Booster usage in cars 2000-2013, in Sweden

Lotta Jakobsson, Magdalena Lindman
Volvo Cars
Sweden

Introduction

Although child restraint systems have high injury preventing effectiveness in case of a crash, the maximum effect of a restraint system is not achieved unless the child is using a system designed for its size and age. For children aged 4 to 10 a belt-positioning booster seat or cushion is recommended and estimated to have an effectiveness of approximately 75% as compared to unrestrained and approximately 30% as compared to seat belt only (Jakobsson et al. 2007). Arbogast et al. (2009) found than children who were aged 4 to 8 and using boosters were 45% less likely to sustain injuries that similarly aged children who were using the seat belt only.

Belt-positioning booster cushions were introduced in the late 1970s (Norin et al. 1979). Today, there are three main belt-positioning boosters; booster cushions (backless), high-back boosters and integrated (built-in) boosters (Figures 1a-c). The systems are used with the vehicle's seat belt, which restrains both the child and the booster.

Figure 1a. Booster cushion, world first 1978

Figure 1b. Example of a high-back booster seat

Figure 1c. Example of integrated boosters (2 stage)

The integrated (built-in) boosters were developed in order to simplify usage and to minimize misuse (Lundell et al. 1991).This was confirmed by Osvalder and Bohman (2008) providing evidence that misuse was almost eliminated. The second generation integrated boosters provided two levels in height, adapting to the growing child (Jakobsson et al. 2007).

The booster cushion utilizes the vehicle's seat belt functionality 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. Important features of booster cushions are the belt-positioning devices (guiding horns); keeping the belt in position during a crash by restraining the booster. This feature is not necessary for built-in boosters. The booster also sets the child in a more upright position and provides more adaptive thigh support, so he/she will not scoot forward in the seat to find a more comfortable leg position. Slouching may result in sub-optimal belt geometry (DeSantis Klinich et al. 1994). In addition, by sitting higher the shoulder part of the seat belt will be more comfortably positioned over the shoulder of the child. It also places the child within the same space as an adult occupant, providing access to the vehicle's safety system such as the lateral impact protection systems, including the inflatable curtain. More so, the child will have a better view when using a booster, which probably makes the trip more comfortable and enjoyable.

Initially, the backrest of the high-back booster was developed to provide a head restraint for the child when seated in a vehicle seat without head restraint. The backrest was also a way of adjusting the length of the cushion to accommodate the shorter thigh length of the smallest children. When removed, the cushion length better provide accommodation to the larger children. In addition, the backrest provides belt-positioning devices for the shoulder belt with the ambition to help guide the belt into a comfortable and safe mid-shoulder position (Reed et al. 2009). Whether the mid-shoulder position is kept during the crash depends on the child seat strength and the vehicle belt geometry. During the last decade, the backrests of the boosters have increased in size to provide lateral support for child occupant comfort as well as designed for head protection in case of a side impact (Bendjellal et al. 2011). However, concerns have been raised whether a backrest with large head side supports offers true protection for the child in real world crash situations, especially for the largest children (Jakobsson et al. 2012)

Over the years, an increase of booster usage is seen globally. The restraint usage for children aged 0-15, in Sweden, from mid-80s to a decade ago, is shown in Figure 2 (Jakobsson et al. 2005). The main raise occurred during the 1980s, and was a result of increasing CRS availability, introduction of rear seat belt laws, and an intense and unanimous public education and communication activities. A child restraint usage law for children up to six years old was introduced 1998 (SFS 1998:1276, Chapter 4 §10). In 2007 it was replaced by a child restraint law requiring all children of stature up to 135cm to use an appropriate child restraint system (SFS 2006:1208 Chapter 4 §10).

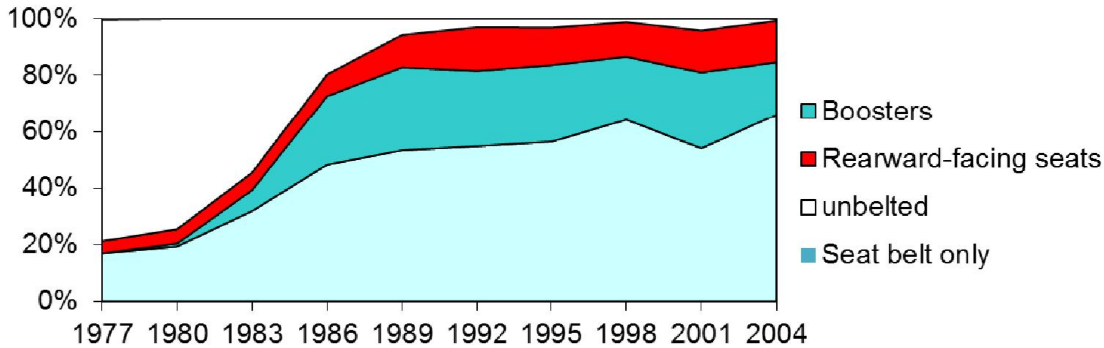

Figure 2. Child restraint usage in Sweden over the years, children aged 0-15 years old (Jakobsson et al. 2005)

Children spend quit much time travelling, and they travel in cars to great extent. In Sweden, the national travel survey contains data on the everyday movements and longer journeys made by Sweden's population aged between 6 and 84 years. According to the most recent study covering 2011-2014, the average distance travelled per person and day for children aged 6-14 years were 27.7 km. In average children travel 17 km per day, which is the by far most frequent travel mode. Without specifying the travel mode, the main purpose of travelling for children were study-related or leisure.

The insurance company Volvia performed a survey in February 2015, where 1000 representative adults (age 20-65) who on a regularly basis transports at least on child aged 0-7 participated (Volvia, 2015). Questions were asked related to children aged 0-10. Regarding the awareness of the child restraint usage law in Sweden, 57% answered that it is illegal to transport children up to 135cm without child restraint, 10% claimed it was legal and 34% did not know. Within the whole sample, 56% claimed they always used a CRS for the children up to 135cm, while 18% stated that they never did. Specifically, for the children aged 4-7, 69% answered always and 6% often, while 3% sometimes or seldom and 22% never used a CRS. For the children aged 8-10, 38% and 21% answered always and often, respectively, while 11% sometimes or seldom and 31% never used a CRS.

The objective of this study is to evaluate and discuss booster usage focusing children aged 4 to 12. Special attention is given to the comparison of usage pattern before and after implementation of a child restraint usage law up to 135cm stature in Sweden 2007.

Methods

Volvo Cars' Statistical Traffic Accident Database, containing information on car occupants in crashes that was collected in a consistent and comparable way over the years, is used in this study. Detailed information about the database is found in Isaksson-Hellman and Norin (2005).

The distribution and proportion of child occupants, aged 4-12, are analysed with respect to type of restraint; such as booster (booster cushion, high-back booster-seat and integrated booster), seat belt only, rearward facing child seat, or unrestrained. Children up to 135 cm are studied separately. The analysis compares the years 2000-2006 and 2007-2013 to provide information on differences between before and after the implementation of the child restraint usage law in Sweden.

The selection for the dataset in this study was children aged 4-12 involved in crashes during the years of 2000-2013; a total of 1260 children, whereof 1235 children with known restraint use were selected for the analysis. 758 of the children were involved in crashes 2000-2006 and 477 during 2007-2013. In total 1074 children in the database had known stature, and among those were 609 children 135cm or shorter; 360 involved in crashes 2000-2006 and 249 in 2007-2013.

Table 1a. Age vs seating position. All children aged 4-12y.

age	front pass. seat	left rear seat	mid rear seat	right rear seat	third row seats	total	% front seat
4	19	56	10	59	1	**145**	13%
5	20	61	12	39	2	**134**	15%
6	15	48	15	37	1	**116**	13%
7	16	42	10	44	0	**112**	14%
8	33	44	16	53	0	**146**	23%
9	30	42	22	44	1	**139**	22%
10	43	47	21	49	0	**160**	27%
11	39	37	17	35	1	**129**	30%
12	48	42	22	42	0	**154**	31%
	263	**419**	**145**	**402**	**6**	**1235**	**21%**

Table 1b. Age vs seating position. Children aged 4-12y, stature ≤ 135cm.

age	front pass. seat	left rear seat	mid rear seat	right rear seat	third row seats	total	% front seat
4	16	50	8	55	1	**130**	12%
5	17	50	11	34	1	**113**	15%
6	13	43	15	28	0	**99**	13%
7	10	35	9	36	0	**90**	11%
8	20	30	8	29	0	**87**	23%
9	6	13	11	21	0	**51**	12%
10	5	6	3	9	0	**23**	22%
11	4	2	0	2	0	**8**	50%
12	4	1	0	3	0	**8**	50%
	95	**230**	**65**	**217**	**2**	**609**	16%

Tables 1a-b show the age versus seating position for all children (1a) and those who are ≤135cm (1b), respectively. The children are rather evenly distributed over age and in average 79% are seated in the rear seats. The average age and stature in the two time periods are similar; 8.2years (SD 2.6) and 132.2cm (SD 7.2) for 2000-2006 versus 7.9years (SD 1.6) and

130.2cm (SD 18.1) for 2007-2013. The average stature (including standard deviation) for each year of age for all the children with known information is displayed in Figure 3.

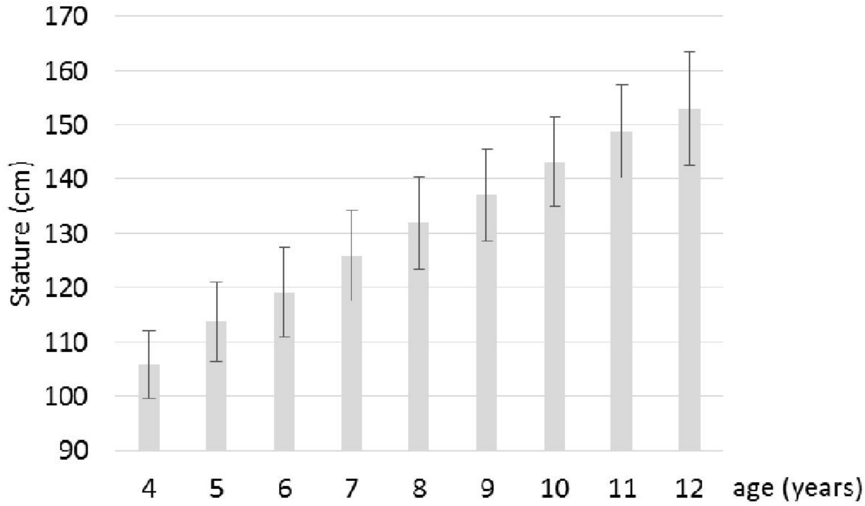

Figure 3. Stature (average including standard deviation) per age. N=1074.

The restraint used per occupant age for the complete selection of children (with known restraint usage), is shown in Figure 4. The restraint usage is high; more than 99% are using some type of restraint. Among the youngest children (age 4-5 years) 84% are using appropriate child restraints for their size and age; mainly booster and some few rearward facing seats. A constant decrease of booster usage at higher age is seen with 47% usage among the 8-year-olds. Irrespectively of booster type, the injury risks are very low in this data.

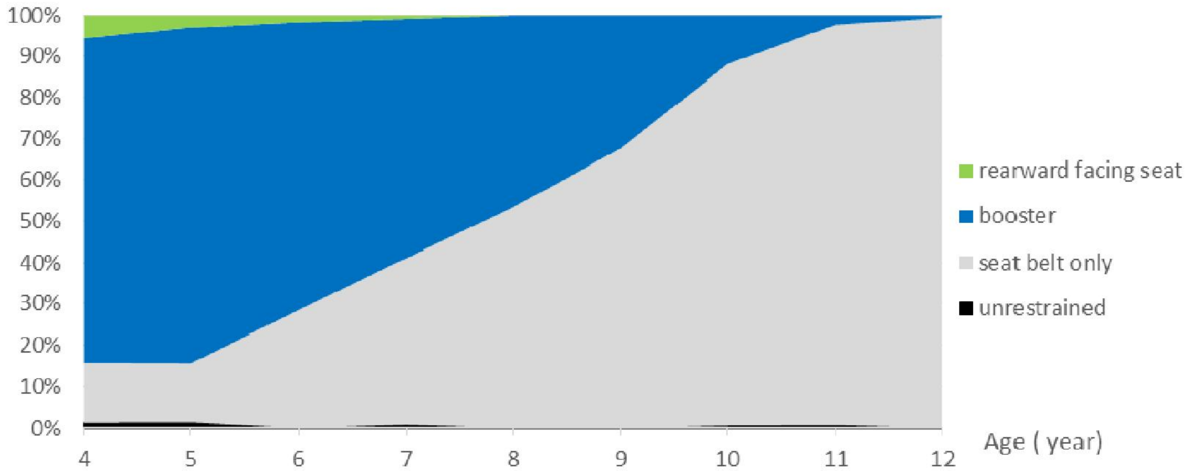

Figure 4. Restraint usage per age for all 4-12 year old, 2000-2013, N=1235.

Results

Figure 5a shows the booster (including some few rearward facing child seats) usage rate per age, comparing the two periods of time; before and after the CRS usage law introduction. For each year of age, the usage is higher for the more recent period in time. In average, for the age group 4-12, the use of booster has increased over the years; from 37% during 2000-2006 to 51% 2007-2013. However, this also means that as many as 49% of children aged 4-12 in 2007-2013, are not using booster or child seats, and are restrained by the safety belt only. Figure 5a includes all children aged 4-12. For the subset of children with known stature ≤135cm (Figure 5b), the same trend between the two time periods can be seen, although higher usage rates in the most recent time period. On average, for this selection, the use of booster increased from 63% during 2000-2006 to 79% during 2007-2013. This represents a relative increase by 26%, which is lower than the 39% relative increase in the non-stature limited selection (Figure 5a).

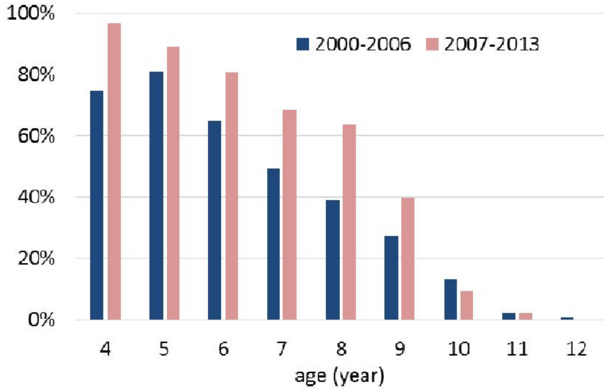

Figure 5a. Booster usage rate per age for <u>all</u> 4-12 year olds, comparing 2000-2006 to 2007-2013

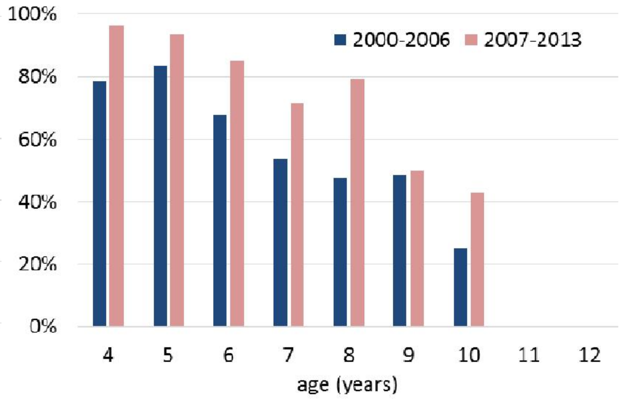

Figure 5b. Booster usage rate per age for 4-12 year old of known stature ≤135cm, comparing 2000-2006 to 2007-2013

Interesting to note is that the rate of seat belt only is 21% within the group that are required to use appropriate child restraints (≤135cm in stature, 2007-2013). This mainly applies to the older children (Figure 5b), with more than half of the 9 and 10 year-olds and none of the sixteen 11- and 12-year-olds, using seat belt only. Hence, not following what is required by law.

Figures 6 displays restraint use for each year of age, including type of booster, for all the children in the dataset, comparing 2000-2006 to 2007-2013. Booster cushions are by far the most common booster type accounting for in total 64% of all the boosters, over the whole time period. Comparing the two time periods, a relative decrease of booster cushions are seen; from 71% to 55% overall (in relation to the total use of boosters). This is a result of a relative increase of both high-back boosters (from 19% to 30%) and integrated boosters (10% to 15%), as seen in Figure 6. In average, the integrated boosters account for 12% of the boosters in the total dataset, quite evenly distributed over age.

The booster cushions are used over the whole age span decreasing over age, while high-back boosters are mainly used among the youngest. Overall, 90% of all high-back-booster seats are used by children aged 4 to 6. Although a relative higher total frequency in the more recent time period, they are still mainly used among the younger children (Figure 6). Based on this data it is quite clear that the oldest children (in the booster-recommended age span) to a greater extent use booster cushions (including integrated boosters) when using a booster at all.

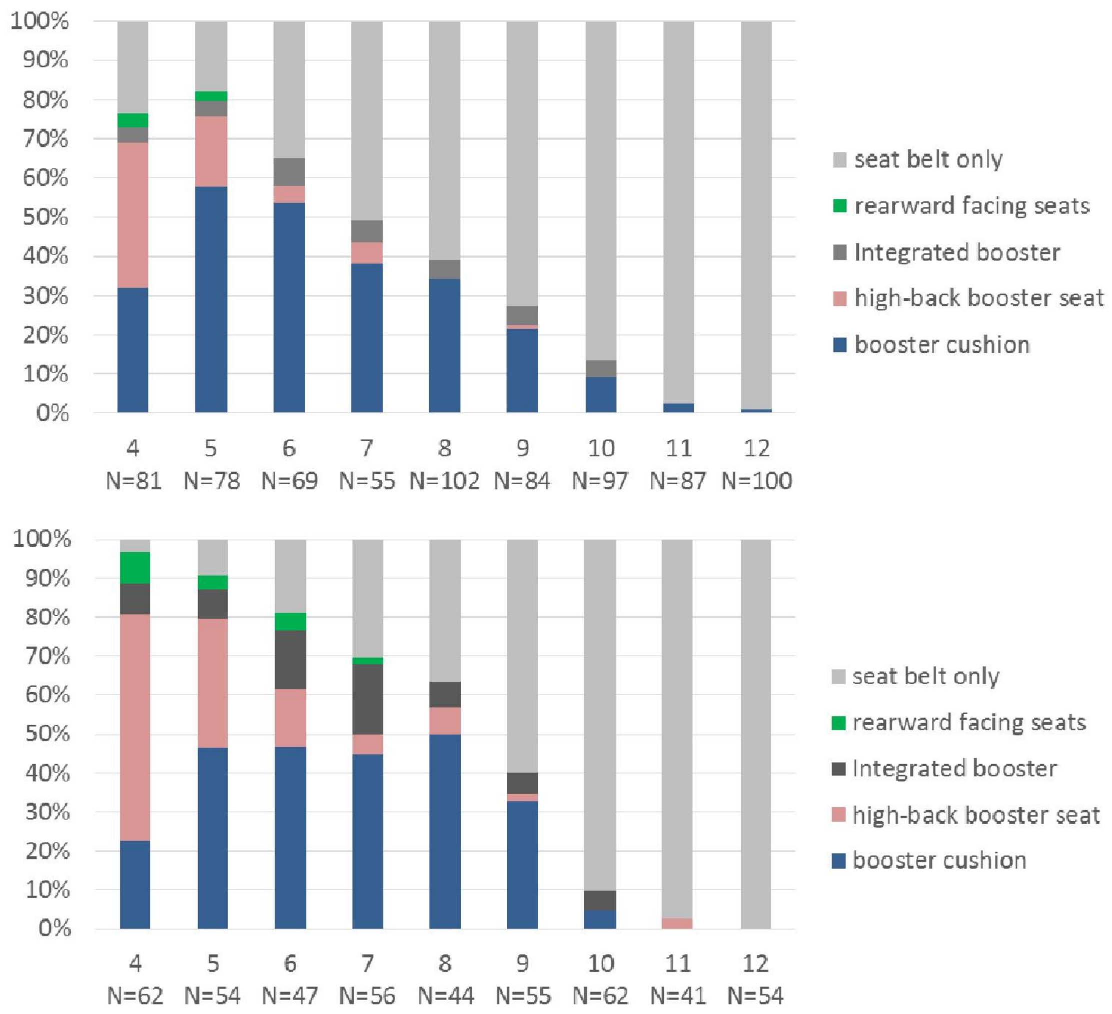

Figure 6. Restraint usage per age for <u>all</u> 4-12 year olds; 2000-2006 (top) versus 2007-2013

In the subset of children with known stature ≤ 135 cm, the same trend as the total dataset is seen, see Figure 7. The majority of the boosters used are booster cushions (68% and 51%, respectively). In average, 27% of the appropriate restraints used are high back booster seats; increasing from 22% to 32% between the two time periods. Even so, 91% of all the high back boodster seats are used by children aged 4-6. Even if a relatively higher amount of the children are using appropriate child restraints (63% and 79%, respectively), still too many are not. Although small numbers, approximately half of the 9 and 10 year olds and all of the 11-12 year olds in the most recent time period are using seat belt only, even though they are required by law to use an appropriate child restraint.

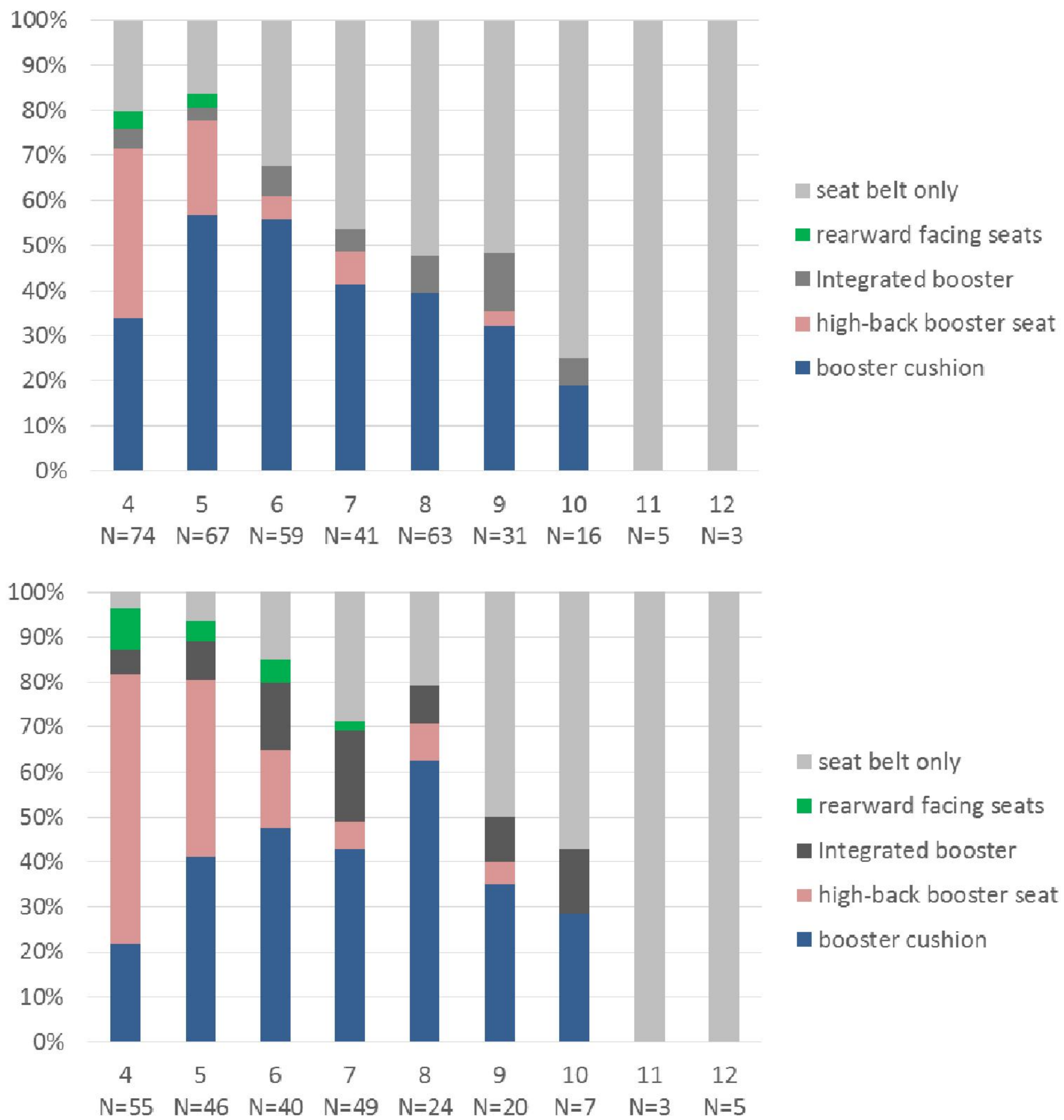

Figure 7. Restraint usage per age for 4-12 year olds of stature 135cm or shorter; 2000-2006 (top) versus 2007-2013

Discussions

Child restraint system usage is still an important issue and especially for the children in the older age range for boosters. Still there is a high injury reduction potential if all children aged 4-10 years (or 12 depending on stature) used boosters together with the seat belt.

Based on this analysis, it is quite clear that the regulation imposing children up to 135cm stature to use appropriate child restraints contribute only to a limited extent to reach its goal. During the time period after the child restraint usage regulation in 2007, only a limited raise in booster usage was reached. The key question for this discussion is how to enable the remaining 21% of the 4-12 year olds (≤135cm) who are required to use restraints to do so, at every trip.

When looking into the travel characteristics for the subsample of non-booster users, it can be seen that; 44% of the “illegally” restrained children were in vehicles with in total 4 or 5 occupants, in 67% occupying the outer rear seat positions and in 41% the trips were of a planned duration of 30 minutes or less. The purpose of the trips were of varied kinds, ranging from vacation trips and daily commutes. Obviously, the data used is not the optimal dataset to study distributions of travel characteristics, but it provides the understanding on that there is a need to address different types of travel configurations and travel situations. In order to gather facts on important travel characteristics, and how it relates to differences in child restraint usage, observational studies are needed and will be essential in setting the direction for measures (technical as well as educational) for increased child restraint usage.

According to national statistics, children's most frequent travel mode is by car, with in average 17 km per child and day. When a child uses a car on a daily basis, this put user friendliness requirements to the booster he or she is supposed to use! The older the children are, they more likely will they travel with friends' cars. There is also an increasing trend of car-pooling in the society today. In these cases; who facilitates the booster, and how is that done? Is it the responsibility of the driver, the parent of the child or the child itself? Should the child bring its own, and in that case what type of booster is required and possible to bring? Optimally, the booster should be in the car, preferably integrated and easy to use, or the booster should be limited in size making it easy to bring along. A booster cushion is a lot easier for the child to bring along than a high-back booster seat. These are important aspects when looking at the total real world safety for this age group.

The database used in this study is representative for modern Volvo cars in Sweden. Volvo cars account for 20-25% of all cars in Sweden, making the data relevant for the situation in Sweden of today. The frequency of non-booster users were in the range of what was seen in the Volvia- survey, supporting that that one out of five children within the age span are non-users, with a higher frequency among the older (Volvia, 2015). The Volvia-survey also provides important input regarding the relative low awareness of the regulations in the area; only 57% answered correctly regarding the child restraint law and the rest either did not know or answered incorrectly. This emphasizes the need to increase awareness.

However, although 57% knew about the child restraint usage law, probably more action is needed than just to increase information and introduce law enforcement! Historically, the most important aspect beside awareness of best practice is availability of attractive design. The results in this study suggest that booster type/design are important measures to encourage increased usage over the whole age range. Again, it is probably also necessary to understand and address the needs in terms of convenience for the specific travel to reach high usage. Likely, different types of boosters are needed to enable optimal usage rates. At longer trips, there is likely a higher need of sleeping support, helping to keep the child in an upright position enabling good protection of the seat belt. While, for shorter trips and when several children are traveling in the car together, this lateral support might not be needed and instead a more space-saving and easy-to-bring along booster cushion would be more beneficial.

This study clearly indicates that there is a higher acceptance among the older children to use booster cushions as compared to high-back boosters. A booster cushion offers essential protection to a child in frontal impacts and puts the child into a better position and protection in a side impacts.

Comparing accessory boosters to integrated boosters, a trend of higher usage rate with increased age is seen for the integrated boosters. Figure 8a displays the number of accessory boosters (comprised by high-back boosters and booster cushions) and integrated boosters over the age groups 4-12, involved in crashes 2000-2013. Figure 8b shows the same data, but with each of the two booster categories adding up to a total of 100%. Although only 12% of all the boosters in the whole selection are of integrated type, it is quite clear that they, (relative to accessory boosters) proportionally are used by more children in the higher age groups.

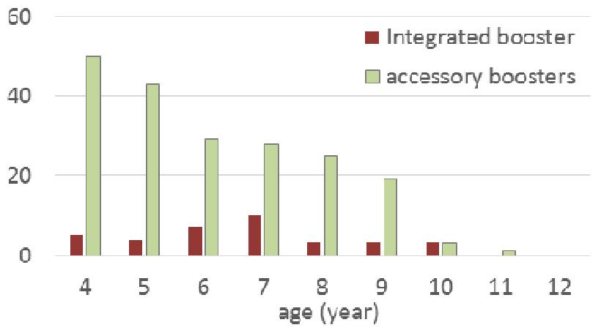

Figure 8a. Numbers of boosters per age, separated in integrated and accessory boosters (including booster cushions and high-back booster seat).

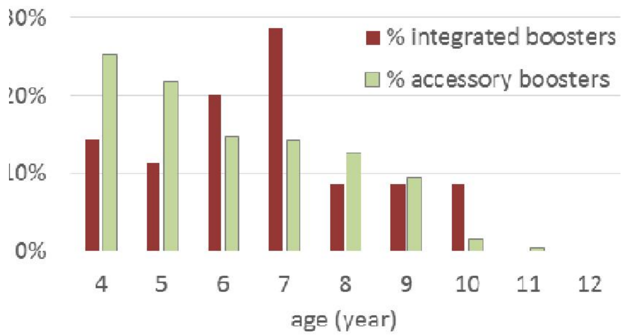

Figure 8b. Relative distribution of boosters per age, separated in integrated and accessory boosters. Each booster category adds up to 100%.

Integrated boosters and booster cushions are shown to increase relative usage among the older age group. Figure 8b indicates that the acceptance of integrated boosters seem to be higher for the older children (8-10), as compared to accessory booster. In an attitude and handling focus group study, integrated boosters were perceived more acceptable as well as superior with respect to avoiding misuse, as compared to accessory boosters (Osvalder and Bohman 2008). Osvalder et al (2013) performed a study with six children aged 7-9, comparing an integrated booster and a high-back booster seat during 1 hour on-road drives, respectively. A more positive attitude was found towards the integrated booster, while the high-back booster seat was perceived hard, created a locked-in feeling and felt unpleasant due to movements when changing postures. Integrated boosters will most likely motivate usage for a group of older children that today mostly are restrained by seat belt only. Another great benefit of the integrated systems is that they are designed together with the vehicle and give possibilities to enhance protection of the child without adding extensive add-on parts to the child restraint system. The Volvo rear seat with the 2-stage integrated booster with seatbelt performance (as well as Inflatable Curtain coverage) adapted to the child is a good example of this (Jakobsson et al. 2007).

For total child safety, one important priority is to increase overall booster usage rate, providing optimal protection to reduce child occupant injury. This study contributes with facts providing guidelines for future development of booster design as well as child occupant safety regulations. From a child occupant safety perspective it is important to encourage more integrated systems and to facilitate good and easy-to-use and bring-along booster cushions to attract the older age group of recommended usage. This together with increased awareness of importance will likely increase the overall booster usage rate.

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