Older Children's Sitting Postures when Riding in the Rear Seat

Lotta Jakobsson, Katarina Bohman, Isabelle Stockman, Marianne Andersson, Anna-Lisa Osvalder

Abstract

An on-road driving study comprising six children aged 8-13 years (138-150 cm) was conducted to increase the understanding of children's natural sitting behavior during a car ride. Each child was video recorded during a pre-determined 40-minute route in the rear seat of a modern car. The route was taken twice; once when the child was restrained using a backless booster and once when the child used the seat belt only.

The children spent most of their riding time in a sitting posture with their upper back and shoulders in contact with the seat back, independent of using a booster or not. Slouched sitting postures were predominantly seen when restrained by the seat belt only, but in one case also when using the booster. The booster helped to position the belt at mid shoulder. In the slouched sitting posture, the booster helped to guide the lap belt below the abdomen. Also, the booster helped to keep the children in a more stable lateral sitting posture.

The study provides details on sitting behavior of children in the transition age for booster use adding valuable knowledge for future safety system improvements. It also takes into account comfort issues.

Keywords belt position, booster, children, postures, safety

I. INTRODUCTION

Belt-positioning booster cushions for children were introduced in the late 1970s [1]. The boosters allow the geometry of the vehicle seat belt to function in a better way with respect to the child occupant. The booster raises the child, so that the lap part of the seat belt can be positioned over the thighs, which reduces the risk of the abdomen interacting with the belt. The booster also encourages the child to sit comfortably relative to leg position and helps to avoid slouching, which may result in the lap belt sliding up onto the child's abdomen [2]. Other advantages of belt-positioning boosters are that the child, by sitting higher, will help position the shoulder belt centrally over the shoulder [2] and the child will also have a better view.

Belt-positioning boosters are effective tools to help protect children from injuries, decreasing the probability of injury in all crash situations [3]-[7]. Durbin et al. [5] showed that the seat belt syndrome-related injuries to the abdomen and spine were nearly eliminated in crashes with children seated correctly on boosters compared to those restrained by seat belts alone. Children aged 4 to 8 years and using boosters were 45% less likely to sustain injuries than similarly aged children who were using the vehicle seat belt only [7]. Children in side impacts derived the largest relative protection from booster seats, with a reduction in risk of 68% and 82% for near-side and far-side crashes, respectively, with no difference in high back versus backless boosters. Arbogast et al. [7] mainly acknowledge the enhanced better shoulder belt fit by the booster as the main contributor, knowing that side impact crashes often have a substantial frontal component [8].

Although some countries recommend booster use up to approximately 10 years of age, the highest age groups within this range are not as frequently restrained using boosters. US statistics [9] shows higher injury risks within the age group 9-12 year as compared to the younger age group (4-8 years). This suggests that the age group of 9-12 years requires extra focus since this age group falls between the traditionally booster-restrained 4-8 year old children and the teenager and small adults that are correctly restrained by the seat belt.

The sitting posture depends on which postures are possible in a specific restraint system. The design may

Lotta Jakobsson is Safety Technical Leader at Volvo Cars Safety Centre and Adjunct Professor in Vehicle Safety at Chalmers University of Technology in Sweden (Ph: +46 31 591814, fax: +46 31 595922, ljakobss@volvocars.com). **Katarina Bohman** is Safety Researcher at Autoliv Research and PhD student at Karolinska Institutet in Sweden. **Isabelle Stockman** is PhD student at Chalmers University of Technology in Sweden. **Marianne Andersson** is Safety Researcher at Saab Automobile and PhD student at Chalmers University of Technology in Sweden. **Anna-Lisa Osvalder** is Professor in Human Factors Engineering at Chalmers University of Technology in Sweden. All authors are associated with SAFER – Vehicle and Traffic Safety Center at Chalmers in Gothenburg, Sweden.

promote a range of sitting postures, including less optimal postures from a safety perspective [10], [11]. Research by [12] provided understanding of how a total of 25 children up to age 8 sit in vehicles while riding in the rear seat. The study included naturalistic observations of 12 families' regular trips for 3 weeks. A key finding was that children were judged as out of the protective zone provided by the child restraint system structure or away from the optimal/preferred location within the restraint around 70 % of the time during their journey. A study by [13] involving six children between three and six years of age evaluated differences in sitting postures for two different types of high back belt-positioning boosters in the rear seat. All these studies contribute with knowledge of children's preferred sitting postures and behavior when riding in the rear seat of a passenger car. However, little is known about how older children sit in the rear seat during normal driving and whether there are differences in sitting postures when using boosters or not.

Hence, the objective of this study was to identify the preferred sitting posture and the shoulder belt positions of 8- to 13-year-old children (135-150 cm), when seated with and without a belt-positioning booster while riding in the rear seat of a passenger car.

II. METHODS

In order to increase the understanding of the natural sitting behavior of children during a car ride, an on-road driving study was conducted to identify preferred sitting postures. Six children between 8 and 13 years old participated in the study, including 3 girls and 3 boys. Their statures ranged from 138 to 150 cm. The children were recruited by contacts within the area of Gothenburg, Sweden. The selection criterion was to include children with a stature of 135-150 cm, being the upper range of transition from booster to seat belt only. It is also the range of the regulation within Europe; 135 cm in Sweden and in several other European countries, while 150 cm in Germany and Switzerland.

The demographics for the children included in the study are given in Table 1. Sitting length is defined as the horizontal buttock to knee pit distance and sitting height is the floor to top of head distance when seated with a straight back, and both feet on the ground.

TABLE 1
DEMOGRAPHICS OF THE TEST SUBJECTS

Child	Gender	Age (years)	Weight (kg)	Stature (cm)	Sitting length (cm)	Sitting Height (cm)
1	Girl	9	39	140	44	75
2	Boy	10	31	141	39	74
3	Girl	13	44	150	45	83
4	Boy	8	30	138	30	75
5	Girl	12	43	149	37	78
6	Boy	10	35	146	36	77

The car used in the field tests was a Volvo XC70 of model year 2010 and was driven by the child's parent during the test. There were no other passengers in the car beside the child test subject. The child was positioned in the outer right position in the rear seat. Each child was taken for a ride on a pre-determined route. The route was taken twice; once when the child was restrained using the booster and once when the child used the seat belt only. The test order of the restraint systems was alternated equally. The route entailed both city and highway driving and each route took about 40 minutes. The booster used in the study was a "Biltex Boulevard" and is shown in Fig. 1. This booster is one of the most frequently used backless boosters in Sweden.

Prior to the test, the parent and the child were informed about the test procedure. The child was asked to wear a tight long sleeve shirt in light color. After each ride, the child was asked to rate comfort with respect to seat and belt comfort on a 5-level scale for each restraint system, with 1 being ‘very uncomfortable’ and 5 being ‘very comfortable'. Between the rides a short interview was also held asking for the child's habits in car riding and restraint system use. After the two rides, the child was asked about a comparison of the two restraints. The child received two movie tickets as compensation for participating in the study.

Fig. 1. Booster type used in study.

Data was collected through observations, using video recordings inside the car. Four film cameras were fixed in the vehicle providing a front view of the child, a perpendicular lateral view of the child, an oblique view of the child, and a front view of the road. Targets were placed on key landmarks of the child; shoulder front and lateral view, upper thigh lateral view and to the head, as shown in Fig. 3 and 6.

From the films, the children's different sitting postures and the shoulder belt positions with duration of one second or longer were assessed and categorized. The total duration of each posture and seat belt position was summed up. A complete set of data was collected for all test subjects in both restraints except for parts of the ride for test subject 3 when using the booster. Due to darkness, only 16 minutes of that ride could be captured on film and thus analyzed.

Classification of sitting postures

The children's sitting postures were systematized by differentiating the sagittal (fore to aft) from the lateral sitting postures (left to right). To design a usable classification system, a number of head and torso positions in the sagittal and lateral directions were defined. The classification was derived from sitting posture categories defined by [13] and [14].

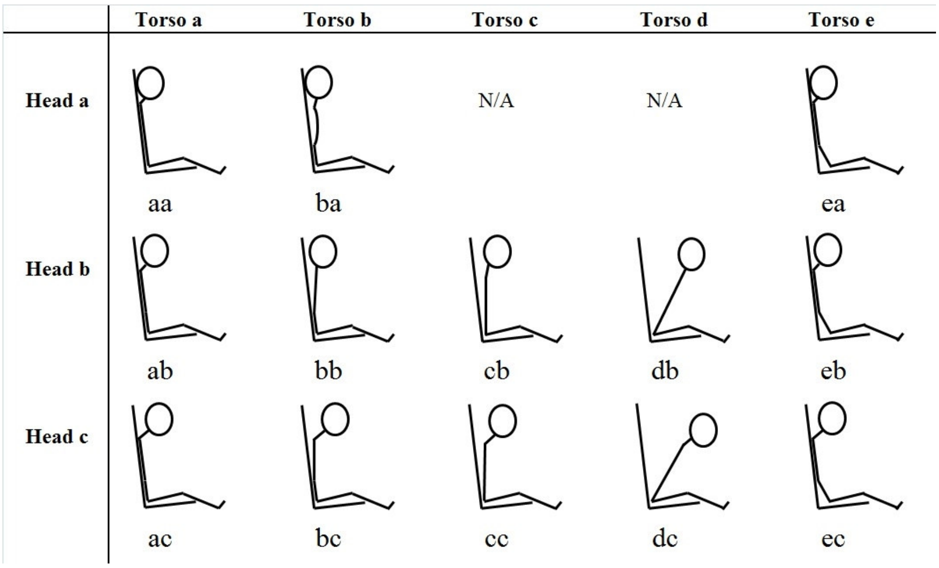

Fig. 2. Sagittal sitting postures

The sagittal torso positions were defined as: 'a' the entire back including shoulders against the backrest, 'b' the entire back but not the shoulders against the backrest, 'c' child remains upright but no part of the back against the backrest, 'd' the torso is leaning forward without contact with the backrest and 'e' the child sits in a slouched position i.e. the upper back including shoulders against the backrest but no contact between the lower back and backrest. The sagittal head positions were defined as: 'a' head against the backrest/head restraint, 'b' head upright relative to the torso, and 'c' head leaning forward relative to the torso. The head and torso positions were combined to make up the sagittal sitting postures as shown in Fig. 2. For example, in the 'ab' posture the child sits with the entire back against the backrest, while the head is upright.

The lateral sitting postures were categorized as illustrated in Fig. 3: 'A' the whole torso in an upright position, 'B' the torso is tilting, but the shoulders are within the outer lines (as shown in Fig. 3) and 'C' the torso is tilting and the shoulder is outside the outer line (as shown in Fig. 3). The direction of the lateral movement is indicated by plus (+) when leaning inboard, and by minus (-) when leaning towards the side window (outboard).

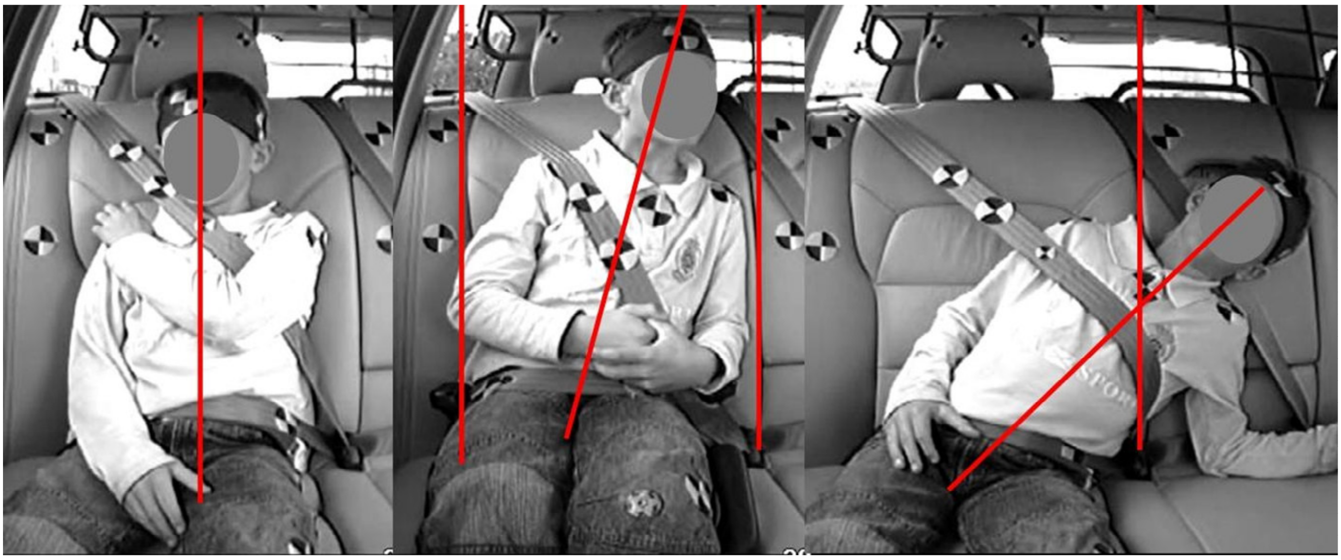

Fig. 3. Lateral sitting postures, from left to right: 'A', 'B' and 'C'.

The shoulder belt position was classified into four categories, as illustrated in Fig. 4: 'A' the shoulder belt is against the neck, 'B' the shoulder belt is on the mid-shoulder, 'C' the shoulder belt is on the edge of the shoulder, 'D' the shoulder belt is off the shoulder.

Fig. 4. Shoulder belt positions, from left to right: 'A', 'B', 'C' and 'D'.

III. RESULTS

Sagittal sitting postures

The total duration of each sagittal sitting posture is presented as a percentage of the total riding duration in Appendix 1, for each test subject in the two restraint types, respectively. Fig. 5 shows the averages of all children comparing the two different restraints for the sagittal sitting postures. Although the average values of the different sitting postures are similar comparing the two restraint systems, the large standard deviations indicate that there are substantial individual differences.

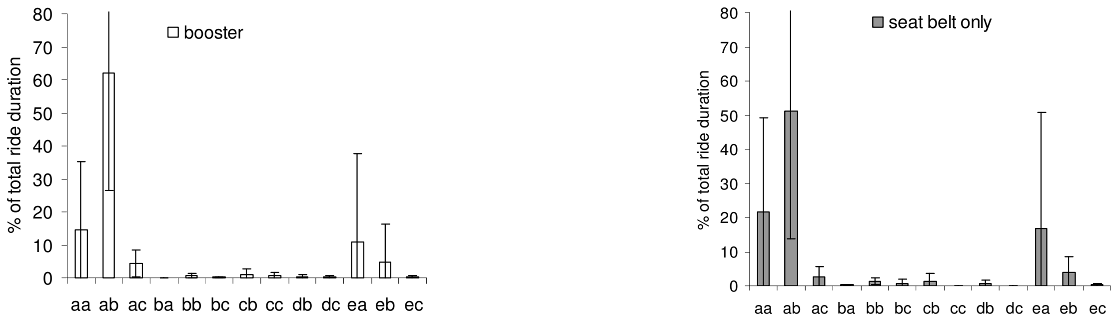

Fig. 5. The distribution of sagittal sitting posture durations, shown as a percentage of the total ride duration. The averages of all children are presented by restraint type (incl. standard deviations). The sagittal sitting postures are defined in Fig. 2.

For all test subjects, except child 4, the most frequent sitting postures were 'aa' and 'ab', i.e. entire back and shoulders against backrest and head against head restraint or upright. Fig. 6a and 6b illustrate examples of these two sitting postures for children using booster or seat belt only, respectively. Child 4 was never in those postures; instead he spent more than 90% for both restraint types in a slouched position, i.e. sagittal sitting postures 'ea', 'eb' or 'ec'.

Fig. 6a. Examples of sagittal sitting postures 'aa' (top) and 'ab' (bottom) for children using boosters

Fig. 6b. Examples of sagittal sitting postures 'aa' (top) and 'ab' (bottom) for children using seat belts only

Independent of using the booster or not, the children spent most of the time in a sitting posture with their upper back and shoulders in contact with the seat back. On average, less than 3% of the time the children were seated in sagittal sitting postures with no shoulder or back contact with the backrest. The extreme positions with no shoulder or back contact occurred usually as a result of the child reaching after something, talking intensively with the driver or looking/investigating the surrounding environment.

Irrespective of level of back and shoulder contact, the children leaned their heads against the head restraint ('a') or had their head upright ('b') on average 97% and 94% of the total trips for seat belt only and booster usage, respectively. Separating the two head positions 'a' and 'b' no general major differences comparing the two restraints used in the study could be seen. The individual variations were substantially more influential than the differences between the restraint systems.

In total, 3 of the children assumed a slouched position during the ride. Beside child 4 who slouched the vast majority of the trip for both restraint types, child 1 and child 5 spent 14% and 18% of their time, respectively, in a slouched position when restrained by the seat belt only (Fig. 7a-c). Only child 4 assumed a slouched position when using the booster. This slouched position was achieved by moving the booster forward as well (Fig. 7c) and it can be seen that the booster helps to guide the lap belt in a more favorable position even when the sitting posture was slouched. It is obvious that child 4 slouched forward for leg comfort reason, especially when using the seat belt only. In this study, he was the child with the shortest sitting length. The slouched sitting postures by child 1 and child 5 seemed more to be a result of general comfort reasons, as a part of their changing posture behavior. For child 1 and child 5 the slouching posture duration took place at one single event for each of them.

Fig. 7a-c. Examples of slouched sitting postures (left to right); a) sagittal sitting posture 'ea' seat belt restrained only, b) sagittal sitting posture 'eb' seat belt restrained only and c) sagittal sitting posture 'ea' when using booster.

Lateral sitting postures

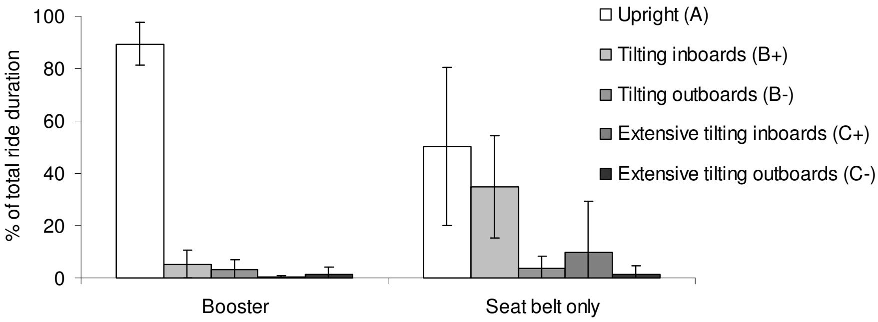

Fig. 8. The distribution of lateral sitting postures durations, shown as a percentage of the total ride duration. The averages of all children are presented by restraint type (incl. standard deviation). The lateral sitting postures are defined in Fig. 3.

The averages of lateral sitting posture durations of all children, including confidence intervals, comparing the two different restraints are shown in Fig. 8. All the test subjects were positioned in more upright lateral postures to a larger extent of time when using the booster compared to using the seat belt only. Details for each test subject are found in Appendix 2. Using the booster, the children were seated upright in 79%-99% of the time. When restrained by the seat belt only, the upright position was less frequent for all the children and the spread between the individuals was large, 0%-91%.

In average, the children when restrained by the seat belt only spent half of their time in a laterally upright position and the majority of the remaining time they were tilted inboard in the vehicle in position 'B'. However, due to the spread between individuals, this was true only for 4 of the 6 children. Child 2 spent 92% in an upright sitting posture tilting sidewise only when the car was turning sharply; he was observing things outside the window or inspecting the targets on his clothes. Child 3 spent no time in an upright sitting posture when restrained by the seat belt only. She initially assumed a sideways rotated posture and sat still in that general posture tilting more or less inboard (Fig. 9a).

During driving in roundabouts or sharp turns the children in most cases tilted laterally during the turns. Another frequent reason for tilting was when they leaned inboard for better visibility between the seats (Fig. 9b). Except for test subject 3 restrained by the seat belt only, limited time was spent in extensive lateral tilting sitting postures by any of the children.

Fig. 9a. Child 3 in lateral sitting postures 'B+' (mid) when restrained by seat belt only.

Fig. 9b. Example of leaning inboard for better visibility. Lateral sitting posture 'C+'.

Fig. 9c. Child 5 restrained by seat belt only in upright sitting posture ('A') and shoulder belt position 'B'

Shoulder belt position

For all children, except test subject 5, the shoulder belt was placed on the mid shoulder for a substantially larger part of the time when using the booster compared to the seat belt only. Test subject 5 had approximately the same time duration of mid shoulder position in both restraint systems. Using boosters, the shoulder belt was positioned on the mid shoulder in 80%-99% of the time and less than 16% of the time against the neck for all the children. This is illustrated as average values in Fig. 10 and details regarding each test subject are found in Appendix 3. Child 2 and child 3 had the shoulder belt above the booster guiding loop, while the other children had the shoulder belt under the guiding loop. Shoulder belt position under the guiding loop usually results in a shoulder belt position closer to the neck.

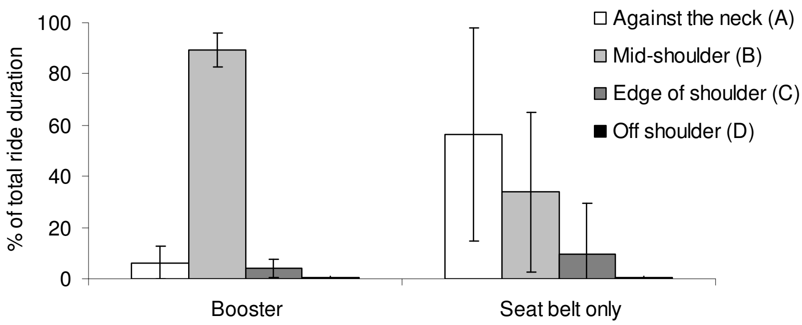

Fig. 10. The distribution of shoulder belt position durations, shown as a percentage of the total ride duration. The averages of all children are presented by restraint type (incl. standard deviations). The shoulder belt positions are defined in Fig. 4.

When restrained by the seat belt only, the variation among the test subjects was larger than while restrained using the booster. Restrained by the seat belt only, 4 of the 6 children had the shoulder belt placed 71%-94% of the time against the neck and 6%-26% of the time on the mid shoulder. Beside test subject 5 who had similar shoulder belt positions irrespective of restraint use (mid shoulder in 90% of the time and less than 8% against the neck), test subject 3 varied substantially from the other test subjects. It was obvious that test subject 3 assumed her sidewise rotated posture (Fig. 9a) to move away from the shoulder belt for comfort reasons, thus resulting in the shoulder belt positions half the time at the edge of the shoulder, and half of the time on the mid shoulder. Child 3 and child 5 were among the tallest child test subjects (150cm and 149cm, respectively). As can be seen in Fig. 9c, child 5 had a natural mid shoulder belt position when seated laterally upright restrained by the seat belt only. The children having a natural initial mid position shoulder belt position remained in the upright lateral sitting posture for a greater proportion of the ride. This is seen for all the children when using boosters.

Subjective comfort assessment

The children's subjective comfort assessments of their perception of the seat and shoulder belt comfort of each of the two restraints are shown in Fig. 11. Two of the six children rated booster sitting comfort higher than without the booster. One child rated equal sitting comfort for the two systems, while the other three rated higher comfort for the seat belt only. The children's rating of shoulder belt comfort followed generally the sitting comfort rating. The similarities indicate that it probably was difficult for the children to separate the different comfort aspects in the subjective assessment.

After the test, the two children (1 and 4) who rated booster sitting comfort higher expressed a preference for using the booster. They were both more accustomed to it. Child 1 stated it was secure, she liked to sit higher and experienced too much sliding without the booster. Child 4 stated that he sat better with the booster and that the belt bothered his neck if sitting without the booster. Child 1 and child 4 were the shortest as well as the youngest among the test subjects; they were also the only two that usually used boosters when traveling in cars. The other four test subjects expressed a preference for using the seat belt only. Child 5 and child 6 reasoned that they were more accustomed to the seat belt only. Child 2 perceived the booster too hard and Child 3 simply claimed it was more comfortable using the seat belt only.

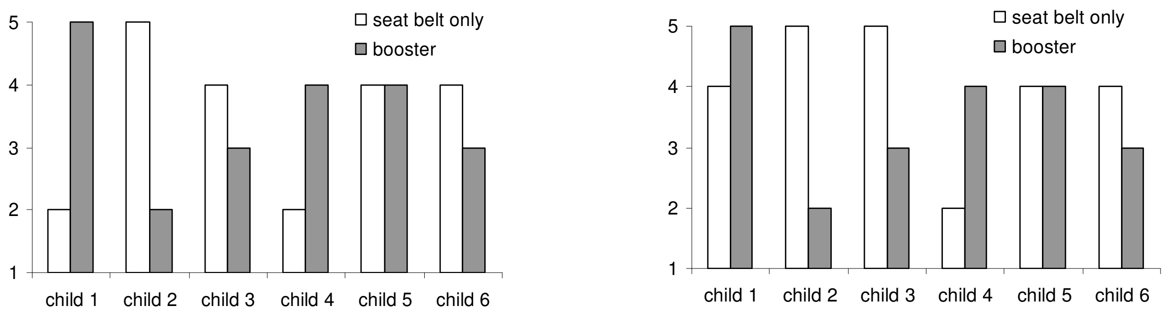

Fig. 11. Self assessment after ride with respect to sitting comfort (left) and shoulder belt comfort (right). Assessed and presented on a 5-level scale (ranging from "1" being 'very uncomfortable' to "5" being 'very comfortable'). One grading for each child and ride.

IV. DISCUSSION

This study addresses 8-13 year-old (135-150cm) children's sitting postures and seat belt positions during natural rear seat riding, which has not been addressed and presented in the literature so far. The children of this age and size range are among the largest children that may be restrained using a booster, and may according to most national regulations be restrained by the seat belt only. This study provides a first insight into the preferred sitting postures and the effect on seat belt fit for older children, contributing to increased knowledge of potential protection effects and facts about real-world restraint aspects valuable for the total safety for this group of rear seat child occupants. Different recommendations and regulations apply for this age group around the world, motivating this type of study.

Methods, including limitations

A sample of six child test subjects, one car model and one type of booster was used in this study. Based on this sample size, valuable and interesting results could be drawn, although a substantially larger sample size is required for statistically sound conclusions. Depending on the rear seat design and belt geometries, the results from this study will probably be more or less pronounced. Also, the design of the booster affects the results.

The children were not riding in their own vehicles, but in a test vehicle equipped with cameras and targets attached to their clothes, their head and to the interior of the vehicle, which may have influenced their normal sitting behavior. The children did pay attention a few times to the targets, mostly in the beginning of the ride, but also occasionally during the entire ride. At the start of the ride, all children paid attention to the cameras. For most children and during the majority of the rides it was obvious that the cameras did not affect their behavior, although it cannot be excluded that they might have behaved differently than in a normal drive in their usual car without cameras. Naturalistic studies monitoring children in the rear seat in daily day driving, such as [12] provide better insight into how affected the children are by the setup in the present study.

This study did not focus on the effect of sitting posture and belt fit of sleeping children. However, one child fell asleep for the last 10 min in the drive when restrained using the booster. The torso was kept upright and stable while sleeping, resulting in a stable mid shoulder position of the shoulder belt. But as the neck muscles became relaxed while the child slept, the head moved sidewise. However, these movements did not cause any changes in shoulder belt position.

Data from parts of one trip (child test subject 3 using booster) was lost due to darkness. Only 16 minutes of the total 40-minute trip was included in the analysis. However, it was decided to include this test subject's values with the average numbers in the analysis even though the trips with known information are not identical. The alternative would be to exclude the test subject completely. This test subject differed a lot in her sitting posture and behavior as compared to the others. She was sitting very still, and she also had a sidewise rotated posture when restrained by the seat belt only (Fig. 9a). She was also the test subject most concerned about the cameras. It can be speculated whether it was the cameras or her type of personality being the main reason for her sitting still. Nevertheless it is likely that she would continued to sit just as still during the last part of the ride which was too dark to judge from the cameras. For this reason it was decided to include this test subject in the average values in the analysis.

Implications of results

The children spent most of their time in a sagittal sitting posture with their upper back and shoulders in contact with the seat back and spent limited time in forward tilting sitting postures, irrespective of booster usage or not. When they did tilt forward, the shoulder belt remained in position. A forward leaning position resulted in the belt “grasping” the shoulder and staying on the shoulder, unless the child deliberately made a movement with the shoulder in order to let the belt slip off the shoulder. The extensive forward leaning positions, which occurred in average less than 3% of the time, were usually as a result of the child reaching after something. Especially child 1 and child 4 were more active in forward leaning than the others. Both these children seemed more restless than the others, and they were also the two youngest (9 and 8 years old, respectively). In a previous study with similar method the younger children (3-6y) using high back boosters had a more upright position and were more active when seated [13]. Child 1 seemed to be moving with music, she looked around a lot and also inspected the markers. Child 4 was very active pulling the belt, seemingly restless and bored. He often leaned to the side and also tried to cover the cameras with his hands once in a while. Child 5 and child 6 moved forward to some extent, while child 2 and child 3 almost constantly had contact with the upper back or shoulder.

Studies have proposed that one of the advantages of boosters is that they effectively shorten the seat cushion length [2], [15]. Children seated on vehicle seats that are too long for them will scoot forward in the seat to allow comfortable leg positions rather than sitting up straight and putting pressure on the backs of their lower legs, the so called "slouch effect". In the present study, half of the children assumed a slouched position when using the seat belt only. The child who slouched more than 90% of his ride was the smallest child, both in respect to stature and sitting length, and it was obvious that he slouched forward mainly for leg comfort reason. The slouched sitting postures by the other two children seemed more to be a result of general comfort reasons, as a part of their changing posture behavior. For the single child who slouched also when using the booster it was obvious that the booster helped maintain the lap belt below the abdomen even when the sitting posture was slouched. A more extensive study is needed to establish the general recommendations for transition from booster to seat belt only. Huang and Reed [16] compared child body dimensions with rear seat geometry of 56 vehicles and found that most of the second-row vehicle seats are longer than the thighs of children less than 12 years of age. Boosters integrated into the rear seats provide a good alternative, with the benefit of attracting more children of this age and adapting the vehicle cushion length to the child's proportions [17].

The shoulder belt being completely off the shoulder was a very rare belt position and was a result of the child manually pulling the belt off the shoulder, leaning extensively inboard for various reasons or making a deliberate movement of the shoulder with the purpose of letting the belt fall off the shoulder. When the children wanted to look forward, they often leaned inboard the vehicle in order to see between the two front seats, which was also a reason for the shoulder belt getting further out on the shoulder (as exemplified in Fig. 9b). In no case was the shoulder belt put under the arm or behind the back. From observational studies it has been seen that shoulder belt behind the back or under the arm may occur [18]-[19], and one reason may be discomfort to the neck. In the current study, the shoulder belt was pulled off the shoulder a few times but in limited duration.

The children having a natural initial mid position shoulder belt position remained in the upright lateral sitting posture for a greater proportion of the ride as compared to the other rides. This is seen for all the children when using boosters and confirms the findings by [2] of better shoulder belt fit when using boosters. The children restrained by a seat belt only more often had seat belt contact with their neck. In order to avoid the neck discomfort, the children then leaned inboard relative to the vehicle. Another common way of reducing neck discomfort was a change in posture such that they rotated their legs towards the door and their pelvis inboard resulting in a lateral movement inboard of the torso. Child test subject 3 assumed this sidewise rotated posture with an inboard lateral tilting torso (Fig. 9a) when traveling with the seat belt only. It was obvious that this was a selected sitting posture to enable the belt to not contact the neck. In some cases the child even pulled the belt away from the neck. The absence of the booster thus resulted in a greater variation of lateral tilting postures, mainly due to neck discomfort

Using the booster, the children were seated laterally upright to a larger extent of time and the shoulder belt was placed on the mid shoulder to a larger extent of time compared to the seat belt only. The spread in variation of sitting postures was larger for the children when restrained by the seat belt only. These objective measures support the idea that the booster would be an effective tool to help keep the children in a desired position overall. Based on the subjective assessments by the children, only two children said they preferred to use the booster. The other four children expressed a preference for using the seat belt only. All four said that they were accustomed to it, one perceived the booster to be too hard and one simply claimed the seat belt only to be more comfortable. The latter child adjusted her sitting posture to avoid the belt to neck contact when using the seat belt only (Fig. 9a). These comfort related perceptions need to be taken seriously in order to enhance total safety for this age group in vehicles.

Using the booster the children were generally in a more stable sitting posture as compared to when using the seat belt only. Also, the lap and shoulder belt fit as shown in this study confirms the enhanced safety potential as identified in prior studies [2]. Hence, the concept of a booster is shown to be a feasible tool to help keep children in desired positions. If the concept of the booster could be made just as comfortable aiming to be the desired restraint for this group of children, a more controlled sitting posture could be achieved. A controlled sitting posture has direct relations to the safety in real world situations and would give greater possibilities for even further safety improvements focused on this age group. A first step in this direction is taken by the rear seat with built-in boosters including child adapted seat belt and side impact head protection [17].

This study offers the first of its kind, especially studying the children of size and age that may be restrained using a booster, and may according to most national regulations be restrained with the seat belt only. By showing the differences in sitting postures and shoulder belt positions, it adds unique and valuable knowledge to be used in improving future restraint systems for these children taking into account also comfort issues for total enhanced safety.

V. CONCLUSIONS

The children spent most of their riding time in a sitting posture with their upper back and shoulders in contact with the seat back, independent of using a booster or not. There were no general differences in head to head restraint distance between when the children were restrained using a booster or a seat belt only. Slouched sitting postures were predominantly seen when restrained by the seat belt only, but in one case also when using the booster.

The booster helped to position the shoulder belt at the mid shoulder. In the slouched sitting posture, the booster helped to guide the lap belt below the abdomen. Also, the booster helped to keep the children in a more stable lateral sitting posture, shown mainly by a larger variation in lateral sitting postures when using the seat belt only.

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VIII. APPENDICES

Appendix 1. - The sagittal sitting posture duration shown as the percentage of the total ride duration. The data is presented by restraint type (B= booster, nB= no booster) for all children and the average of all children. The sagittal sitting postures are defined in Fig. 2.

	average		Child 1		Child 2		Child 3		Child 4		Child 5		Child 6	
Pos.	**B**	**nB**	**B**	**nB**	**B**	**nB**	**B**	**nB**	**B**	**nB**	**B**	**nB**	**B**	**nB**
aa	**14,5**	**21,6**	3,2	11,0	50,4	5,3	0,0	4,1	0,0	0,0	3,5	38,7	29,7	70,2
ab	**62,1**	**51,1**	78,3	61,7	44,4	88,0	99,5	95,3	0,0	0,0	83,7	38,5	66,8	23,0
ac	**4,5**	**2,6**	9,4	6,4	5,2	5,8	0,2	0,0	0,0	0,3	9,0	0,9	3,5	2,0
ba	**0,0**	**0,2**	0,0	0,0	0,0	0,2	0,0	0,0	0,1	0,2	0,0	0,0	0,0	0,7
bb	**0,6**	**1,2**	1,5	2,7	0,0	0,2	0,0	0,4	1,1	2,3	1,1	0,6	0,0	1,2
bc	**0,2**	**0,6**	0,5	3,2	0,0	0,0	0,0	0,0	0,3	0,0	0,5	0,1	0,0	0,0
cb	**1,0**	**1,4**	4,6	0,2	0,0	0,4	0,3	0,0	0,1	5,9	0,9	0,8	0,0	0,9
cc	**0,6**	**0,0**	0,6	0,1	0,0	0,0	0,0	0,1	2,9	0,0	0,0	0,0	0,0	0,0
db	**0,4**	**0,6**	1,0	0,4	0,0	0,0	0,0	0,0	0,0	0,0	1,2	1,4	0,0	2,0
dc	**0,3**	**0,0**	1,1	0,0	0,0	0,0	0,0	0,0	0,5	0,0	0,0	0,0	0,0	0,0
ea	**10,9**	**16,6**	0,0	4,8	0,0	0,0	0,0	0,0	65,5	86,3	0,0	8,6	0,0	0,0
eb	**4,7**	**4,0**	0,0	8,5	0,0	0,0	0,0	0,0	28,0	5,0	0,0	10,2	0,0	0,0
ec	**0,2**	**0,2**	0,0	1,0	0,0	0,0	0,0	0,0	1,4	0,0	0,0	0,0	0,0	0,0

Appendix 2. - The lateral sitting posture duration shown as the percentage of the total ride duration. The data is presented by restraint type (B= booster, nB= no booster) for all children and the average of all children. The lateral sitting postures are defined in Fig. 3. * only 16 min of the ride

	average		Child 1		Child 2		Child 3		Child 4		Child 5		Child 6	
Pos.	**B**	**nB**	**B**	**nB**	**B**	**nB**	**B**	**nB**	**B**	**nB**	**B**	**nB**	**B**	**nB**
A	**89,4**	**50,1**	79,2	53,7	98,2	91,6	87,3*	0,0	82,3	45,4	90,1	44,2	99,1	65,7
B+	**5,3**	**34,8**	3,8	32,6	1,0	2,8	12,7*	50,1	10,8	47,2	3,2	53,9	0,4	22,3
B-	**3,4**	**3,9**	9,8	11,9	0,8	5,6	0,0*	0,0	4,9	0,3	4,2	1,7	0,5	3,7
C+	**0,4**	**9,6**	0,3	0,8	0,0	0,0	0,0*	49,9	0,6	6,1	1,7	0,1	0,0	0,7
C-	**1,5**	**1,6**	6,9	1,1	0,0	0,0	0,0*	0,0	1,4	1,0	0,8	0,0	0,0	7,6

Appendix 3. – Shoulder belt positions duration shown as the percentage of the total ride duration. The data is presented by restraint type (B= booster, nB= no booster) for all children and the average of all children. The shoulder belt positions are defined in Fig. 4. * only 16 min of the ride

	average		Child 1		Child 2		Child 3		Child 4		Child 5		Child 6	
Pos.	**B**	**nB**	**B**	**nB**	**B**	**nB**	**B**	**nB**	**B**	**nB**	**B**	**nB**	**B**	**nB**
A	**6,2**	**56,3**	16,0	88,4	7,9	93,9	0,0*	0,0	10,6	77,2	2,4	7,8	0,2	70,6
B	**89,4**	**33,9**	80,4	10,8	92,1	6,1	92,6*	50,1	83,6	20,0	88,5	89,6	99,2	26,5
C	**4,0**	**9,5**	2,9	0,8	0,0	0,0	7,4*	49,9	5,8	2,2	7,5	2,5	0,6	1,5
D	**0,4**	**0,3**	0,7	0,0	0,0	0,0	0,0*	0,0	0,0	0,6	1,6	0,0	0,0	1,3