Child restraint misuse analysis and usability assessments

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1 Introduction

TRL has a long history in the provision of independent, impartial research and has carried out broad based research programmes to support the development of policy in the UK and Europe and to support the development of international standards.

In response to improved Regulations and Standards, Child Restraint Systems (CRSs) have changed considerably over the past thirty years, with an immense improvement in their performance. It is understood that a poor performing, CRS will always perform poorly, no matter how well it is fitted, so good performing CRSs are essential to provide optimal protection to children in accidents. However, it is also recognised that inappropriate use or installation of CRSs will degrade the potential for protecting children in car crashes.

The incorrect installation, often referred to as "misuse" of child restraints is a large problem across Europe. Over the last few years, the misuse rate of child restraints in vehicles has been constantly presented as between 60% and 70%.

There have been many "fit and use" checking clinics held throughout the UK, by various road safety professionals including clinics carried out by the TRL Child Safety Centre. These clinics provide the following advice to parents:

- The suitability of CRS relating to child development
- The compatibility of the restraint their using with their vehicle
- The method of attaching their CRS to the vehicle
- The method of installing their child into the CRS

In 2010, drawing on their research experience, TRL began working to coordinate the collection and analysis of the information gained during these individual exercises.

This paper discusses the progress, presents the status of the National Database and discusses the benefits and limitations of collecting data from dedicated fitting clinics. In addition, the paper discusses the common consequences of the common misuse modes that have been recorded at these checking clinics.

2 Coordinating the Approach

Most parents ask for their method of child restraint to be checked "on the spur of the moment" and as such, are in a hurry to go about their daily business. Therefore the response to a request at a "fit and use" check clinic must be both swift and informative, both for the parent and for the assessor.

The approach to this overall exercise was firstly to develop a form that would collect the essential information needed, to understand the key issues, whilst keeping the information collection time to a minimum. It is essential to collect the information in a way that, where possible, avoids the form user providing written descriptions. However it is also important to capture all the information relating to the different modes of misuse and inappropriate use.

The second step was to develop a database to receive the information. The database was to be designed to minimise data entry time and, where possible, using drop down menus. This would standardise the input and allow the analysis to be more straightforward.

The third step was to disseminate the form to any road safety professionals who wished to use it and contribute to the larger dataset.

3 Progress

TRL developed an initial form based on a number of inputs, the primary two inputs were 1] a form used for a previous study (developed by TRL, for use with a Department for Transport (DfT) accident study project) and 2] a form used by Britax during their fit checks in Ireland. The previous accident study project, carried out for the DfT, had involved the distribution of a questionnaire form to UK retailers and child restraint manufacturers, so that it could be given to consumers at the point of sale. The idea of the study was that if the child restraint was then involved in an accident, the form would be completed and returned to a "freepost" address at TRL. The form requested details about the accident, the vehicle, the restraint and the occupant. The information was then collated into a database, which was analysed annually to inform the DfT of trends and areas of concern in the real world.

The resulting form, that was initially developed from these previous studies, was used by the TRL Child Safety Centre, Britax and Graco at a fit checking clinic, which was supported by Halfords, and the "THINK" campaign, (UK Department for Transport Safety initiative).

The aim of the programme is that every time a child restraint checking event is held in the UK, the information gathering forms will be used, completed and sent to TRL, who will then add the information to the National database.



Figure 1 - Fit and Use clinic at Halfords

Since that initial event, TRL have been working closely with the UK Local Road Safety Authorities and Road Safety Professionals to support similar events in their local areas.

The final version of the form will collect information anonymously. However the age, weight and height of the child are recorded. This is to allow the appropriateness of the child restraint, in use, to be determined. This is achieved by comparing the age and weight of the child to the recommended range for that type of child restraint. A visual check of the child in the CRS is made at the time of completing the form to assess whether the child is too tall or too small for the child restraint. This information also provides an understanding of how closely parents monitor their child's height and weight.

Information about the type of child restraint being used is also recorded. This includes the intended and actual orientation of the child restraint in the vehicle, as well as the method of attachment of the CRS to the vehicle, e.g. seat belt, ISOFix, anti-rotation device, etc. The position of the CRS placement in the vehicle is also recorded.

The second part of the form records whether there is any misuse found during the check. The misuse is split into three categories; compatibility with the vehicle, attachment of the CRS to the vehicle, attachment of the child to the CRS.

The compatibility with the vehicle section identifies whether it is possible to correctly install the type of CRS in the vehicle. This includes identifying whether the seat belt buckle is too long or there is no top tether anchorage for an ISOFix CRS etc.

The attachment of the CRS to the vehicle section investigates whether the CRS is correctly attached to the vehicle. This includes items like whether the seat belt routing is correct and whether the seat belt is correctly tensioned.

The attachment of the child to the CRS section aims to identify whether the child was correctly installed in the CRS. This includes items such as whether the harness is too slack and whether the harness is at the correct height for the size of occupant.



Figure 2 - Check and Use Clinic at Tesco Supermarket

The updated version of the information collection form was used during a clinic held at the Tesco supermarket in Wokingham, with the local Road Safety Officer, representatives from the Good Egg and Volunteers from the Police services, Fire services and the TRL Child Safety Centre.

In 2012 TRL began collaborating between TRL and Good Egg. This has resulted in the amount of information gathered from these child seat checks increase further.

TRL have developed the database and have begun the process of entering the information received from the information forms that have been received. This database can then be used to identify trends and areas of child restraint misuse that may need solving through education or future legislation. Some of the findings from the analysis of the database, so far, are discussed in the following sections.

4 Initial analysis of the database

4.1 Knowledge of Child Growth

It is important that children use an appropriate CRS for their stage of development. There are differences between legal restraint use and best practice of restraining children.

Legal use of restraint type is based on child mass, until the child reaches 150cm (135cm in some countries) or twelve years old. In order to be able to determine whether a child restraint is appropriate for a child occupant, the weight and the height of the child were queried during the child restraint use check. However it was found that 44% of those asked did not know either piece of information about their child (Figure 3).

55% of people surveyed knew the weight of their child, but did not know their height. Of the 22% of those who knew the height, only 3% didn't know the weight.

The information collected so far does seem to contradict the reported current thinking that parents are more aware of the height of their child than the weight. The draft new Regulation, under development in the GRSP informal group, will categorise child restraints on child stature rather than child mass range, as it has been reported that more people know the height of their child as opposed to their weight. Parent awareness of child growth may change over time.

The data currently held in the database is weighted towards, but not exclusive to, pre-school aged children. It may be the case that parents with younger, pre-school children are more likely to know the mass of their child. This clearly is an area for further study.

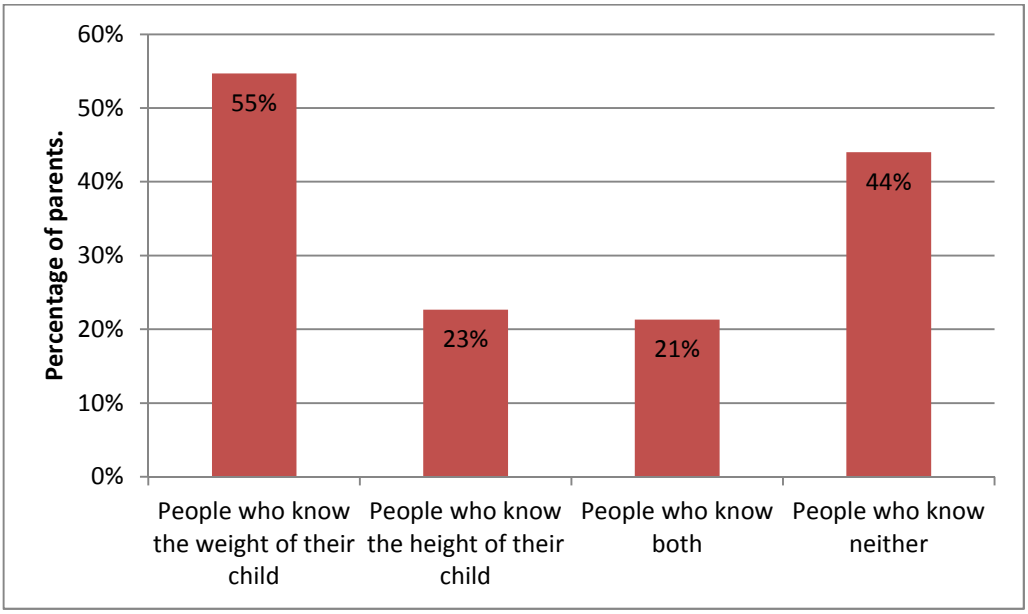


Figure 3: Knowledge of child growth

4.2 CRS appropriateness

The database has been queried to look at whether the child restraint used were appropriate for the children using them. The age and weight of the child was compared to the type of child restraint that was used, to conclude whether the CRS was appropriate.

As previously mentioned, although the mass of the child was not always known for every child that was surveyed, a judgement could still be made based on the age and visual assessment of the size of the child.

This analysis showed that 6% were found to be using child restraints that weren't appropriate due to the weight of the occupant (Figure 4). Of these, 5% were inappropriate because the child was too light and 1% because the child was too heavy.

The chart also shows that 7% were found to be using a particular child restraint before they had reached the recommended age.

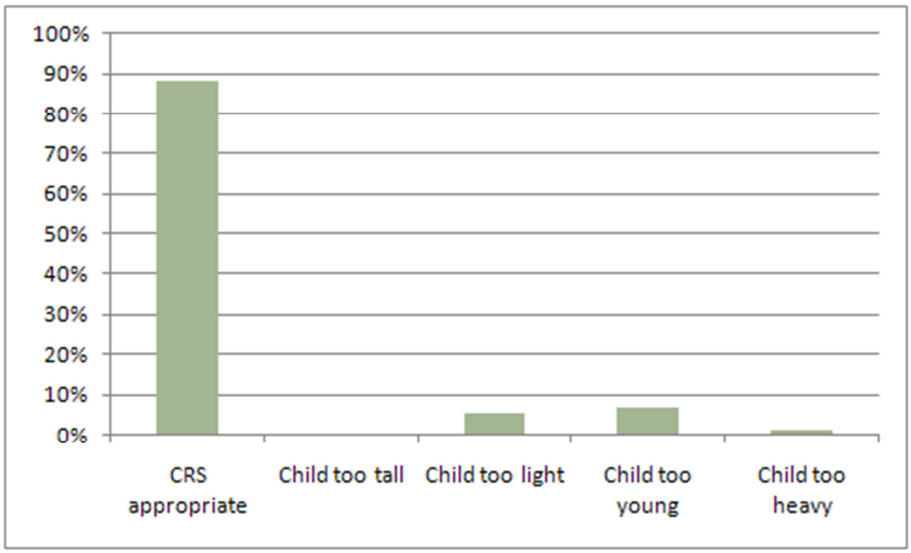


Figure 4: CRS appropriateness

The appropriateness of the type of child restraint was investigated further using three categories; rearward facing child restraints, forward facing integral child restraints and forward facing non-integral child restraints.

4.2.1 Rearward facing child restraints

All the rearward facing child restraints surveyed were either Group 0 or Group 0+. The analysis of the age of child using rearward facing child restraints found that no child over 1 year-old was using them. This implies that parents may be keen to have children forward facing as soon as possible.

The weight of occupants using the rearward facing confirms this theory. No children over 10kg were found to be using rearward facing seats. Children can use Group 0+ child restraint systems until they reach 13kg, which is lighter than an 18month old 50th percentile mass child.

4.2.2 Forward facing integral child restraints

The theory that parents are keen to place their child forward facing as soon as possible is corroborated by the age profile of the forward facing integral child restraints. These are child restraints with an integral 5-point harness system.

Figure 5 shows around 8% of those using these types of child restraints were under 9 months old. This is the typical recommended minimum age that children are kept rearward facing.

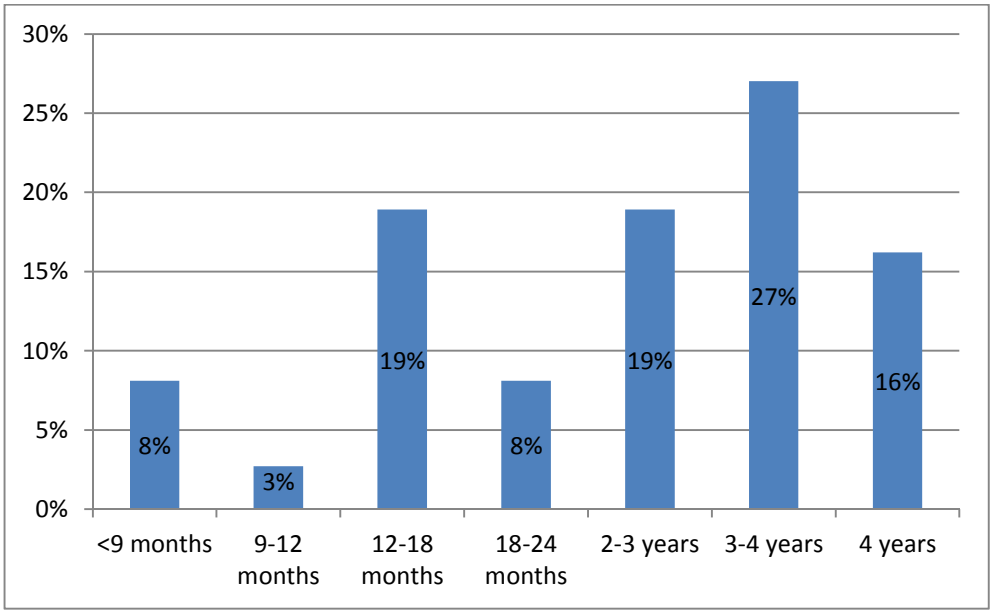


Figure 5: Occupant age profile – Forward facing integral CRSs

However the weight profile for children using forward facing integral child restraints shows that no children under 9kg were using these forward facing child restraints. 9kg is the minimum weight for forward facing child restraints, soon could argue that legally, these CRSs were being used appropriately. However, it has long been recommended that children remain rear facing until they reach 18 months old.

Therefore this implies that parents were possibly changing to forward facing child restraints as soon as their child's weight exceeded 9kg, the minimum allowable mass for forward facing restraint use and not necessary considering the age or development of the child.

The weight profile also shows that one occupant exceeded the maximum mass of 18kg for a Group I child restraint.

4.2.3 Forward facing non-integral child restraints

These types of seats are booster seats and booster cushions which use the vehicle 3-point belt to restraint the occupant and the child restraint. The analysis of the weight of occupants using booster systems shows that a couple of cases were found to be under the minimum weight for booster systems (15kg) (Figure 6). However these occupants were perceived to be old enough to be suitable for this type of child restraint (Figure 7).

It therefore may be that parents switch a child to a booster seat based on their age rather than their weight.

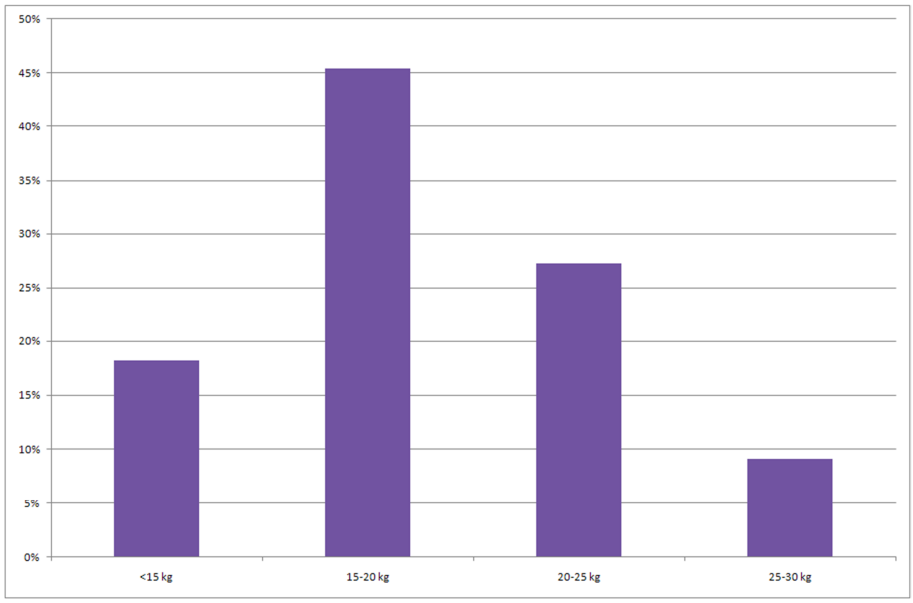


Figure 6: Occupant weight profile – Forward facing non-integral CRSs

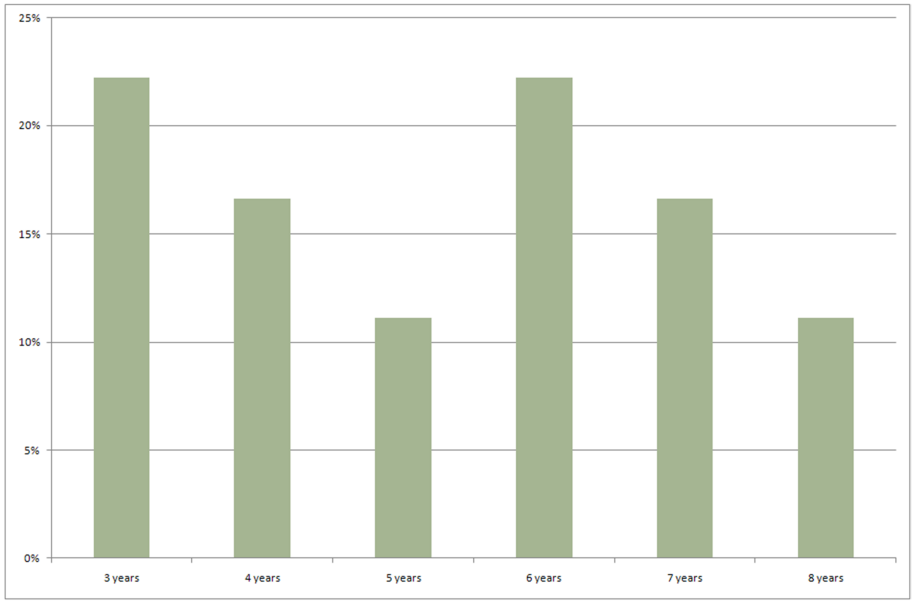


Figure 7: Occupant age profile – Forward facing non-integral CRSs

4.3 Child restraint misuse

The TRL survey form also investigates the misuse of the child restraints being checked. Misuse of the child restraint is split into three different categories:

- CRS compatibility with the vehicle
- CRS attachment to the vehicle
- Child attachment to the CRS

The misuse in each of these categories was investigated.

4.3.1 CRS compatibility with the vehicle

In general, of those child restraints checked, the compatibility of the child restraint with the vehicle was good. Only three incompatibility cases were found.

Two cases of incompatibility with the vehicle were due to the seat belt buckle being too long. The other misuse case was due to the fact the vehicle did not have a top tether anchorage for the Group I ISOFix CRS (used as a Universal approved product) to use and the CRS user had not purchased the "optional" top-tether. In fact, the user was unaware of what a top tether was.

4.3.2 CRS attachment to the vehicle

The misuse rate for the CRS attachment to the vehicle was found to be relatively high. 47% of the child restraints were found to be incorrect. Figure 8 shows the CRS attachment to the vehicle misuse modes.

The most common misuse modes were slack in the seat belt (29%) and incorrect seat belt routing (21%). Both of these are very common misuse modes.

Other misuses modes included twists in the seat belt, incorrect head pad guide height and the pram bases being left on an infant carriers, etc.

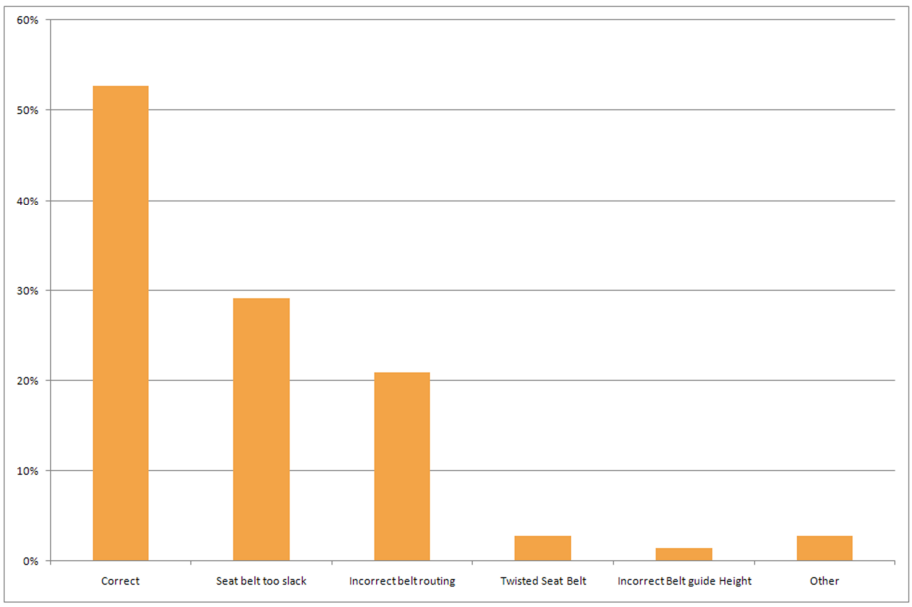


Figure 8: CRS attachment to the vehicle misuse modes

4.3.3 Installation of Child in the CRS

The misuse rate for the child attachment to the child restraint was also high. 39% of children were found to be incorrectly installed in the child restraint. Figure 9 shows the child attachment to the CRS misuse modes.

The common misuse modes were a slack harness (22%), with another 7% having a very slack harness.

10% had twists in the harness and 10% had the harness height too low. There were cases where the harness had been misrouted after removal of the cover and also cases of the harness buckle length requiring adjustment, as it was too long.

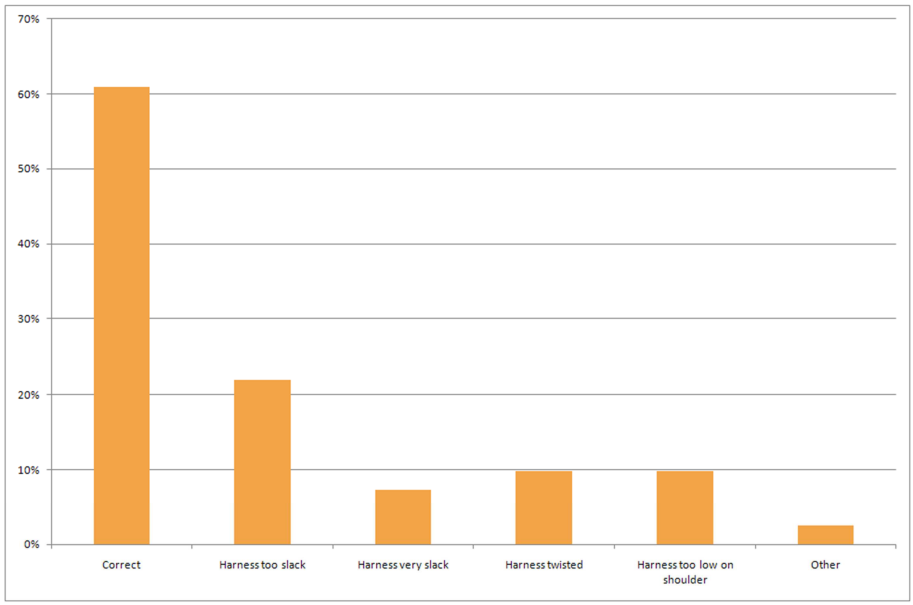


Figure 9: Child attachment to the CRS misuse modes

5 Mis-use implications

The implications of the two main misuse areas have been considered. These are the attachment of the child restraint to the vehicle and the attachment of the child to the child restraint.

5.1 CRS attachment to the vehicle

The main misuse modes when attaching the child restraint to the vehicle were found to be:

- Seat belt too slack
- Incorrect routing
- Twisted seat belt
- Incorrect head pad/belt guide height

5.1.1 Slack seat belt

The perceived implications of the seat belt being too slack are that this will mean the child restraint is not held in place in the vehicle, during a dynamic impact event. Therefore the excursion of the seat and therefore the child will increase.

This would mean the chances of the head contact a part of the vehicle are increased. Contact with the vehicle seat in front or the dash will result in an increase of risk of injury to the head.

Lesire *et al.* (2007) conducted a series of misuse reconstruction sled tests as part of the CHild Injury Led Design Project (CHILD). These reconstructions included the results of introducing large amount of slack into the seat belt for a forward facing harness child restraint. Lesire concluded that slack in either part of the seat belt created a significant increase in risk of injury to the head.

Any slack in the seat belt is going to degrade the performance of the child restraint and increase the injury risk. The amount of slack will determine whether it is a slight or major misuse.

5.1.2 Incorrect routing

There are many different types of incorrect routing of the seat belt because the seat belt routing varies greatly between different designs of child restraint. It is therefore difficult to specify specific the consequences of certain incorrect routings.

However each child restraint has been approved to Reg.44 using the belt routing specified by the manufacturer. Therefore any deviation from this is most likely to result in the child restraint not providing the optimum performance.

Some specific examples would be for booster seat and cushions when the vehicle seat belt is not placed under a horn (when supposed to) that this could result in the lap section of the belt lying too high across the abdomen of a child. Lesire's misuse reconstructions showed that this would result in serious abdominal injuries to the child.

Another common example is the seat belt not being routed through a guide. This is a common mistake seen during the check clinics. The likely result is that the child restraint would not be restrained by the seat belt as efficiently as possible. This would therefore result in the child restraint travelling further forward and thus increasing the head excursions of the child. This again increases the chances of the child's head contacting a part of the vehicle's interior, therefore increasing the risk of injury.

5.1.3 Twisted seat belt

The effect of twisted seat belt can vary depending on the design of the child restraint and location of the twist. A seat belt is more efficient without a twist and therefore introducing a twist is similar to introducing a little slack into the seat belt.

Therefore the consequences would be similar to the slight slack in the seat belt. The child restraint is not restraint as effectively as possible. This will most likely increase the head movement of the child. Therefore increasing the risk of injury for the child, as a result of head contact with the vehicle interior.

5.1.4 Incorrect head pad/belt guide height

For booster seats, incorrect positioning of the head pad, if it contains the belt guide for the seat belt, is critical to correctly placing the seat belt on the centre of the shoulder.

If the belt guide is not located in the correct place, the seat belt will most likely not be placed in the correct position. Lesire found that when the belt guide was placed too high there was a potential increase of injuries to the head, neck and chest. This is most likely because raising the belt guide positions the seat belt higher across the chest and closer to the neck.

The secondary implication for a head pad at an incorrect height is that it may not provide the suitable side impact protection, because the head is placed in the incorrect place relative to the padding.

5.2 Installation of Child in the CRS

The main misuse modes when attaching the child into the child restraint were found to be:

- Slack harness
- Very slack harness
- Twisted harness
- Harness too low

5.2.1 Slack harness

The general guide for how tight a harness should be is that it should be tight enough that you can just fit two fingers under the harness at the shoulder. However many parents don't tighten the harness to this degree.

The consequences of slack in the harness are that, similar to slack in the seat belt, the child will not be restrained as effectively. This will again result in the child's head travelling further forward. This could result in an increased risk of injury due to contact with the vehicle interior.

5.2.2 Very slack harness

In the worst instance this is when a harness is not be tightened at all, or alternatively the harness is tightened during the winter when the child is wearing more clothing and then subsequently not readjusted when the child has less clothing on.

As well as creating a situation that will have the same consequences as slight slack in the harness as discussed above, there is the potential for the child to slip out of the harness. An example would be that arms or shoulders slip under the harness during an impact.

Lesire showed that if this was to occur the injury risk to the head, neck, chest, abdomen and limbs are all significantly increased. A very slack harness is therefore a major misuse mode.

5.2.3 Twisted harness

A twisted harness will degrade the ability of the harness to restrain the child. Depending on where the twist is, could vary the seriousness of the detriment to the user.

Lesire conducted a sled test which found that a twist to the harness increased the injury risk to the chest of the child.

5.2.4 Harness too low on shoulder

Not adjusting the harness height position on the shoulder as a child grows is a common mistake. If the harness is too low for a forward facing child restraint, a compression load can be applied to the child's spine during an impact.

Lesire found that there was an increased risk of injury to the chest during a sled reconstruction test. Lesire also found that if the harness height is set too high that there is an increased risk of injury to the head, neck and chest. It is therefore important that the correct harness height is maintained as a child grows.

6 Summary

The findings from the analysis of the check it fits database have shown the following trends:

- 43% of parents did not know the weight or height of their child. This indicates that the selection of child restraint may be based more on age and visual compatibility of their child with the CRS, rather than weight of the child.
- Generally the appropriateness of child restraints being used was good.
- There seemed to be a trend to use forward facing child restraints as soon as possible, with some being used by children under 9 months.
- There also seemed to be a trend to transfer children to booster seats as soon as possible with a large percentage of 3 year-olds using them. Some of whom were below the 15 kg minimum weight limit for Group II.

Analysis of the misuse modes found that:

- Child restraint to vehicle compatibility was high.
- However only 53% of child restraints were correctly installed in the vehicle. The common misuse modes were slack in the seat belt and incorrect seat belt routing.
- The child to CRS attachment analysis found 60% were correct. The common misuse mode was slack in the harness.

This all shows that although parents are becoming more aware of the need to restrain children in appropriate CRSs, education of child restraint users is still required.

TRL plan to continue working with Road Safety Authorities and Road Safety Professionals to carry out checking clinics in the future to help provide the much needed education to the public, whilst at the same time collecting and coordinating the collection of information on child restraint use.

TRL also offer a service to assess the usability of child restraints based on the usability assessment devised as part of the New Programme for the Assessment of Child-restraint Systems (NPACS) programme. It is hoped that this will help to improve the usability of child restraint designs and therefore reduce the likelihood of misuse.

The TRL Child Safety Centre is committed to growing the National database for child restraint use, collating the data from these events. This will allow further and much broader analysis of restraint use to be conducted into the future.

This type of study on a broad scale is particularly important with the challenges ahead that parents face during the transition stages of introducing new Regulation that will bring the different classifications and labelling into the retail environment.

7 Acknowledgements

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- The UK THINK campaign and Local Authorities of Birmingham, Wokingham, Bracknell and Cambridgeshire.
- Road Safety GB
- The Participating Fire Services and Police Services
- The AA and the RAC
- The Child Accident Prevention Trust (CAPT).
- The BPA, Britax, Graco, Halfords and Tesco.
- Good Egg

8 References

Lesire P., Cuny S., Alonzo F., Tejera G. and Cataldi M. (2007) Misue of child restraint systems in crash situations – danger and possible consequences. 51st Annual Proceedings Association for the advancement of automotive medicine 15-17th October 2007.