REAR SEAT FRONTAL IMPACT PROTECTION FOR CHILDREN SEATED ON BOOSTER CUSHIONS – AN ATTITUDE, HANDLING AND SAFETY APPROACH

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ABSTRACT

Real-life data has shown that booster cushions are highly beneficial to belted children, but misuse and non-use problems remain. Furthermore, the rear seat belt system may be optimized for both children and adults.

The aim of this study was to evaluate protection concepts offering benefits in from of attitudes, handling and safety perspectives, for children seated on booster cushions.

Focus groups, observations and sled tests were performed. Initially, focus groups consisting of 16 children aged 7-8 years discussed the use of booster cushions. Seven children and their parents were then observed buckling up in a car using an integrated booster cushion and an aftermarket booster cushion. Lastly, sled tests were conducted with a Hybrid III 6 year old dummy seated on different booster cushions and restrained by various seat belt systems, including belt load limiting and pretensioning.

It was found that children wanted to use booster cushions for safety and comfort, but perceived the use of booster cushions as childish. Parents motivated non-use due to inconvenience.

The handling study showed that adults felt secure when handling the integrated booster cushion because it could only be unfolded in one way. Integration facilitated buckling up. Furthermore, it was stable when entering or leaving the car. Misuse was detected for most children when using the aftermarket booster cushion as opposed to only one case of minor misuse with the integrated version.

The sled tests with retractors with belt load limiting and pretensioning resulted in reduced head, neck and chest loading as well as forward displacement.

By using an attitude, handling and safety approach, the combination of integrated booster cushion, belt pretensioning and load limiting would increase appropriate usage of restraints, decrease dummy injury values and keep forward displacement, thereby saving rear seat occupant lives.

INTRODUCTION

Occupants of all ages and sizes can be seated in the rear seat. Due to the presence of frontal airbags in the front seat, the rear seat might be the only available space for children in the car. Cuerden et al. (1997) found that children, females and older occupants sat oftener in the rear seat compared to the front seat. Smith et al. (2004) found in NASS-CDS data that 62% of all rear seat occupants were less than 15 years of age. Swedish data showed that 50% of all rear seat occupants were children (Krafft, 1989).

Although children have a lower risk of injury or death compared to adults (PCPS, 2006), motor vehicle accidents were the leading cause of death in children over three years of age in the US (Subramanian, 2005). There is a need for continuous improvement of the safety for rear seat occupants. The challenge is to design a restraint system for the rear seat suited to the wide range of occupants.

Booster cushions – use, misuse and non-use

At approximately 4 years of age, children should stop using child safety seats (forward or rearward seats with internal harnesses) and begin using booster cushions or booster seats (a booster cushion with back). It is recommended to continue using a booster cushion until approximately 10-12 years of age (NHTSA, Swedish Road Administration). The European Union has decided that by 2006 all concerned countries in Europe should have introduced a new law enforcing children shorter than 135 cm to be restrained with additional protective equipment such as infant seats, child safety seats or booster seats/cushions (European Directive, 2003). A child of 133 cm corresponds to a 50th percentile of 9 year olds (Pheasant, 2001).

Durbin et al. (2003) showed that the injury risk for children aged 4-8 years was reduced by 59% when seated on a booster cushion compared to a seat belt only. In the same study, seat belt syndrome related injuries to abdomen and spine were nearly completely eliminated in accidents with children seated on booster cushions/seats compared to only seat belts.

It could be assumed that parents perceive the booster cushion as much easier to use and handle compared to forward/rearward facing child safety seats, since the seat and the child are buckled up simultaneously by the seat belt in one handling sequence. Observation studies confirmed a higher misuse rate (80%) with child safety seats compared to booster seats (39%) (NHTSA, 2004). Still, there remain problems with non-use and misuse of booster cushions.

In a study by NHTSA (2004), critical child restraint system (CRS) misuse was identified by a number of experts. The parameters applicable to booster cushions were: Age and weight inappropriateness of CRS, placement of CRS in relation to airbag, installation and secureness of CRS to the vehicle seat (tight seat belt), fit of vehicle seat belts across child in belt-positioning booster seat, and defective or broken CRS elements. The same study showed that the most common misuse of booster cushions were improper fit of shoulder belt (21%), loose seat belt (16%), improper fit of lap belt (10%), and age/fit inappropriateness (9%). A study by the European CHILD project (Willis et al., 2006) showed a misuse rate of 67% among booster cushions, where belt routing problems over the guiding loops was the main problem (25%), followed by belt twisting (20%) and belt behind the back (16%), using French data.

Recently, Partners for Child Passenger Safety (2006) showed how restraint use by age group 4-8 has increased from 15% in 1999 to 54% in 2005 in the USA. Although, there has been considerable improvement, a large proportion of children 4-8 and 9-12 years old are still inappropriately restrained by seat belt alone.

Several studies have been carried out to determine the reasons for using or not using booster cushions. Bingham et al. (2005) performed a survey with 350 parents of 4 to 8 year-olds. The majority (93%) understood that booster cushions reduced the risk of injury, but 37% of parents said they would not use the booster cushion for short trips. Reasons for using booster cushions were safety, comfort, control of the child and enabling the child to see out of the car. The most common reasons for part-time non-usage were that the child rode with others, was in a hurry, and was too big or just refused to use the booster cushion. For the question “What would make booster seat use easier?” several test subjects answered; “built-in seat”, “required by law”, “everyone using it” and “the child likes it”.

Similar findings were observed by Charlton et al. (2006) in their Australian questionnaire study to parents of children aged 4-11 years. The most frequent reasons for non-usage were that the child was too big, followed by the child disliked the booster cushions or were more comfortable in a seat belt only and that they were too “grown-up”.

Most studies of booster-use attitudes have been directed towards adults, thus giving limited knowledge of children’s attitudes towards the use of booster cushions and how they handle the booster cushions.

Crash safety

Over time, vehicle structures have become stiffer (Swanson et al. 2003) resulting in less intrusion and decreased injury values. In addition, front seat protection nowadays normally includes pretensioners, load limiters and airbags. In the rear seat functions such as pretensioner and load limiters are rarely included.

Until now, real-life data has shown rear seats to be safer than front seats (Braver, 1998). However, Kuppa et al. (2005) showed in a double paired comparison of FARS data that occupants older than 50 were significantly more effectively restrained in the front seat than in rear seat. A new analysis of the same data by Kuppa (2006) showed a new trend that the rear seat was less safe than the front seat in newer car models (year model 1999-2005) compared to older car models (year model 1991-1998) This new trend was also recognized in British data by Welsh et al. (2006) in a study comparing older car models with younger car models (1998 and later).

Aim of the study

The aim of this study was to evaluate protection concepts offering benefits, in form of attitudes, handling and safety perspectives, for children seated in booster cushions.

The study was limited to occupants aged 6 to 8 years. This age group should be directly restrained by the seat belt seated on a booster seat/cushion.

METHODS

The study was divided into three parts: attitude, handling and safety. The bulk of the safety study (sled tests) were published previously (Bohman et al., 2006).

In the attitude and handling studies children of 7 to 8 years were participating. This is a critical age when children stop using booster cushions (PCPS, 2006), despite a continued need for them.

Attitude study

The attitudes towards usage of booster cushions were studied by using three focus groups with a total 16 children at 7-8 years of age. Each group discussion lasted for about one hour. Reasons for use and non-use were identified. The study took place at the children’s primary school.

Handling study

In a handling study, 7 children (7-8 years) together with a parent were observed when buckling up in a real car in a laboratory environment. Two different booster cushions were used: an integrated booster cushion (IBC) with one elevated height (Volvo V70, year model 2005) and an aftermarket booster cushion (BC1) (Kid, Britax) (figure 1). This particular booster cushion offered better comfort with thicker padding compared to many aftermarket booster cushions. It also has a well defined belt routing path with red markings under the guiding loops. It also has an adjustable width, but was set to the maximum width in the tests.

Figure 1. The IBC and the BC1 used in the handling tests.

The children in the study still used booster cushions and considered themselves as consistent users. They were also used to aftermarket booster cushions.

Participants were observed by 4 video cameras and a voice recorder. The children were asked to position the booster cushion, sit on the booster cushion, buckle up, unbuckle, leave the car, and remove the booster cushion. The parent was then asked to position the booster cushion, buckle up the child, unbuckle and then remove the booster cushion. adults. Information on attitudes towards booster cushions was also collected in the handling study.

In addition to the observations, interviews and surveys were conducted with both children and

Sled tests

Frontal sled tests were performed with a reinforced car body, front and rear seat included. A Hybrid III 6 year old child dummy (HIII 6y dummy) was positioned on the left outboard position in the rear seat. Three different 3-point belt retractors were used: a standard configuration, a retractor with pretensioner and a retractor with both pretensioner and load limiter. Hereafter the systems will be referred to as STD, STD+P and STD+P+LL. The belt force limit was 3,3 kN. The retractor was directly mounted on a shelf behind the seat back with direct belt outlet eliminating the need for an additional pillar loop.

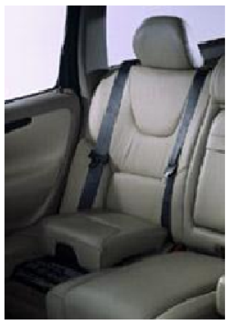
Four booster cushions were used, two aftermarket booster cushions with backrest (BCb1, Volvo Booster seat and BCb2, Maxi-Cosy Rodi XP), one aftermarket booster cushion without backrest (BC2, Volvo booster cushion) and one integrated booster cushion (IBC, Volvo V70), which was designed with the vehicle seat (figure 2). The aftermarket booster cushions had belt guidance (guiding loops) for the lap belt. The BCb1 had a weight of 2.6 kg. BCb2 had shoulder belt guidance as well (pillar loop type) with a weight of 4.8 kg. The BC2 had a weight of 1.2 kg. All booster cushions were tested with the three different seat belt restraints, except for the BCb2, not tested with the STD+P.

The crash pulse used in the tests was based on a mean of 5 real-life frontal crashes in which AIS2+ injuries were found in belted rear seat occupants (figure 3). The pulse data was provided by Folksam Insurance Company, Sweden, which has installed crash pulse recorders in a range of cars. The Δv was 55 km/h, peak acceleration 27g at 25ms and a mean acceleration of 12.1g. Some additional tests were run with a USNCAP test pulse for a large family car

BCb1

BCb2

BC2



IBC

Figure 2. Booster cushions for sled tests.

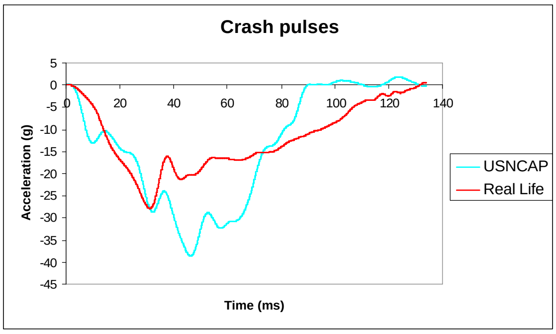


Figure 3. Crash pulses for the sled tests.

with a Δv of 56 km/h, peak acceleration of 38.6g and a mean acceleration of 19.3g.

RESULTS

Attitude

From the child's perspective, the most common reasons for using a booster cushion were: easier to see out, better seat belt comfort (particularly for the shoulder belt), safety and "parents told them to".

From the child's perspective, the most common reasons for not using a booster cushion were: the booster cushion was perceived as being childish, crowded with 3 (or more) in the rear seat, friends not using the booster cushion and if the family had only one booster cushion, the youngest child used it.

The most common reasons for using a booster cushion according to the adults were: safety and comfort, including both proper belt fit and the ability see out of the car.

From the adult perspective, the most common reasons for not using a booster cushion were: inconvenience with storage and transportation, lack of space with 3 in the rear seat and the child negatively influenced by friends.

For the question to adults "Why did children prematurely stop using the booster cushion?", the answer was mostly related to inconvenience in combination with poor knowledge about child crash safety. Adults often expressed thoughts that the children wanted to feel older. Not using a booster cushion seemed to be a sign of getting older.

When the children talked about their own booster cushions they usually described them in means of color, pattern and if the sitting surface was hard or soft.

Handling

Timing of the handling sequence - The average time to perform each action in the handling sequences for the two booster cushions is shown in the figures 4 and 5.

For the children, there was a marked difference between the two booster cushions for the time to fold up the IBC/put in BC1 and time to fold back the IBC/take out the BC1 respectively. It was the first time the children used an IBC and the average fold up time was 19 seconds the first time. They were asked to repeat the handling sequence a second time, and the time was reduced to 7 seconds. The time to unfold the IBC was reduced from 13 seconds to 4 seconds when repeated a second time.

The adults reduced the folding up time of the IBC from 6 to 3 seconds, when repeating the handling sequence a second time. There was no difference in time between the first and the second time the adults unfolded the IBC.

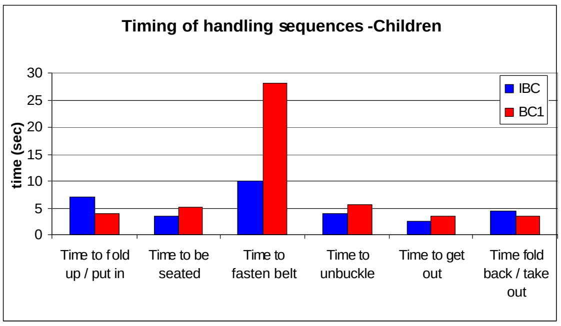


Figure 4. Average time for each action in the child's handling sequence.

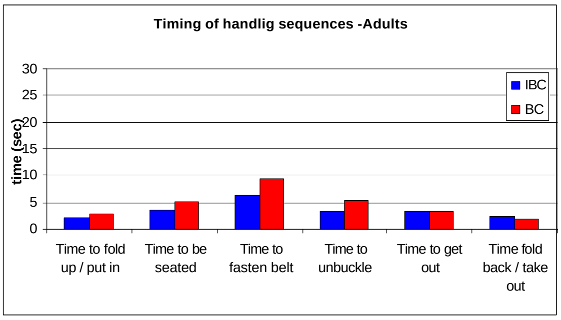


Figure 5. Average time for each action in the adult's handling sequence.

Parents felt secure when unfolding the IBC whereby it could only be done in one way.

Both booster cushions were perceived as being easy to leave and enter. However, the IBC was easier since it lacked guiding loops. The IBC was also more stable while the BC1 was unstable and moved around, especially during the entering phase.

Buckle up - It was easier and faster to buckle up the child on the IBC since no belt routing around guiding loops were necessary. The IBC also allowed easy access to the buckle. The BC1 required the adult and child to lean further forward in order to be able to see and access the buckle, whereby it was partly hidden by the guiding loops.

The parents appreciated the small risk of incorrect belt routing when seated on the IBC, due to the lack of guiding loops.

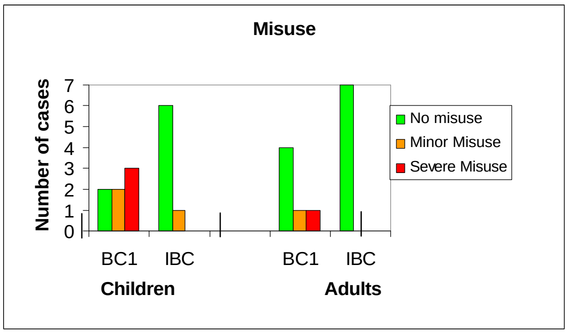


Figure 6. Misuse in the handling study of the BC1 and IBC.

Misuse was detected for 5 of 7 children when buckling up on the BC1 (figure 6). Two of the children failed to guide the lap belt under the guiding loops and one child had excessive slack. These three cases of misuse were graded as severe, according to the misuse study by NHTSA (2004). The other two children had the shoulder belt positioned over the guiding loops, graded as minor misuse. Severe misuse was detected for 1 of 7 adults when buckling up seated on the BC1, where the parent had failed to guide the lap belt around the outboard guiding loop. Two parents failed to put the shoulder belt under the guiding loop. One case was regarded as minor misuse, since the shoulder belt was too close to the neck, while the other case was not regarded as misuse, since the child was tall (140 cm) and the belt did not come too close to the neck.

One case of misuse was detected for the IBC, where the child had twisted the diagonal belt. It was graded as minor misuse. No misuse occurred when the parents buckled up the children on the IBC.

Sled tests

In figures 7 and 8, the effect of pretensioning and load limiting is expressed by the load with

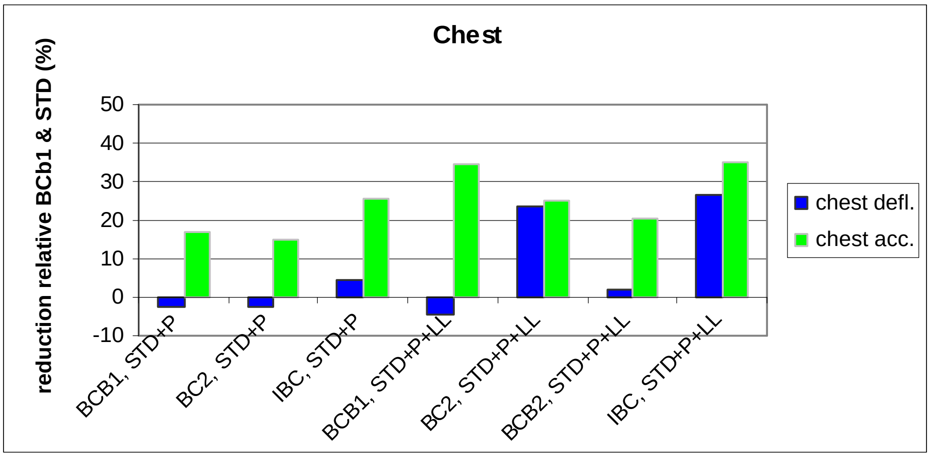


Figure 7. Reduction of chest loading for various retractor systems and booster cushions relative loading for configurations BCb1 with STD.

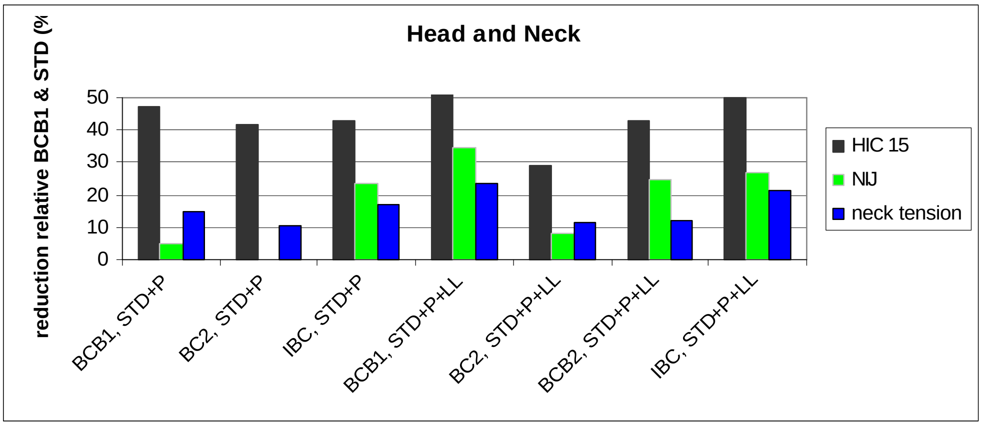


Figure 8. Reduction of head and neck loading for various retractor systems and booster cushion relative loadings for configuration BCb1 with STD.

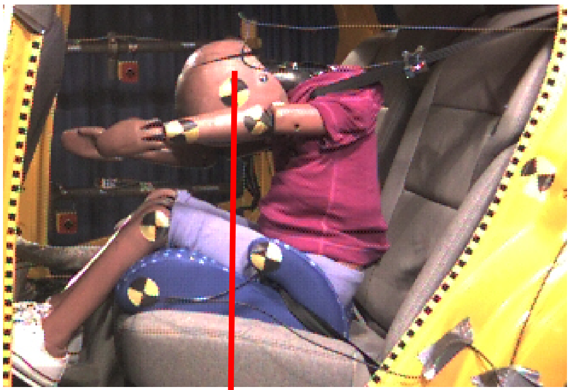
booster cushion with back and seat belt with a standard retractor (BCb1+STD). Adding a pretensioner to the standard retractor reduced the chest acceleration from 16-25%, HIC15 42-47%, NIJ 0-24% and neck tension by 10-17%, but had only a limited effect on chest deflection. When adding a load limiter to the pretensioner, chest acceleration and neck loadings were further reduced. Additionally, the effect of load limiting reduced chest deflection by 23% and 27% compared to a standard retractor for the BC2 and the IBC respectively. The average shoulder belt force was 4.2 kN with the STD and 3.3 kN for the STD+P+LL.

No head impacts with the interior occurred for any belt configuration.

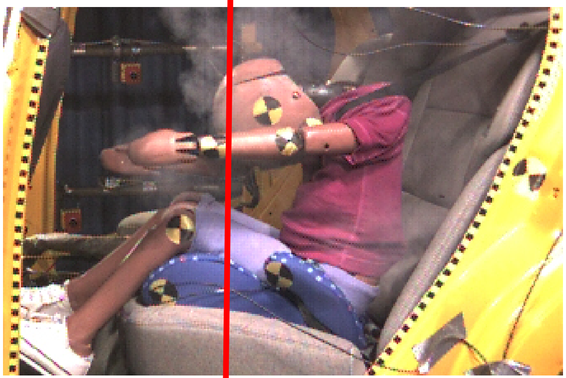
In four tests, BCb1+STD, BCb2+STD, BCb2+STD+P+LL, BC2+STD+P+LL, the shoulder belt slid off during the loading phase and fastened in the gap between shoulder and arm.

Some additional tests were run with the more severe USNCAP pulse with the HIII 6y dummy restrained on the BCb1 with the STD and STD+P+LL. In these tests, all the dummy loadings were higher compared to tests using the real-life pulse. When the pretensioner and load limiter were added to the system, all dummy loadings were reduced. Chest acceleration was decreased by 35% but chest deflection was less affected (5%). Neck loadings were decreased from 11-16%. Shoulder belt force reached 6.4 kN with the STD and 3.7 kN with the STD+P+LL. The shoulder belt slid off the shoulder during loading phase when the dummy was restrained by the standard belt.

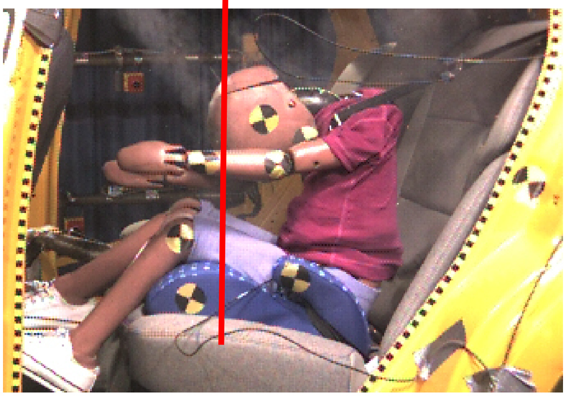
Head forward displacement - The displacement of the head was within legal requirements (ECE R44) for all four types of booster seats and for all seat belt configurations. The longest forward displacement of the head was found when the dummy was seated on an aftermarket booster cushion restrained with a STD belt. When the pretensioner was added the forward head displacement was reduced by 23 to 74 mm for the various booster cushions. When the load limiter was added to the retractor (LL+P) displacement was increased compared to retractor with pretensioner, but was still a shorter displacement compared to STD configurations (figure 9). The shortest forward head displacement was found with the IBC for all seat belt configurations.



9a) No pretensioner



9b) With pretensioner



9c) With pretensioner and load limiter

Figure 9. a,b,c Forward displacement of the HIII 6y dummy seated on the BC2.

Not only the retractor function influenced head forward displacement, but the initial position of the head was also important. The initial position of the head was up to 130 mm forward with a booster with back compared to a booster without back (figure 10).

10a) Initial position – BCb2

10b) Initial position –IBC

Figure 10. a,b Initial position of the HIII 6y dummy in two different booster cushions.

There was a tighter coupling to the integrated booster cushion and the rear seat, preventing the IBC to move forward during the crash compared to the various aftermarket booster cushions, even when a pretensioner was added and thereby restricting forward displacement of the aftermarket booster cushion (figure 11).

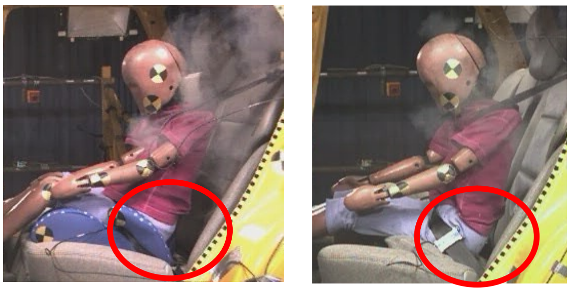


Figure 11. The HIII 6y dummy restrained by BC2 (left) and IBC (right) at 60 ms. The belt include both pretensioner and load limiter. Note the difference in forward displacement of the BC compared to IBC.

DISCUSSION

Attitude and handling

Adult's attitudes in this study were similar to findings in the study by Bingham et al (2005), showing that inconvenience was a major issue in the non-use of booster cushions. Availability and ease of handling could reduce inconvenience-related causes of non-use.

Another important attitude issue identified was the importance of the child feeling more grown up. A study by Edwards et al. (2006) confirmed the findings that children were concerned because "booster seats were for babies" and they saw adult belts as a more "grown-up" choice. The fact that Jakobsson et al. (2007) showed continued use of the integrated booster cushion in children up to 11 years of age indicated the importance of offering an appealing, "grown-up" restraint system.

Several studies (NHTSA, 2001, Winston et al. 2000) showed the problem of premature transition to seat belts in the age group intended for booster cushions. Children aged 9-15 have a greater injury risk than lower age groups (PCPS, 2006). Furthermore, a study (Kuppa, 2005) showed an increase in abdominal injuries in children older than 8 years, which could be a consequence of decreased booster cushion use.

Huang and Reed (2006) measured the seat cushion length of 56 late-model vehicles and found that only 13% of the children taller than 145 cm had a proper seating position without slouching using an average seat cushion. Using a booster cushion shortens the seat cushion length allowing the child to bend the knees without slouching resulting in a more comfortable and safer position. NHTSA recommends continued booster cushion use up to 145 cm, corresponding to a 50th percentile for an 11 year-old child. In conclusion, it is important, however possible, to continue to encourage children to use booster cushions until the age of 10-12 years.

It was unexpected in this study that 5 of 7 children had misuse problems with the BC1. These children were used to this type of booster cushion and considered themselves as "consistent users" normally putting on their seat belts themselves. Furthermore, they were aware of being observed and thus should have been more cautious when buckling up. Still, misuse occurred.

Two children and two parents placed the shoulder belt above the inboard guiding loop of the BC1, although this may not have been a severe misuse problem. But if poor fitting of the shoulder belt caused discomfort by rubbing the neck it may have lead to placing the belt under the arm or behind the back when trying to avoid discomfort resulting in severe misuse.

One child twisted the shoulder belt one turn when buckling up with the IBC. It was considered a minor misuse. In this case, the twist did not affect belt geometry and it was also considered to have a limited effect on the pretensioning of the seat belt.

The misuse occurring with the BC1 due to the belt routing problems around the guiding loops could not occur on the IBC. The integrated booster cushion can be designed without guiding loops since it is fixed attached to the vehicle and the anchorage points of the belt is possible to design to maintain a good belt geometry of both booster seated children as well as adults.

It was observed that only 5 of 14 tightened the belt after buckling up on the IBC and the corresponding figures for the BC1 were 4 of 14. It was the same two children and two adults who tightened the belt for the two booster cushions. This is an indication that neither children nor parents regularly tightened the belt after buckling up on the booster cushion. Belt slackening could easily occur, especially for the lap belt part, when buckling up on a booster cushion with guiding loops. A belt pretensioner eliminates slack in the belt system in the initial phase of a frontal crash.

Information to parents on booster cushion use will always be needed, but this study showed moreover that improving the design of the booster cushion could encourage booster cushion use as well as decreasing misuse.

In an ongoing study by the authors, 150 children aged 4 to 12 children were observed when buckling up in two different designs of booster cushions. Misuse, such as bad belt routing and belt slack, are some of the parameters to be analyzed.

Sled test

Mechanical and mathematical simulations with the HIII 50th percentile and HIII 5th percentile for the rear seat exposed to frontal impact at 48 km/h were conducted in parallel to the current study. Various load limiting levels and pretensioners were evaluated.

The HIII 50th percentile dummy had a belt force of 7.3 kN (pretensioner included, no load limiting) and when the load limiting of 5 kN was added the chest deflection was reduced by 12%.

The HIII 5th had a belt force of roughly 6 kN when only a pretensioner was added to the belt system. When a load limiter level of 5 kN was added, chest deflection was reduced by 10%. With a further reduction of the belt force to 3 kN chest deflection was reduced by 31% compared to the case without load limiter. The head did not impact the front seat back.

Chest, head and neck loading of the HIII 6y dummy was reduced when belt force was reduced from 4.2 kN to 3 kN. Results showed the need of adapting the load limiting level to the size of the occupant.

Tylko et al. (2005) conducted full frontal rigid tests with late model vehicles (2003 to 2005) in range of 40 to 56 km/h with a HIII 6y dummy in the rear seat. Belt force loads of more than 6 kN were measured for the HIII 6y dummy seated in the rear seat, resulting in high chest loading for deflection and acceleration. Although real-life data has not indicated that chest injuries were a problem to booster-seated children (Kuppa et al. 2005), Tylko et al. (2005 found chest deflection as high as 52 mm in their tests. High chest deflections were also associated with belt sliding off the shoulder.

Accident data has shown that the head was the most frequently injured body region among children (PCPS, 2006). Sled tests in this study showed that by introducing a pretensioner, head forward displacement could be reduced, even when a load limiter was introduced. Adding a load limiter in combination with a pretensioner, did not increase the risk of head impact with the interior.

The HIII 6y dummy was sensitive to belt geometry, whereby the belt slide off the shoulder for some configurations thereby increasing the risk of impacting the interior. This emphasizes the importance of maintaining good control of belt geometry for the child, which could be achieved by designing the booster cushion together with the seat belt.

Some additional misuse sled tests were performed with incorrect belt routing over the guiding horn of the BC2. This could only occur when using the booster cushion (with or without backrest) and not with the IBC, since there is no guiding horn for that design. When the lap belt was above both guiding horns, the dummy slid off the booster cushion, whereby the cushion was not restrained. The dummy submarined, but due to lack of instrumentation, the severity of injury to the abdomen or lumbar spine could not be estimated.

CONCLUSIONS

To motivate parents to use a booster cushion for the children it is essential to eliminate inconvenience by offering a booster cushion easily accessible and easy to handle.

To encourage continued use of booster cushion up to the ages of 10-12 years, the design must be appealing while reducing feeling of being childishness.

An integrated booster cushion offers fast and easy handling, with a reduced risk of possible misuse.

A load limiter of about 3 kN reduced loadings to HIII 6y. When adding a pretensionern to the retractor it was possible to reduce head forward displacement and while adding a load limiter it was still possible to keep the head forward displacement shorter than with a standard retractor.

By applying an attitude, handling and safety approach the combination of integrated booster cushion, belt pretensioning and load limiting would increase appropriate usage of restraints, decrease dummy injury values and keep forward displacements thereby saving rear seat occupant lives.

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REFERENCES

Bohman K., Boström O., Olsson J., Haland Y. 2006. ”The effect of a pretensioner and a load limiter on a HIII 6y, seated on four different types of booster cushions in frontal impacts”, IRCOBI, Madrid, Spain.

Bingham R C, Eby D, Hockanson H, Greenspan A. 2005. “Factors Influencing the Use of Booster Seats: A Statewide Survey of Parents”, The University of Michigan Transportation Research Institute Ann Arbor, UMTRI-2005-14

Braver. 1998. “Seating positions and children’s risk of dying in motor vehicle crashes”, injury prevention, v4:181-187.

Charlton J, Koppel S, Fitzharris M, Congiu M, Fildes B. 2006. “Appropriate Use of Booster Seats and Seatbelts by Australian Children Aged 4-11 Years. *4th Int. Conf. Protection of Children in Cars*, Munchen, Germany.

Cuerden R., Scott A., Hassan A., Mackay M.1997. “The injury experience of adult rear seat car passengers”, IRCOBI.

Durbin DR, Elliot MR, Winston FK. 2003. Belt-positioning Booster Seats and Reduction in Risk of Injury among Children in Vehicle Crashes. JAMA, 2003. 289(21): p2835-40

European Directive 91/671/EEC as amended by 2003/20/EC

Edwards SA., Anderson RWG., Hutchinson TP. 2006. “A survey of driver’s child restraint choice and knowledge in South Australia”, CASR REPORT SERIES, CASR012.

Huang S., Reed M. 2006. “Comparison of child body dimensions with rear seat geometry”, SAE no 2006-01-1142.

Jakobsson L, Isaksson-Hellman I, Lundell B. 2005. “Safety for the Growing Child – Experiences from Swedish Accident Data”, *Proc of 19th Int. ESV Conf*., Paper no. 05-0330, Washington DC, USA.

Jakobsson L, Wiberg H., Isaksson-Hellman I, Gustafssoon J. 2007. “Rear seat safety for the Growing Child – a new 2-stage integrated booster cushion”, *Proc of 20th Int. ESV Conf*., Paper no. 07-0322 Lyon, France.

Kuppa S., Saunders J., Fessahaie O.,2005. “Rear seat occupant protection in frontal crashes”, 19th International Technical Conference of the Enhanced Safety of Vehicles.

Kuppa S.2006. “Frontal crash protection for rear seat occupants”, SAE Government/Industry meeting.

Krafft, Nygren, Tinvgall. 1989. “Rear seat occupant protection. A study of children and adults in the rear seat of cars in relation to restraint use and car characteristics”, 10th International Technical Conference of the Enhanced Safety of Vehicles.

NHTSA. 2001. “Premature graduation of children to seat belts”, Traffic Tech, Technology Transfer Series, No 253, US Department of Transportation, Washington DC.

NHTSA. 2004. “Misuse of child restraints”. DOT HS 809 671, US Department of Transportation, Washington DC.

Partners for child passenger safety. 2006. “Fact and trend report”, October 2006.

Pheasant S., 2001. “Bodyspace”, Taylor & Francis Inc. Philadephia, USA.

Smith, Cummings. 2004. “Passenger seating position and the risk of passenger death or injury in traffic crashes”, Accident, Analysis and Prevention, Vol. 36, pp.257-260.

Swanson J., Rockwell T., Beuse N., Summers S., Summers S., Park B. 2003. ” Evaluation of Stiffness Measures From the U.S. New Car Assessment Program”, 18th Int. Technical Conf. of the Enhanced Safety of Vehicles.

Subramanian R. 2005. “Motor vehicle traffic crashes as a leading cause of death in the United States, 2002” Traffic Safety Facts, Research Note, DOT HS 809 831, US Department of Transportation, Washington DC.

Tylko S., Dalmotas D. 2005. “Protection of rear seat occupants in frontal crashes”, 19th International Technical Conference of the Enhanced Safety of Vehicles.

Welsh R., Morris A., Frampton R., Thomas P. 2006. “A review of secondary safety priorities”, PPAD p/33/129, S0316/VF, Department of Transport in UK.

Willis C., Le Claire M., Visvikis C., Kirk A., Grand R. 2006. “Overview report of research into the incorrect use of child restraints in selected countries”, Task 1.2, CHILD. www.childincar safety.com

Winston FK., Durbin DR., Kallan MJ., Moll EK. 2000. ”The danger of premature graduation to seat belts for young children”, Pediatrics, 105:1179-118