INJURY RISKS OF CHILDREN TRAVELLING IN CARS

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ABSTRACT

The German In-Depth Accident Study (GIDAS) collects since mid 1999 accidents in Dresden and surrounding area as well as Hannover and surrounding area following a statistical sampling method that makes the data set representative for the German accident situation.

After a case by case review of all child restraint system (CRS) items of the data base the data quality is improved significantly and now allows for example analysis of the protection level of different CRS architectures (e.g., rear facing compared to forward facing or forward facing integral compared to booster seats) what was hardly possible before because of lack of information. As far as possible from the accident information also use pattern (no misuse detected, misused CRS inappropriate use of CRS will be included in the paper as well.

For the analysis the German national accident statistics and GIDAS data from the entire collection period involving children up to including 11 years as car occupants in accidents not including accidents with vulnerable road users.

The data set was recoded for CRS and CRS use variables based on a case-by-case review using child safety expert knowledge.

In frontal impact accidents without further consideration of age children in rearfacing CRS are protected best while forward facing integral CRS and booster seats are slightly less protective. In lateral impact accidents forward facing integral CRS are protecting the occupants best.

Although the case-by-case review allowed for a large number of cases a recoding of the variables there are still a number of unknowns in the data base that limit the final quality of the final conclusions.

INTRODUCTION

For the analysis of injury risks of children in road transport accident data is crucial. Within this study data of the GIDAS accident database that provides accident data that is representative for Germany due to its study design is used. After a redesign of the CRS related variables in the database all cases involving children in CRS were individually reviewed in order to fill the new variables also for older cases.

The data is used to obtain a general overview of the CRS types used and detected misuse as well as to analyse the injury risks observed for different CRS architectures.

GIDAS ACCIDENT DATA BASE

In Germany accident data is collected in different level of detail and different sample sizes by different organisations. These are for example the German statistical office that collects and reports all police reported road traffic accidents with injuries at a very global level and the GIDAS in-depth accident database to name two examples. GIDAS (German in-depth accidents study) is an in-depth accident database with comprehensive information concerning the accident occurrence, the vehicle information as well as personal information such as causation and injury information. The methodology used is an on-scene investigation of a representative subsample of accidents with injuries in the regions of Hanover and Dresden which is well capable of representing the German accident situation. In total approx. 2,000 accidents with injuries are reported annually in GIDAS which represents approx. 1% of the German accidents with injuries. The team normally consists of 2 members for technical data collection and one member for the medical data collection. The GIDAS data collection is jointly sponsored by BASt and FAT.

With respect to children in cars there are several variables that can be used. In the past mainly the following variables were coded:

- ECE weight class(es)
- Kind of attachment of the CRS
- Orientation of the CRS
- Make, model and approval no.
- Availability of an impact shield

An important problem w.r.t. to the availability of data for children was that the CRS were often removed from the accident car before the arrival of the accident research team in order to use the CRS in the ambulance if the child was injured or a car of relatives/friends to take the child to school etc. in case the child was not injured. The accident data collection process tasked the technical team members to collect the CRS data. Following the experience that the CRS was often removed from the cars, in 2014 an additional question was attributed to the medical team member to ask the parents for the CRS architecture (e.g., baby shell, booster etc.). After a short monitoring period an additional specification was allowed in order to distinguish between backless boosters and high back boosters within the booster group as well as FF harness seats, RF harness seats and impact shield seats within the toddler CRS group. In addition variables to better describe the used interface between CRS and car, the kind of fixation of the child in the CRS, the usage of harness, toptether and support leg etc. was added.

Furthermore restraint system misuse is coded in the data base. However, restraint system misuse is difficult to assess after an accident.

ACCIDENT STUDY RESULTS

According to the German national requirements children up to including 11 years of age or 150 cm in stature, respectively, are obliged to use a suitable CRS when travelling in passenger cars. Following that children up to including 11 years are considered in this study as children.

Based on the German national accident statistics there is a positive trend of the number of killed and injured children since the reunion in 1990, see Figure 1. However, this positive trend is partially caused by the German demographics with an absolute reduction of the number of children (drop from 1991 to 2014 by 21%).

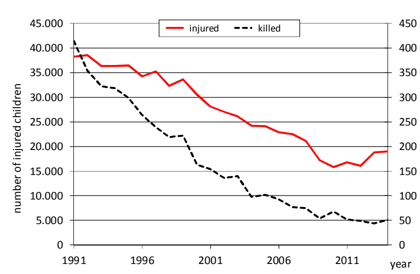

Figure 1. Trend of injured and killed children in Germany 1991 – 2014.

When looking at the age of killed children in cars, see Figure 2, it is obvious that except for 1 year old children the risk appears to be similar for all ages in Germany. One year old children are at much higher fatality risk than the others. When comparing the situation with Sweden this seems not to be the case. However, due to the differences in the total number of children being involved in road traffic accidents in Germany and Sweden, the Swedish numbers are quite small.

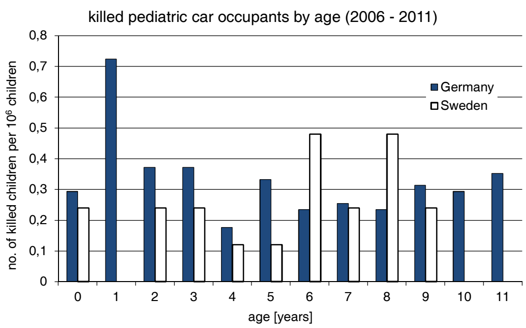

Figure 2. Age distribution of killed children in cars, comparison between Germany and Sweden.

For this study all accidents with children as car occupants using a CRS (including unknown usage) collected between summer 1999 and 2015 that were completely coded and reconstructed were reviewed, the new variables recoded and the old ones completed or corrected if necessary. In total 1452 child occupants in CRS are included in the sample.

CRS Use and Misuse

Of the 1452 recorded children in CRS involved in car accidents 417 were involved in accidents with vulnerable road users (VRU, such as pedestrians, cyclists and motorcyclists) in which no important harm for the car occupants are expected. Furthermore 364 children were involved in other accidents or multiple accidents. Both groups are not considered for the investigation of the injury risk; the first group because the injury risk in minor in these accidents and the last group because the accident situation is somehow unclear for further analysis within the sample. The latter cases would require a case by case analysis. However, for the general analysis of CRS use pattern these accident situations are also of relevance.

Table 1.
Used CRS architecture

	all accidents	**accidents with VRU**	**accidents with cars, trucks, objects**	**other and multiple accidents**
Children in CRS	1566	417	785	364
baby shells	**88**	**25**	**43**	**20**
toddler seats including:	**358**	**102**	**165**	**91**
- harness FF	310	89	142	79
- harness RF	4	1	3	0
- shield	13	5	4	4
boosters including:	**631**	**160**	**316**	**155**
- backless boosters	260	74	131	55
- highback boosters	332	75	166	91
integrated CRS including:	**24**	**3**	**11**	**10**
- integrated harness CRS	18	2	9	7
- integrated booster CRS	5	0	2	3
not specified CRS	**21**	**4**	**9**	**8**
unknown CRS architecture	**444**	**123**	**241**	**80**

Table 2
Observed misuse modes depending on CRS architecture

	all CRS	baby shell	harness other than baby shell	impact shield	high back booster	backless booster	unknown and not specified
installation misuse including	**23**	**9**	**9**	**0**	**3**	**1**	**1**
- wrong installation direction	3	2	1				
- wrong belt path	5	3	2				
- slack for CRS installation	4		3		1		
- wrong seating position in the car	1		1				
securing misuse including	**19**	**0**	**4**	**6**	**9**	**0**	**0**
- upper belt guide not used (high back boosters)	5				5		
- impact shield not used	6			6			
- hight adjustment incorrect	2				2		
- wrong belt path (harness)	1		1				
Other	**4**		**2**			**2**	
unknown	**9**				**2**	**1**	**6**

In the accident sample 79 children were seated in a baby shell, 305 children were using a toddler seat (of which the majority were forward facing harness seats) and 589 children were restraint with booster seats (318 using a backless booster and 248 using a high back booster). Integrated CRS were used by 25 children of whom 5 were using an integrated CRS with 5-point-harness. The CRS was not further specified in 4 cases and for 450 children it remained unknown whether or not a CRS was used and if a CRS was used which kind of CRS was used, see Table 1. For the following analysis the 6 toddler CRS that were not possible to further specify are considered as forward facing harness CRS, the 23 booster CRS that were not possible to further specify are considered as backless booster and the 5 integrated CRS without further specification are regarded as integrated booster CRS.

In only 9 cases the CRS was attached to the car using ISOFIX (1 babyshell with base and 8 FF harness seats). A support leg was used in 4 cases, while a toptether was never observed.

In 99 of the 1566 cases misuse was reported, see Table 2. It is important to note that the detection of misuse is very difficult after the accident because the child is normally not restrained in the CRS anymore and often even the CRS is not in the original position. Especially for baby shells, that are often removed from the car before releasing the child, the situation is completely unclear when recording the accident. Therefore it can be expected that misuse is systematically underreported in the study and only very severe forms of misuse are recognised.

In contrast to dedicated misuse studies the misuse rate recognised in the GIDAS accident sample is with 6% very small. Normally misuse rates of approx. 65% are reported [Müller 2013]. Comparable to other studies the installation misuse is mainly applicable for smaller children, i.e., using baby shells and toddler CRS and the total misuse rate is also higher for these children, see Table 2. Notable is the relative high number of shield CRS that were used without the impact shield (of 12 impact shield CRS 6 were used without the shield).

Inappropriate use of CRS is easier to detect in accident investigations. Inappropriate use means for example to early change from rearfacing to forward facing CRS. Although being administratively possibly ok a change to forward facing with an age below 12 months appears not optimal from the safety point of view. In contrast the new regulation for the homologation of CRS (ECE R129) does not allow forward facing use of CRS for children with an age below 15 months. Thirty-two children with an age of 12 months or less were using a forward facing harness type CRS – for children below 15 months the number was 39. When looking at all forward facing CRS including boosters and shield systems 29 children were using them with an age of 12 months or less and 48 children with an age below 15 months. In addition 39 children with an age below 3 years were using a booster type CRS.

Injury Risks

The injury risks are analysed depending on the type of restraint system used divided for the different impact directions. As mentioned above in this analysis only children involved in car accidents against cars, trucks and objects excluding multiple accidents were included. That leads to 754 children in this group. Furthermore baby shells and rearfacing toddler seats are grouped together to rearfacing CRS and as already described above the not further specified toddler seats are considered as forward facing toddler seats and are combined with forward facing harness systems and shield systems. Because of the low number of shield CRS an isolated analysis for these CRS type for different impact configurations does not make sense. The not specified booster seats are considered as backless boosters. The integrated CRS are included in their corresponding add-on CRS architecture group.

In order to distinguish between the impact directions in this study the principle direction of force (PDOF) is used. The PDOF codes in a clock-like system the direction of forces towards the occupant. Frontal impacts are those with a PDOF of 11, 12 and 1; for lateral impact the PDOF was 2, 3, 4, 8, 9, 10 and for rear impact 5, 6, 7.

In frontal impact accidents the children in rearfacing systems have the smallest share of injuries. Severe injuries (i.e., MAIS 3+ injuries) are observed only in booster type CRS and for children with unknown CRS usage (including those were it remained unclear whether or not a CRS was used). Children using backless booster seats have the highest risk to sustain injuries, see Figure 3. For high back boosters and forward facing toddler seats the injury risk appears to be equal, while RF CRS seem to offer better protection and backless booster CRS worse. Overall 392 children are involved in frontal impact accidents of which 4 sustained MAIS 3+ injuries.

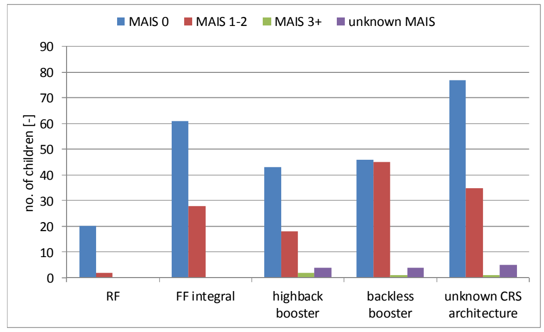

Figure 3. Injury severity depending on CRS architecture in frontal impact accidents.

The accident severity distribution shows comparable trends for all types of CRS architectures, see Figure 4. In approx. 91% the accident severity shows a delta-v below 40 km/h.

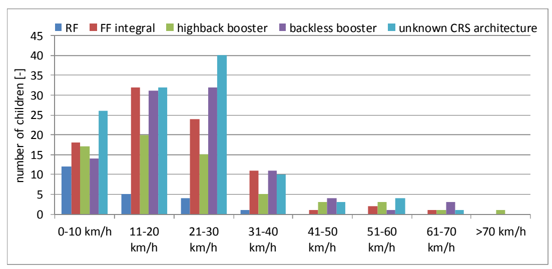

Figure 4. Delta-v distribution in frontal impact accidents.

In lateral impact accidents with the impact direction from the side of the seating position of the child (i.e., struck side or near side impacts) the protection level is best in forward facing integral CRS, see Figure 5. However, the number of cases is quite low following that the numbers have to be considered with caution, especially because the impact severity and the location of the impact with respect to the seating position (e.g., impact against the front door and seating position in the rear seat) was not taken into account. For example only three rearfacing CRS were included in the sample. For booster CRS (high back boosters and backless boosters) the protection level appears very low. There are more injured children than uninjured children observed in booster seats. In struck side lateral impacts no MAIS 3+ injury was observed. In total 75 children are included in this group.

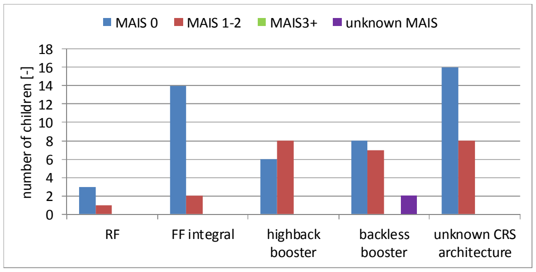

Figure 5. Injury severity depending on CRS architecture in near side lateral accidents.

The analysis of the accident severity indicates an overrepresentation of medium accident severities (10 – 20 km/h) for rearfacing CRS, while for backless boosters the accident severity appears to be considerably high, Figure 6. Nevertheless the impact location is still not considered therefore the individual accident severity for the occupant is not adequately considered. In total 19% of the accidents have a delta-v between 20 and 30 km/h (the area of ECE R129 side impact testing) with approx. 71% below that level and 9% above.

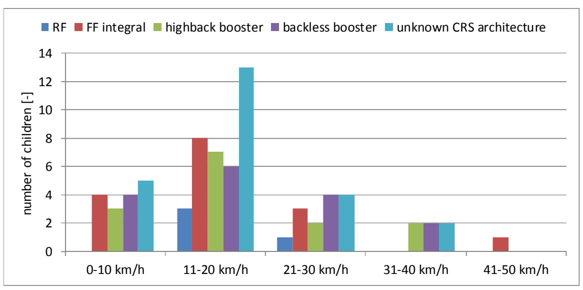

Figure 6. Delta-v distribution in near side lateral impact accidents.

For far side occupants also occupants using centered seats were considered. Comparable to struck side occupants in lateral impact accidents the number of cases is quite low. However, the location of the impact is less important for far side occupants as in most of the cases they do not suffer from intrusion. The risk to become injured as a far side child in lateral impact is generally lower than for struck side occupants, see Figure 5 and Figure 7. Comparable to near side accidents the protection level in forward facing toddler seats appears to be best. In this configuration especially backless booster indicate a high risk for suffering injuries. In the non-struck side accidents no MAIS 3+ injury was observed. In total 104 children are included in this group.

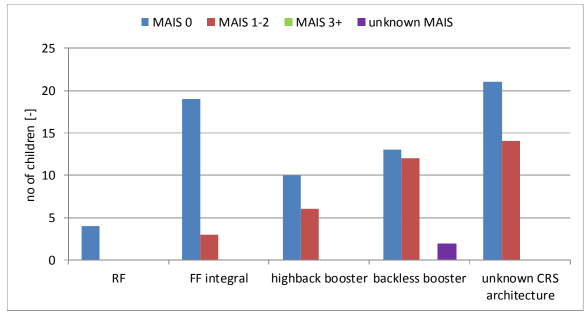

Figure 7. Injury severity depending on CRS architecture in far side lateral accidents.

Rearfacing CRS in far side occupants are mainly observed in accidents with a delta-v below 10 km/h, see Figure 8. Especially for backless boosters the accident severity in the sample appears to be relatively high.

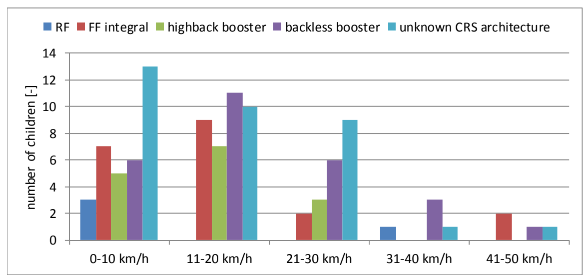

Figure 8. Delta-v distribution in far side lateral impact accidents.

In rear impact collisions the overall injury risk for MAIS 1 and 2 injuries seems to be quite high. While RF systems and toddler seats seem to offer a sufficient protection level this seems to be different for booster type CRS, see Figure 9. However, this might be caused by differences in age as well. Especially babies and toddlers are unable to report on whiplash symptoms while the kids normally using booster seats are. Also for rear impact collisions no MAIS 3+ injury was observed. In total 212 children in rear impact accidents are included.

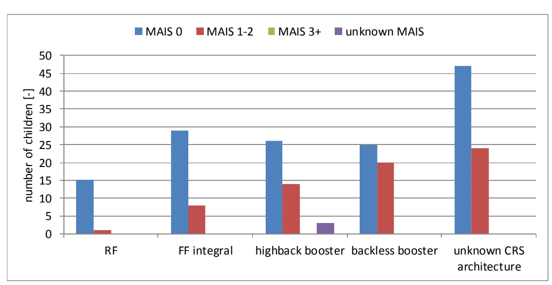

Figure 9. Injury severity depending on CRS architecture in rear impact accidents.

For rear impact accidents the accident severity appears equally distributed for all CRS architectures, see Figure 10. In approx. 80% of the case the delta-v does not exceed 20 km/h.

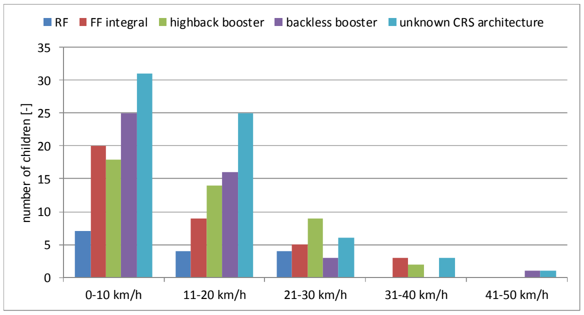

Figure 10. Delta-v distribution in rear impact accidents.

In addition to front side and rear impact collisions also roll-over collisions are analysed, Figure 11. In this study all accidents leading to at least a quarter turn are included. Furthermore isolated roll-over accidents are treated the same way as roll-overs following an initial collision. Following that it is unclear for this study whether or not the roll caused the reported injury.

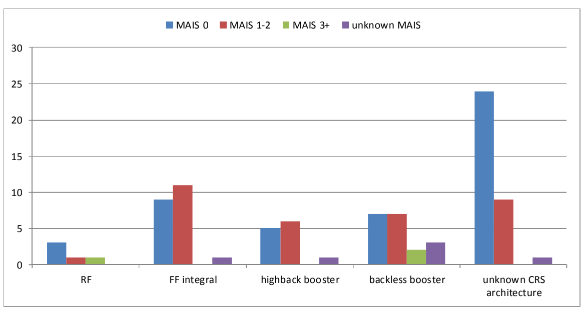

Figure 11. Injury severity depending on CRS architecture in accidents with roll-over (at least a quarter turn).

The first thing to notice for roll-over accidents in this study is that the number of unknown injury severity and unknown CRS architecture is relatively high, 6 unknown MAIS and 34 unknown CRS architecture, respectively. Independent from the CRS architecture the injury risk in roll-over accidents is relatively high, Figure 11. There are much more children injured than uninjured which is different for all other impact types. Among the 91 children being involved in a roll-over three children were MAIS 3+ injured. However for those accidents with a roll-over caused by a previous impact the accident severity is expected to be considerably high therefore the injury might be a result of the initial impact. The accident severity is not analysed for roll-over accidents.

Amongst the 785 children in CRS that were involved in accidents with cars, trucks or objects only 4 sustained MAIS 3+ injuries. All of them were involved in frontal impact accidents that account for approx. half of the analysed accidents. The severe injuries were located at the head or the abdomen. Assuming the same share of severe injuries for the other impact types the sample size is too small to expect MAIS 3+ injuries within the sample for lateral and rear impact accidents.

CONCLUSIONS

The study analysis completely coded and reconstructed accident data of the GIDAS accident data base from the years 1999 to 2015 involving children as car occupants using a CRS (including those where CRS usage was unknown). In total 1566 children are included of which 417 had an accident with a vulnerable road user, 785 had an accident with a car, truck or object and 364 had multiple impacts or other collisions. For the analysis of injury risks only the group with accidents with cars, trucks or objects was analysed.

The analysed accident data indicates that German children are relatively well protected when being involved in an accident as car occupant that is using a child restraint system (CRS). Less than 1% of the sample is severely injured (MAIS 3+) and approx. 1% of the frontal impact sub group is severely injured. For frontal impact only a very small number of accidents had an accident severity (expressed in delta-v) exceeding the frontal impact test procedure (i.e., 50 km/h) according to ECE R44 or ECE R129, respectively. For lateral impact there are more injured children than for frontal impact indicating a higher injury risk.

Misuse and inappropriate use of CRS was detected only in a small number of cases. However, misuse is difficult to detect after accidents due to changes in the securing situation between the time of impact and the arrival of the research team at the scene. For this reason it would be interesting to compare the results of misuse field studies from the accident collection areas with the accident data. A relatively often observed misuse mode was the nonuse of an impact shield which occurred in approx. 50% of the cases with shield CRS.

Only a very small number the CRS was attached to the car using ISOFIX. The use of a toptether was never reported in the accident data sample.

In the future children not using a CRS shall be included in the study as an additional subgroup. Furthermore it appears to be sensible to analyse the multiple and other impacts for inclusion in the analysis.

REFERENCES

Müller, Gerd: “Fehlgebrauch von Kinderschutz-systemen im Fahrzeug”, Dissertation TU Berlin, 2013