacts (where the predominate impact causing injury has been recorded as frontal) - 20 adult seat belts, 2 forward facing harness CRS and 5 Booster seat/cushion).

The highest severity injury that has been recorded to contact with a deployed frontal airbag is to 4 year old in a group 1 harness system. The AIS 4 pulmonary contusion (bilateral) is attributed to the deploying airbag but is it noted that also harness contact could have made a contribution to the injury. This was the only AIS ≥ 3 injury and the child survived. The EES of the head on impact with another car was 70 km/h and the delta v was 79 km/h (maximum deformation of 920 mm) with intrusion to the passenger compartment starting. This is a substantial impact and without the airbag deployment, head excursion to the dashboard may have occurred with associated head injury being possible. Further detail in the case shows that the CRS was badly damaged during the impact with failure of the structure. The airbag therefore may have paid a part in the protection of the child from worse injury.

Figure 59: Views of seating position and general state of CRS after the accident

Side Airbags

Seat or door mounted

There are 8 instances of a deployed side airbag in a position with a restrained child (6 with adult seat belts and 2 in rear facing CRS). One child is in the rear. Of these, 3 occurred in frontal impacts and 5 in lateral impacts (the predominate impact causing injury being recorded). Of the 5 children involved in a lateral impact, only 1 has AIS 3 level injuries, which is a relatively low number in regard with the general severity of this database. Additional investigations could be conducted, examining each case with side airbag deployment and making comparison to another child of a similar age, restrained in the same type of CRS with similar intrusion but with no airbag fitted. This would be a way to estimate the safety benefit of the combination of ‘car and side airbag’. This activity will be done in further analysis as it is very time consuming to find the correct case without any guarantee of sound results.

Head level (tube or curtain)

There are more instances (23) of a deployed head level side airbag in a position with a restrained child that a seat or door mounted airbag as these systems often cover the front and rear passenger compartments. Of these, 13 occurred in frontal impacts and 10 in side impacts (the predominate impact causing injury being recorded). Eleven children are restrained with adult seat belts, 1 in rear facing CRS, 6 in forward facing harness CRS and 5 using a booster seat/cushion. There are no injuries attributed to head level side airbag deployment. The same work will be conducted as for seat or door mounted side airbags in order to check that the airbag deployment is not the origin of injuries of children and to investigate safety benefit.

6.3. Child Restraint Systems

Integrated CRS

There are 6 children restrained with integrated booster systems in the database, 2 are in the same vehicle. Two are in lateral impacts and 4 in frontal impacts. It is therefore difficult to conduct an analysis of such systems with such low numbers. No failure of integrated CRS has been reported and no misuse has been mentioned.

ISOfix

The number of child occupants using ISOfix to restrain their child restraint in the accident database is low at 7, with 3 of these children in the same vehicle. All cases with children using ISOfix are in the CASPER dataset (rather than the earlier datasets). Surprisingly, given that they are a relatively recent addition to the CRS market, 6 of the 7 children are restrained in ISOfix booster seats, and one in a forward facing harness system.

7. COMPARISON OF INJURY RECORDING SYSTEMS

7.1. Background

The previous CREST and CHILD projects used the AAAM AIS90 system for recording injuries. At the beginning of the CASPER project it was decided that all previous cases would be changed from AIS90 to AIS98, and AIS98 would become the primary injury recording system for CASPER. Additionally, when possible, all new CASPER cases would be coded to AIS2005 (updated 2008) for child occupants. This would be an exploration of the most recent AIS injury recording system whilst keeping the link with previous cases and the injury risk curve work already undertaken.

In the following two sections, overall comparisons are made regarding the injury recording systems. The first evaluates the change from AIS90 to AIS98 as the primary recording system and the second an indication of the level of change, in comparison to AIS98, if using AIS2005 in the future as the primary injury system.

7.2. Change from AIS90 to AIS98

Main Considerations

It was thought that for children the major change from AIS90 to AIS98 would be for femur fractures. In AIS90, 5 AIS codes are available that can reduce the AIS severity score from 3 to 2 for occupants below 12 years old (femur not further specified, condylar, shaft, subtrochanteric and supracondylar). The below 12 years old codes are not available in AIS98 and therefore no severity score reduction takes place.

Away from age specific codes other main changes are (from AIS90 to AIS98):

- AIS severity for heart contusions reduced from AIS 3 to AIS 1 (441099, 441002 and 441004)
- AIS severity for certain duodenum laceration codes reduced from AIS 3 to AIS 2 (541020 and 541022)
- Flail chest (unstable chest wall) not further specified is reduced from AIS 4 to AIS 3
- Rib cage fracture NFS (not further specified) (450210) AIS 1 changes to multiple rib fractures not further specified AIS 2 (same code)

In each body region in AIS98, codes are available with AIS 9 severity scores that reflect that it is known that some injury has occurred in that region but the injury is not known. These codes are not available for all body regions in AIS90. Codes are also added in AIS98 for death without specific injury information. For example, 115999.9 – Died without further evaluation; no autopsy, which builds upon 115099.9 – closed head injury NFS (Use also for traumatic brain injury NFS).

Maximum Abbreviated Injury Score

Injuries in only the CREST and CHILD datasets were recorded with AIS90. Therefore the comparison here of AIS90 and AIS98 selects only the CREST and

CHILD datasets and children that are restrained with known MAIS. Children with MAIS unknown are excluded even if it is known that injuries were fatal.

Figure 60 and Figure 61 show the Maximum Abbreviated Injury Score for the same set of CREST and CHILD restrained children under the AIS90 and AIS98 injury recording systems.

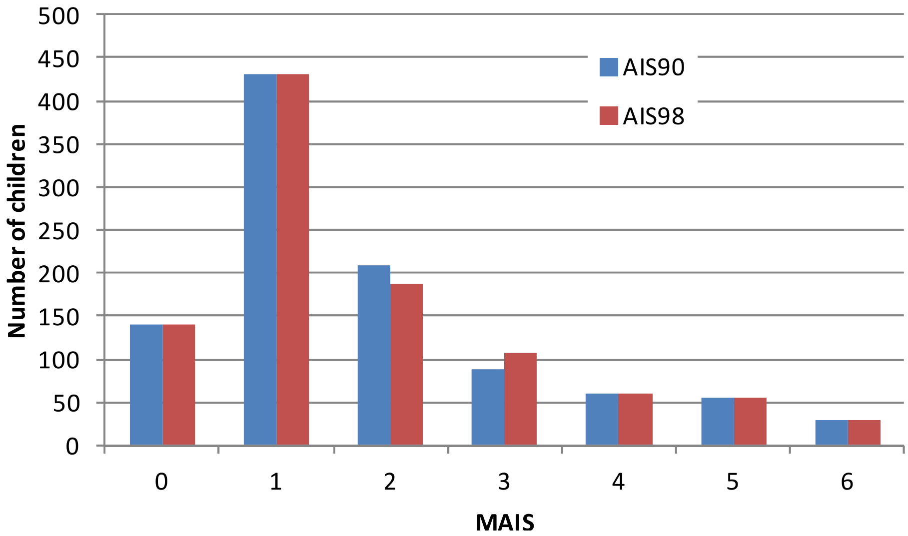


Figure 60: MAIS severity by recording system (1008 restrained children)

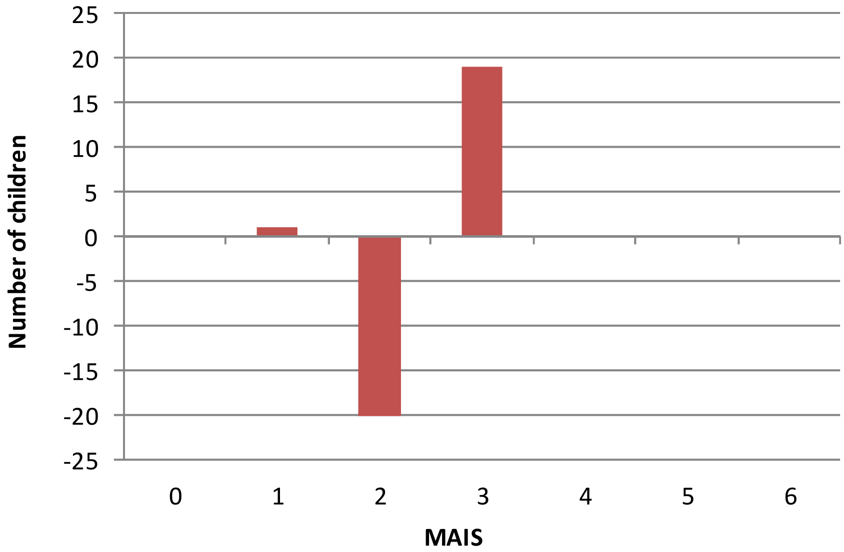


Figure 61: MAIS severity differences AIS90 and AIS98 (1008 restrained children)

In Figure 61 the columns indicate the situation in AIS98 compared to AIS90. For example, there are 19 more MAIS 3 children in the sample when using the AIS98 system than in AIS90. Differences can clearly be seen between the MAIS 2 and 3 levels and one child has a MAIS changed to 1. Although across this number of children (1008) only 20 are affected, which is a small proportion.

MAIS by Body Region

To find which body regions are causing the differences shown in Figure 60 and Figure 61, Figure 62 illustrates the MAIS ≥ 3 rate by body region – the proportion of children with AIS ≥ 3 injuries in each body region.

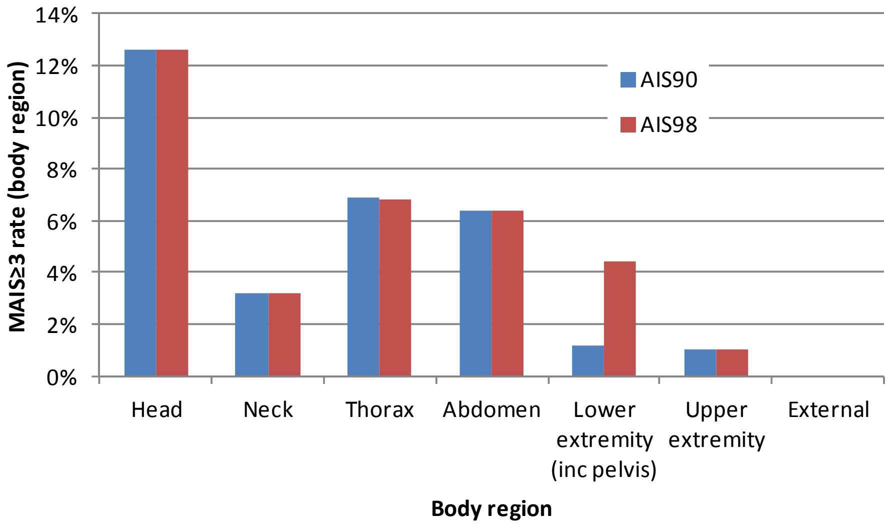


Figure 62: MAIS ≥ 3 (body region) by recording system (1008 restrained children)

Figure 62 shows that the majority of the difference between the recording systems is shown to be in the lower extremities, with an increase for AIS98. Inspection of the cases shows these injuries to be femur fractures. There is a decrease in AIS severity (from AIS90 to AIS98) for one restrained child in the thoracic region. This is a reduction in heart contusion from AIS 3 to AIS 1 (441002).

7.3. Comparison of AIS98 and AIS2005

Main Considerations

There are major differences between the AIS98 and AIS2005 (updated 2008) injury recording systems, changes that are much more pronounced than those between AIS90 and AIS98.

In AIS90 there are 1,331 individual injury codes, in AIS2005 this number increases to 2,104 (Barnes 2009). Overall, not concentrating on any particular body region, changes are introduced both in actual injury severity levels for individual injuries and reflecting the level of detail required from the medical information to be able to code an injury to a particular severity level.

The first major set of changes consider advances in medical care that lower the threat to life of particular injuries. The second set of changes is a consideration that more detailed injury information is often required in AIS2005 to assign a certain severity level than in AIS98. For example, cerebrum intraventricular hemorrhage (140678) is AIS 4 in AIS98. But in AIS2005 just this knowledge of the injury allows only AIS 2 to be recorded. If associated coma of over 6 hours is known then AIS 4 can be recorded.

In this overview it is not possible to cover the many changes but, as an example, one injury that does appear often in the dataset is 'concussion', which is AIS 2 in AIS98 but in AIS2005 if no time of unconsciousness is available (NFS) then the injury is AIS 1.

Maximum Abbreviated Injury Score (MAIS)

All child occupants in the CASPER dataset were recorded with both AIS98 and AIS2005 injuries. Many children in the CHILD dataset have also been coded with AIS2005 injuries.

There are 452 restrained child occupants recorded in the database with information for both AIS 98 and AIS2005 systems, with 87 uninjured (MAIS 0) and 51 having unknown injuries (MAIS 9). The comparison here selects only the restrained children with known MAIS. Children with MAIS unknown are excluded even if it is known that injuries were fatal.

Figure 60 and Figure 61 show the Maximum Abbreviated Injury Score for the same set of CHILD and CASPER restrained children under the AIS98 and AIS2005 injury recording systems.

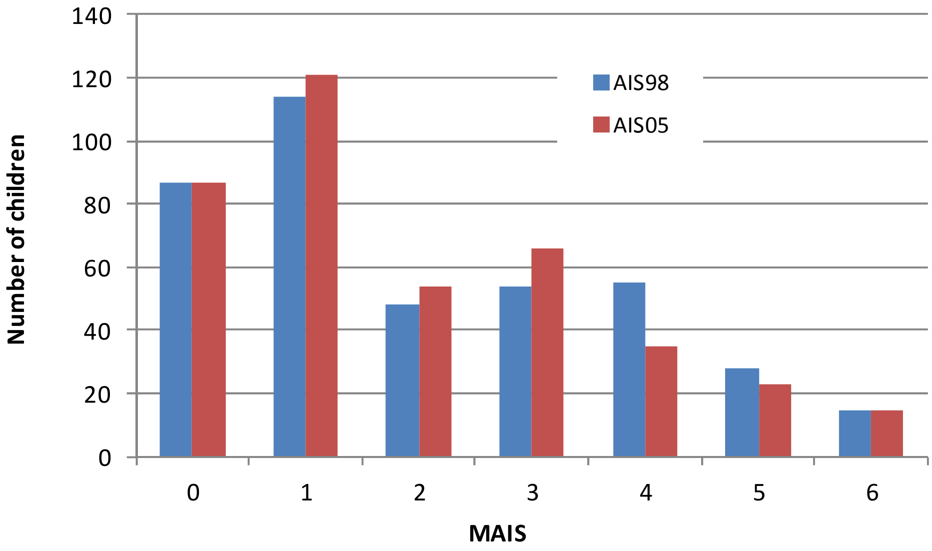


Figure 63: MAIS severity by recording system (401 restrained children)

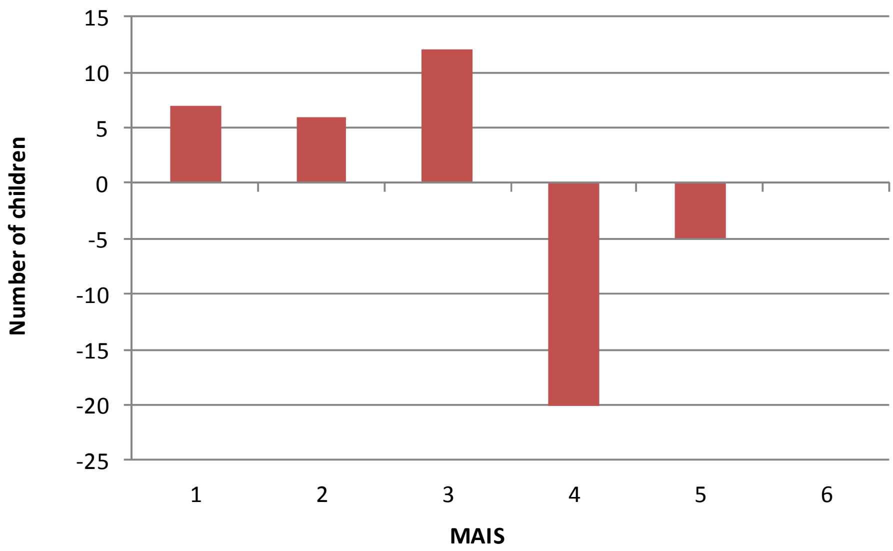


Figure 64: MAIS severity differences AIS98 and AIS2005 (401 restrained children)

In Figure 64 the columns indicate the situation in AIS2005 compared to AIS98. For example, there are less MAIS 4 children in the sample when using the AIS2005 system than in AIS98. A shift from MAIS 4 and MAIS 5 to lower MAIS values can be seen, involving 25 of the 316 children.

AIS Severity by Injury

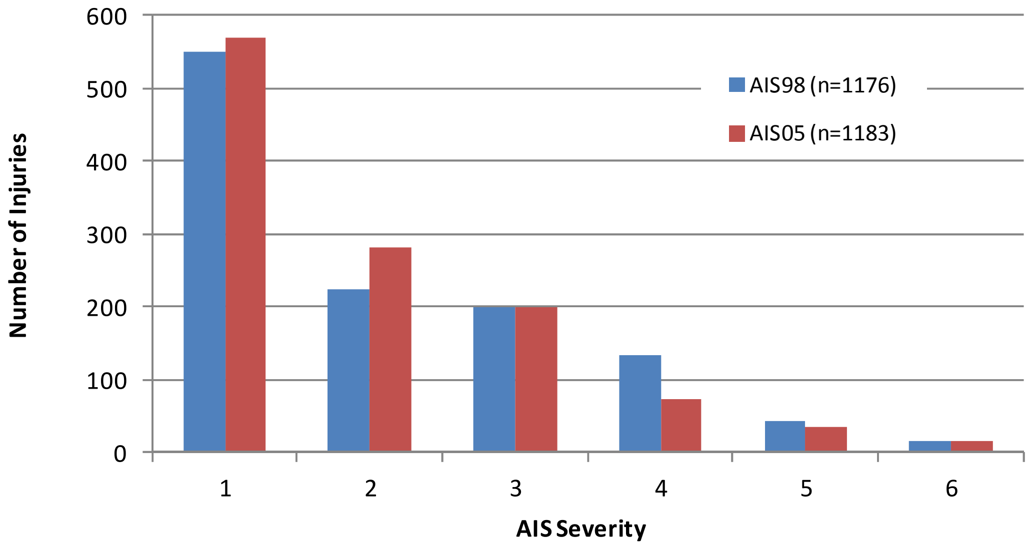


Figure 65: AIS severity for all injuries by recording system (401 restrained children)

Figure 66 shows the differences at each AIS severity point between the AIS98 and AIS2005 recording systems. As an example there are 61 less AIS 4 injuries recorded in the AIS2005 system than the AIS98 system for the same group of 401 restrained children (with some injury).

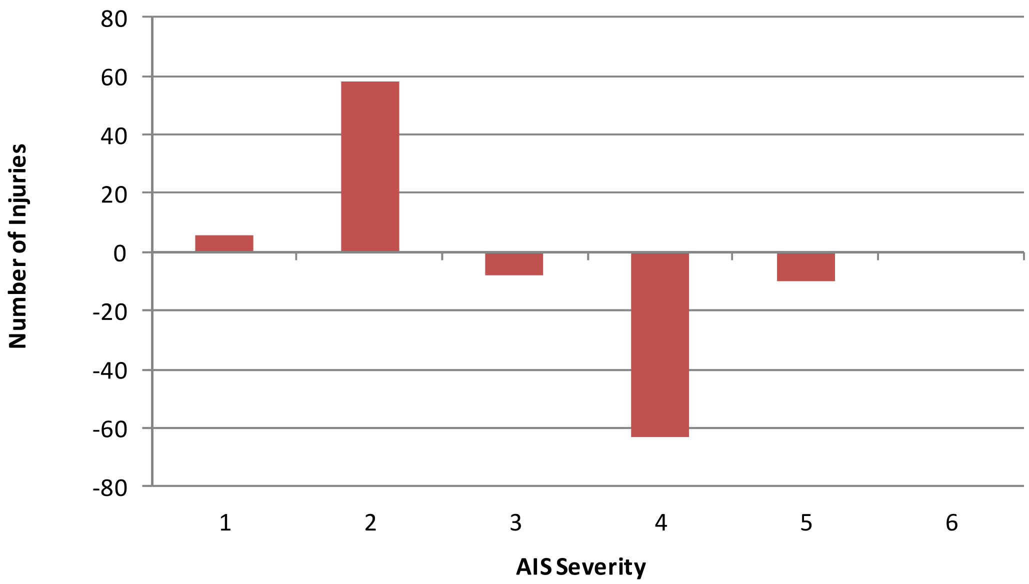


Figure 66: AIS severity differences for all injuries between AIS98 and AIS2005 (401 restrained children)

In Figure 66 the columns indicate the situation in AIS2005 compared to AIS98. For example, there are more AIS 2 injuries for this sample when using the AIS2005 system than in AIS98 and less AIS 4 injuries.

MAIS by Body Region

The largest difference in injury severity in Figure 66 is seen between AIS 2 and AIS 4. Therefore, to find which body regions are causing the differences, Figure 67 illustrates the MAIS ≥ 3 rate by body region – the proportion of children with AIS ≥ 3 injuries in each body region.

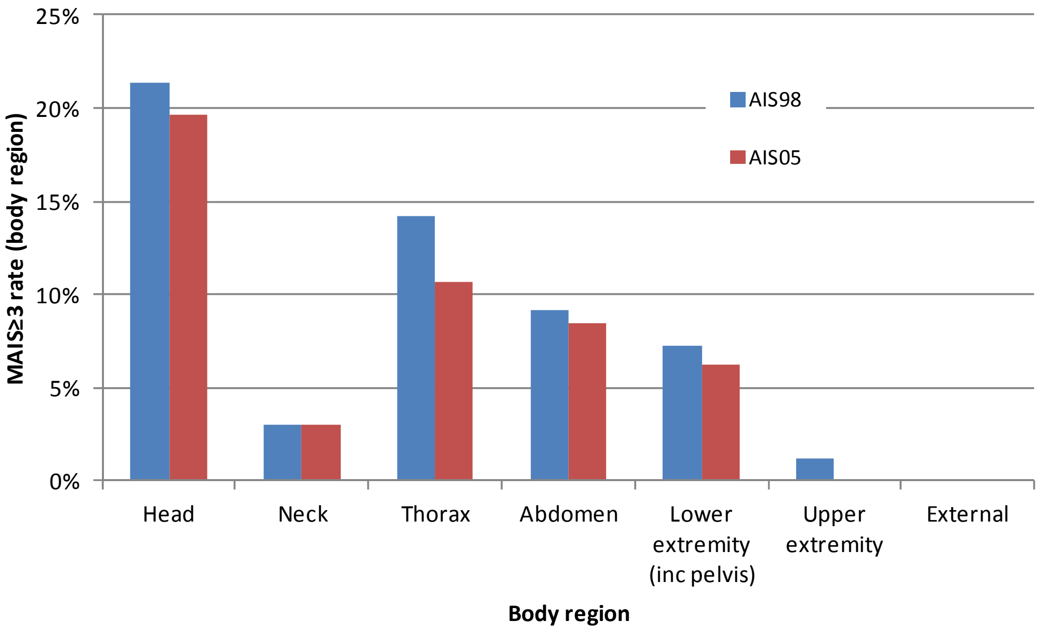


Figure 67: MAIS ≥ 3 (body region) by recording system (401 restrained children)

Figure 67 shows that the differences between the recording systems is shown to be in the spread across the body regions but in particular the largest percentage drop is for thoracic injuries. Looking at the actual thoracic injuries that have decreased in AIS severity from being AIS 3 in AIS98, the majority involve lung contusion, with unilateral 'not further specified' and 'minor' reducing to AIS 2 in AIS2005. Similarly, but in lower numbers, pneumothorax also features, especially 'not further specified' (442202) which reduces to AIS 2 in AIS2005.

Of the 8 head injuries reduced from AIS ≥ 3 in AIS98 to below AIS 3 in AIS2005; 4 are cerebrum intraventricular hemorrhage (AIS 4 to 2), 2 are cerebrum subarachnoid hemorrhage –one slight and one not associated with coma - (AIS 3 to 2) and 2 are cerebrum hematoma petechial hemorrhages - not further specified - (AIS 3 to 2).

8. DISCUSSION / CONCLUSIONS

8.1. Methodology

Whilst the in-depth investigation of collisions involving restrained children is complex, with the addition of dedicated restraint systems adding a layer of investigation compared to studying adults, it is believed that the process used of group discussion gives the best opportunity to ensure consistency and the best quality of information possible. By establishing the parameters to be collected at the start, with a common database, teams are able to focus on important considerations whilst carrying out the investigations and seek advice from the wider group when required. Crash severity and injury mechanisms in particular benefit from this approach of the combined groups' experiences.

Sampling

As made clear during this report the cases found in the CASPER dataset are not proportionally representative of the accident situation across Europe, or in individual countries. Cases are collected to reflect the scientific aims of the project regarding new injury criteria and being sufficient in detail to accurately replicate the crashes in full scale physical reconstructions or virtual simulations with a high degree of confidence. The case selection criteria and the severity of the impacts limits the conclusions that can be drawn from analysis of the database but as long as these limitations are kept in mind the accident is important for identifying the body regions that are being injured in different types of CRS.

Quality of Restraint Use

The consideration of misuse remains a challenge and the knowledge continues to grow with the collection of further accident cases, experiences from field surveys and sled testing. In particular it can be difficult to appreciate low level misuse (for example, small amounts of slack), especially in low severity impacts, and to separate injury outcome from normal crash circumstance and injury outcome from misuse in high severity crashes.

The overall rate of misuse identified (16%) in frontal impacts is lower than figures found in misuse field studies (surveys and checking days). It is likely that at best the database is considering severe misuse, rather than being able to highlight slight misuse. In the sample most misuse is seen for rear facing infant carriers. This is due to the clear misuse of the CRS being in the place of a deployed frontal airbag, leading to serious injury. For forward facing CRS with harness, misuse situations are well defined and can be found from evidence during investigation, for example, poor seat belt routing (in situ or from marks on CRS), incorrect harness strap height. For booster systems and just the adult seat belt, the restraint situation between the CRS and car and between the seat belt and child is lost. So, although of course there are still possibilities to identify misuse from CRS marks and injuries, the possibilities are less. The lower rates identified for booster and seat belts may also correspond with fewer possibilities for misuse errors as the restraint systems become less complex.

Care has been taken in the group, and should be taken into consideration in similar future activities, that misuse can still be present but the evidence is not available. This can be both practically, for example the CRS is not present during investigation, or crash severity is too low for misuse to be apparent.

Inappropriate use is difficult to analyse fully when height or weight are often unknown during data collection, leading age to be relied upon as an estimation of appropriate use (when height and/or weight are not known). The approach taken in CASPER of a set of rules for the coding of appropriate use is recognised as being limited when height or weight are not known, but is thought to be the best approach possible with data collection across multiple teams (consistency is ensured) and when no further information is available.

8.2. Frontal Impacts

Overall

There are 450 restrained children in the dataset in frontal impacts with type of restraint and injuries known (or it is known that no injury has occurred). Of these children, 45% have a MAIS ≥ 2 and 25% have a MAIS ≥ 3. There are a further 19 restrained children with fatal injuries but the actual injuries by AIS and body region are not known.

There is a general trend for a shift in cumulative EES % graph towards higher EES for higher overall injury level, as expected. Of the MAIS ≥ 3 children or those with fatal injuries, approximately half are in a vehicle for which the EES is over 60 km/h and approximately 25% over 70 km/h, exceeding the design criteria of cars and CRS (ECE R44 frontal impact test conditions).

Selecting MAIS ≥ 3 children or those with fatal injuries and filtering by whether misuse is identified, shows that the cases with misuse identified are shifted towards a lower EES distribution than cases with no misuse identified. The difference is less apparent at higher EES values as the effect of misuse is likely to be more masked at higher severity as the natural effects of higher severity - higher loads on the body and intrusion - play a larger role. Overall, there are higher MAIS ≥ 2 injury levels for restrained children in the sample where it has been possible to identify misuse, compared to those restrained children with misuse not identified.

The same relationship is not apparent for appropriate use. This may be due to the definitions of inappropriate injury used, especially when weight and/or height are not known. In particular the recording of restrained child up to and including 11 years old being inappropriately restrained in just the adult seat belt (where otherwise no information is known regarding weight and/or height) is quite strict.

Restraint Types

Rearward facing CRS: In the CHILD/CASPER dataset there are 33 children using rearward facing child restraint systems, of which 13 are not injured. Even though case numbers are small it is clear that the head is the most seriously injured body region with 36% having a head injury of AIS ≥ 2. Of the 28 AIS ≥ 2 injuries for rearward restrained children, 26 are to the head. There are no AIS ≥ 2 injuries to the neck or extremities.

Forward facing CRS: In the CHILD/CASPER dataset there are 103 children using forward facing child restraint systems with a harness, of which 21 are not injured. It is clear that the head is the most seriously injured body region with 28% of the children sustaining an AIS ≥ 2 head injury and 51% of all the 116 AIS ≥ 2 injuries being to the head. At the AIS ≥ 2 level, half of the head injuries are attributed to the seat back in front and a quarter to the ‘own kinematics’ and ‘deceleration fields’ combined. At the AIS ≥ 2 level, the other body regions start to feature equally but increasing the AIS to ≥ 3 shows the neck, abdomen and thorax are more prominent than the face and extremities.

Booster systems: In the CHILD/CASPER dataset there are 132 children using booster systems either with or without backrests, of which only 13 are not injured. Serious injuries are more distributed across the body regions than for harness shell systems with both upper (14%) and lower extremity (14%) regions, the abdomen (21%) and the thorax (15%) featuring strongly at the AIS ≥ 2 level, along with the head (14%). At the AIS ≥ 3 level the thorax features as the most injured body region with 14% of the children in this sample having such an injury. The abdominal and head regions are also evident at 11% and 9% respectively. Of the 184 individual AIS ≥ 2 injuries just under one third are to the abdomen with seat belt contact given as the contact, when identified, in all cases, as with thoracic injuries.

Adult seat belts only: In the CHILD/CASPER dataset there are 169 children using just the adult seat belt, of which only 10 are not injured. At the AIS ≥ 2 level the extremities, both upper extremities (18%) and lower extremities and pelvis (12%), feature strongly, along with the head (14%) and abdomen (14%), followed by the thorax (11%). At the AIS ≥ 3 level the abdomen has an AIS ≥ 3 injury for 10% of the 169 children, followed by the thorax (8%) and then the head and lower extremities are equally prevalent at 5%. As with booster systems, abdominal injuries are mainly attributed to the seat belt, as are the thoracic injuries.

8.3. Lateral Impacts

Overall

There are 148 restrained children in the dataset in lateral impacts with type of restraint and injuries known (or it is known that no injury has occurred). Of these children, 46% have a MAIS ≥ 2 and 34% have a MAIS ≥ 3. This MAIS ≥ 3 is higher than the frontal impact sample. There are a further 15 restrained children with fatal injuries but the actual injuries by AIS and body region are not known.

The proportion of misuse situations identified is half that in the frontal impact sample and a relationship between misuse and a rate of higher injury is not apparent. It is possible that misuse is more difficult to identify in lateral impact or has less of an effect on injury outcome in a higher proportion of circumstances (for example, struck side 90 pure lateral impacts).

‘Lateral from front’ and ‘pure lateral’ together are the impacts experienced the by large proportion of restrained children in lateral impacts. As this is a sample with a shift toward serious injury selection this could indicate a higher risk of injury with a pure lateral impact or a frontal component, although exposure rates for different impacts are not known – there could simply be less lateral impacts with a rear component. The proportion of children with MAIS ≥ 2 or fatal injuries is highest for purely lateral impacts (54%), followed by lateral from front (50%) and then lateral from rear (41%).

There are 92 restrained children sitting on the struck side in a lateral impact and 71 are non-struck side. Struck side children have greater proportions of both MAIS 2-3 and MAIS 4-6 or fatality than non-struck side children. For these struck side children the rates of higher injury levels are much higher when there is direct intrusion to the area in which they are seated. Generally the level of maximum intrusion around the struck side child’s position has a link with the level of injury severity, with an overall increase in maximum injury severity towards higher intrusion. At over 300 mm of maximum intrusion, 68% of the 41 restrained children on the struck side are MAIS ≥ 2, 44% are MAIS ≥ 4 or have fatal injuries. This analysis would benefit from individual case review as the injury outcome can be very dependent upon the exact position of intrusion, the principal direction of force and type of CRS.

Illustrations of the difference in risk of getting an AIS ≥ 2 injury are shown in Table 12. It is visible in terms of the rate of children injured at the AIS ≥ 2 level in the sample with a coherence for all restraint systems considered and it is also true looking at the number of injuries sustained by each severely injured child which is on average 1.74 times higher on the struck side than for injured children on the non-struck side. Combining frequency and number of injuries per injured child leads to a rate of AIS ≥ 2 injury per child 3.2 higher on the struck side. This table also underlines the efficiency of shell systems on the struck side with a rate of AIS ≥ 2 injuries per child 1.65 times lower than for these just using the adult seatbelt.

	Struck side					Non-struck side			
	shell	booster	seatbelt	total		shell	booster	seatbelt	total
Number children	29	23	30	82		14	21	23	58
AIS ≥ 2 children	14	17	17	48		4	8	8	20
% AIS ≥ 2 children	48%	74%	57%	59%		29%	38%	35%	34%
AIS ≥ 2 injuries	46	59	79	184		9	13	22	44
AIS ≥ 2 injuries per AIS ≥ 2 child	3.29	3.47	4.65	3.83		2.25	1.63	2.75	2.20
AIS ≥ 2 injuries per child	1.59	2.57	2.63	2.24		0.64	0.62	0.96	0.76

Table 12: Difference of injury risk struck vs non struck side

Restraint Types

Shell System CRS: On the struck side there are 29 children using shell systems with a harness, of which 4 are not injured. The head is the most seriously injured body region, followed equally by the thorax and lower extremities at the AIS ≥ 2 level and strongly by the thorax at the AIS ≥ 3 level. For the head injuries known contacts to rigid parts vary as expected, according to direction of impact and crash partner. On the non-struck side there are only 14 children using shell systems with a harness, of which 4 are not injured. The number of individual AIS ≥ 2 injuries is small (9 injuries only applying to 4 children) and they are distributed across five body regions.

Booster seat/cushion: On the struck side there are 23 children using booster systems, of which 2 are not injured. The rate of serious injury to the head is very high, in itself and compared to the shell system and adult seat belt restrained children. Abdominal injuries do feature at the AIS ≥ 2 level but at a lower rate than lower extremities and the thorax, and equal to the face. At the AIS ≥ 3 level, injuries are only seen for the head, then thorax and lower extremities. On the non-struck side there are only 8 children with AIS ≥ 2 injury(ies) with injuries distributed across the body regions but with the head having the highest number followed by the thorax.

Adult seat belts On the struck side there are 30 children using only the adult seat belt, of which 3 are not injured. The rate of serious injury to the head is slightly higher than for shell systems. At the AIS ≥ 2 level, lower extremity injuries have the second highest injury rate, followed by the thorax. This relationship between the lower extremities and the thorax is reversed at the AIS ≥ 3 level. On the non-struck side there are only 8 children with AIS ≥ 2 injury(ies). The rates of head and lower extremity injury are high at both AIS ≥ 2 and AIS ≥ 3 levels, followed by thoracic injuries.

8.4. Safety Technologies

It continues to be difficult to collect a significant number of data regarding new safety technologies across all ages, restraint conditions and crash types/severities. New technologies (except side head airbags) are concentrated on the front seats whilst the majority of crash data is for children seated in the rear. Whilst future investigation activities will collect data on new technologies in the rear (for example, during the time of CASPER thoracic side airbags in the rear have started to slowly appear) an approach of revisiting the cases already collected and combining individual case reviews with results from reconstruction or misuse testing results could start to form a more complete picture of the effectiveness of safety technologies (car or CRS) for restrained children. It would also be advantageous to record type of airbag in more detail in the database, for example, mounting for passenger airbags or size and extent of side airbags.

There are still only 7 children using an ISOfix system in the database, 3 of them in the same vehicle. There could be different explanations for this. The numbers of ISOfix in the fleet could still be low. Parents/carers who spend the extra money on ISOfix systems may be less likely to be involved in an accident and when they are involved the vehicle may be more expensive, newer or larger. When accidents occur ISOfix systems may protect their occupants to such a degree that they do not appear in notifications, although the CASPER criteria also includes high severity low injury impacts so they should still be included. Within this task the possibility of these points being realised is not addressed but could be investigated in further studies by using sales data, marketing or CRS use surveys and CRS testing data.

Eight cases are available of deployed passenger airbags and rear facing infant carriers. Whilst 5 of the children are reported as having survived, the children are very young and the brain injuries are likely to be important at a critical time of development.

8.5. Injury Recording

The situation regarding injury recording is an interesting one for the on-going work in the area of child passenger biomechanics due to the balance between using the newest and most accurate recording systems and being able to link back to previous work (especially the CREST and CHILD projects).

AIS90 to AIS98

The noticeable change in using AIS98 instead of AIS90 as the core injury recording system is the increase in MAIS value (to 3) for 20 children due to the below 12 year old femur fracture codes not being available in AIS98. Whilst this is not a large change as a proportion of the entire sample (1008), as it focuses on one body region it should be taken into account in any injury criteria work that may compare previous results to CASPER results in this body region.

AIS98 to AIS2005

Regarding differences between the AIS98 and AIS2005 it is no surprise that revisions in the AIS system show an overall reduction in the injury severity score of certain regions as advances are made in medical care. But it is also clear that AIS2005 is a more demanding system in terms of the medical information and evidence required (for example, volume of loss, depth, length, time) and this can lead to injuries coded in AIS98 being given lower severity scores due to the extent of the injury being not as well documented. Sometimes, 2 or 3 AIS2005 codes that cover just one code in AIS98 are building to the same injury severity as the AIS98 code but more information on the extent is required to be able to code the highest injury severity. For example, cerebrum intraventricular hemorrhage (140678) is AIS 4 in AIS98. But in AIS2005 just this knowledge of the injury allows only AIS 2 to be recorded. If associated coma of over 6 hours is known then AIS 4 can be recorded. Another example is that ‘concussion’ is AIS 2 in AIS98 but in AIS2005 if no time of unconsciousness is available then the injury is AIS 1 (NFS).

The proportion of restrained children MAIS ≥ 3 in AIS98 is 37.9% and AIS2005 34.7%, similarly for MAIS ≥ 4 the proportion drops from 24.4% in AIS98 to 18.2% in AIS2005. Currently it is not clear what proportion of the decrease is due to a genuine reduction in the injury severity score (medical progress) and what proportion is due to the greater level of injury detail required in AIS2005 for certain injuries.

It is recommended that any future activities are coded with both AIS98 and AIS2005, to ensure consistency with previous biomechanics work and enable injuries in new road accident cases to be recorded as accurately as possible.

8.6. Further Work

For lateral impacts a review of individual cases to understand intrusion levels with reference to child age, restraint type and importantly specific direction of impact, but also intrusion levels for specific body regions.

A case by case analysis could also be conducted to enlarge the understanding of some extreme crash conditions to which child have been surviving and the same approach could be used to evaluate the potential benefit of airbags in frontal and side impacts.

Individual case review to separate booster systems into just cushions and those with backrests, with further separation as to whether the backrest endeavours to provide lateral impact.

Combination of individual case reviews with results from reconstruction or misuse testing results to start to form a more complete picture of the effectiveness of safety technologies (car or CRS) for restrained children.

Deeper analysis regarding the reduction in injury severities from AIS98 to AIS2005 to understand the contribution of injuries with a genuine reduction in severity compared to a lack of medical information leading to reduction.

REFERENCES

Ernst Tomasch, Graz University of Technology, AT. 'Accident Reconstruction Guidelines, Part of Deliverable D4', EC PENDANT Project, October 2004

Gennerelli T.A, and Wodzin, E. (2005) editors, The Abbreviated Injury Scale, AAAM, Illinois 2005.

J Barnes, A Hassan, R Cuerden, R Cookson, J Kohlofer. 'Comparison of injury severity between AIS 2005 and AIS 1990 in a large injury database', AAAM 2009

The Abbreviated Injury Scale 1990 revision, AAAM, Des Plaines Illinois 1990.

The Abbreviated Injury Scale 1990 revision - Update 1998, AAAM, Des Plaines Illinois, 1998.