

Child Restraint System (CRS) usage in fatal car crashes in Sweden and the potential of rear-facing CRS to influence injury outcomes

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Abstract

In line with Vision Zero, this study examines how fatal injuries to child car occupants in Sweden can be prevented. Specifically, the potential of rear-facing seating as a safety measure for children is explored. Starting in the late 1960s, Sweden pioneered the promotion of rear-facing seating even for toddlers and has a long tradition of transition directly from rear-facing child restraint systems (CRS) to belt-positioning boosters. The national recommendation is to stay rear-facing to at least the age of four. This study presents a case-by-case study of child car occupants (0-6 years) who have been fatally injured in a car accident in Sweden 1992–2024. Data was extracted from the Swedish national in-depth crash database, which includes all fatally injured road users. The car model years ranged from 1972 to 2013. In total, the dataset included 99 fatally injured children in 83 cars, of which 58 were 0–3 years old (i.e. had not turned 4 years old). Among these aged 0-3 years, 29% were restrained according to the Swedish recommendations of using rear-facing CRS. The rest were restrained in a forward-facing CRS (33%), unrestrained (33%), or restrained by the seatbelt only (2%) and the remaining small part was unknown. 20% of the 4-6 years old were unrestrained. It was estimated that potentially up to 48% of the children aged 0-3 years could have survived if using a rear-facing CRS, and additionally 27% of the 41 children 4-6 years old. Most crashes in where CRS use was not judged to have altered the outcome occurred in cars manufactured before 2003, prior to the introduction of ECE R94/95 standards.

Introduction

Sweden has a strong safety culture, and a strong commitment to Vision Zero. There has been a substantial decline in traffic injuries and fatalities over recent decades, especially among the youngest children [1, 2]. Since 2007, Swedish law requires that children shorter than 135 cm must use a type-approved restraint appropriate for their size. Starting in the late 1960s, Sweden has been a pioneer in promoting rear-facing seating also for toddlers. This tradition of remaining in rear-facing child restraint systems (CRS) until they are large enough to use belt-positioning boosters, contributes to some of the lowest child fatality rates in road traffic accidents. When comparing child occupant fatalities in Germany and Sweden, the higher number of fatalities among 1 year-old child occupants in Germany was most likely due to common practice of transitioning to forward-facing CRS at that age during the period of the data (2006-2011) [3]. While Swedish children are transferred forward-facing some years later [4].

Most expert agrees that rear-facing CRS is the safest form of travel for young children in motor vehicles, especially for infants, however there is no general agreement for how long. Studies have confirmed that a rear-facing CRS substantially reduces the risk of serious and fatal injury in the event of a crash, particularly in frontal impacts, which is the most common and severe type of impact, but also in side impacts [5-8]. Children require dedicated restraint systems due to their unique anatomical characteristics. When properly restrained, especially in rear-facing CRS, their injury risk in crashes is comparable to, or even lower, than that of adults [1, 4-9]. The anatomical and physiological characteristics of babies and toddlers, such as a relatively large head size and, underdeveloped neck vertebrae and musculature, make them especially vulnerable when exposed to a frontal impact when restrained in a forward-facing position. A rear-facing CRS provides optimal protection to the head, neck, and spine by distributing crash forces more evenly across the child's back and minimizing head movement relative to the torso. Moreover, a rear-facing CRS provides robust protection by allowing the child's body to sink into the seat, keeping the body within its protective shell during various impact angles. Furthermore, a rear-facing restraint system, when securely attached to the vehicle, results in a shorter delay in the child's deceleration compared to a forward-facing child. According to Turbell [6], the neck loads were three times greater in crash tests when using a forward-facing CRS compared to rear-facing, whereby increasing risk for neck injuries. International guidelines – including those from the World Health Organization (WHO), the American Academy of Pediatrics (AAP), and various European road safety authorities – recommend that children remain rear-facing in cars for as long as possible; the recommended age limits have increased in recent years.

Sweden has successfully adopted the Vision Zero which is a strategic approach towards a safe system whereby no one is at risk of being fatally or severely injured while using the road transport system [9]. Although Sweden has a strong safety culture, with low number of fatalities, it is important to examine these fatalities in greater detail to reach Vision Zero. More specifically, this paper aims to investigate the influence of various factors on a case-by-case basis and estimate the potential rear-facing restraints as a safety measure.

Method

A case-by-case study was performed investigating car crashes on Swedish roads between 1992-2024, with at least one fatally injured child six years old or younger. The study cases were taken from the Swedish Transport Administration (Trafikverket) national in-depth crash database covering all fatally injured within the road transport system in Sweden. The selected subset included all fatally injured 0-6 years old child passenger car occupants. The data was divided into two age groups (based on the Swedish recommendation which specify rear-facing CRS to at least the age of four):

- Age 0–3 (including 3 years old that not yet turned 4 years)
- Age 4–6 (including 6 years old that not yet turned 7 years)

All cases included use of restraint categorized into direction of travel:

- Rear-facing CRS (including infant and toddler seats)
- Forward-facing CRS (including booster cushion, booster seat, and CRS with harness)
- Seatbelt only (including 2-, and 3- and 5-point belts)
- Unrestrained (includes no seatbelt or restraints without type-approval).

All children were assessed whether or not they were sitting according to the Swedish recommendations. That is, children 0-3 should be using a rear-facing CRS while children aged 4-6 should be restrained in a forward or rear-facing CRS. Based on the information in the database, the likelihood of survival if properly restrained was estimated and categorized. This was assessed by a small group of four subject matter experts in crash casualization, injury biomechanics, and traffic prevention strategies. Each case was assigned one of three categories of estimated possibility of survival.

- **Non-survivable** include cases where the fatality could not be prevented. These cases were characterized by e.g., no estimated space left at the child's position in the car, faulty technology (e.g., no seat belt), the vehicle's crash performance was too low, crash severity beyond expected survivable limits, or if the fatality was due to non-crash-related circumstances, such as fire or drowning. Two cases of unconfirmed suicide are included and were both categorized non-survivable.
- **Likely survivable** was used if the fatal injuries could have been mitigated with a correctly used CRS. The type of CRS for which the estimated possibility of survival was assessed based on the child's age and stature. Children in the 0-3 age group were all assessed in relation to rear-facing CRS. While the children in the 4-6 age group were individually assessed according to their stature; those shorter than 125 cm were assessed in relation to a rear-facing CRS, while those who were taller were assessed in relation to a forward-facing CRS, mainly booster.
- **Potentially survivable** were cases that could not be classified as "likely survivable" but were considered to have some potential to be survivable.

The cases were categorized and analyzed starting with the age and use of restraint type, followed by the crash circumstances (counterpart, estimated speed and crash severity, vehicle crashworthiness and crash severity). To estimate and categorize the

likelihood of survival if properly restrained, data such as age, gender, mass/statue, injury type, fatal injury, seatbelt usage, CRS usage, crash description, counterpart, vehicle model, vehicle model year, crash event, impact direction, estimated crash severity, posted speed limit and road type, were used. Descriptive statistics (frequency, and proportion) were used to present the cases.

Result

In total, 99 children aged 0–6 were fatally injured as car occupants on Swedish roads between 1992 and 2024 (Figure 1). Twice as many cases were collisions (66%), i.e. involving at least one other motor vehicle, compared to single-vehicle crashes (34%) (Appendix 1). Frontal impacts accounted for more than half of the collisions (58%). Since 2010, there has been a substantial reduction in fatalities (Figure 1). On average, 1.2 children were fatally injured each year during the last decade (2015–2024), compared with 5.8 per year during the first decade (1992–2001), representing a 79% reduction. The last four years about one child has been fatally injured annually (Figure 1). The number of children that did not travel according to national recommendations of using rear-facing CRS to the age of 4 decreased from 72% in 1992–2007 to 58% in 2008–2024. The majority of fatally injured children were involved in crashes prior to 2008, and it is estimated that up to 37% of these could likely survived if using a rear-facing CRS (Table 1). None of the four children fatally injured 2021–2024 were assessed to have survived the accident, irrespective restraint system. Two were restrained in a rear-facing CRS (age 1 and 3) and two in a forward-facing CRS (age 4 and 6) (Table 1).

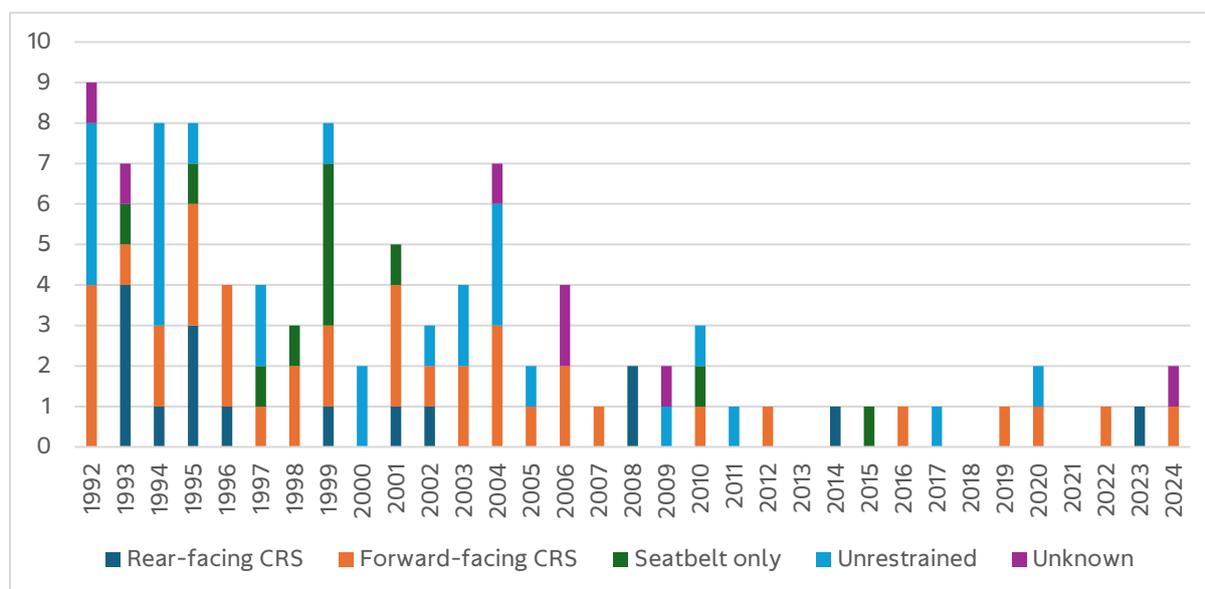


Figure 1. Fatally injured children 0–6 years old, in car crashes during 1992–2024 on Swedish roads, shown by year and type of restraint use. In 2013, 2018, and 2021 no child below the age of 7 was fatally injured in Sweden.

Table 1. Estimated survival possibility all children.

<i>Estimated survival possibility</i>	Early period	Recent period	Last years
	1992-2007	2008-2024	2021-2024*
	n	n	n
Non-survivable	40	11	4
Fire/drowning	8	2	-
High severity crash	31	9	-
Technical malfunction (no seatbelt)	1	-	-
Likely survivable with rear-facing CRS	29	5	-
Likely survivable with forward facing CRS	3	1	-
Potential survivable rear-facing CRS	4	1	-
Potential survivable forward-facing CRS	3	1	-
Total	79	19	4

* No fatally injured child during 2021 |

Among the 0–3 years old (n= 58), 62% were restrained (28% in a rear-facing CRS, 34% in a forward-facing CRS), while 33% unrestrained (Table 2). In total, 69% of the 0–3 years old were not restrained according to the Swedish recommendation. Among the 4–6-year-olds (n=41), 68% were restrained (44% were in a forward-facing CRS, 24% restrained by the seatbelt only), while 20% were unrestrained (Table 2). None of them used rear-facing CRS.

Table 2. Restraint use per age group (1992–2024).

Restraint use	Age 0-3	Age 4-6	1992-2007	2008-2024
	n	n	n	n
Rear-facing CRS	16	-	12	4
Forward-facing CRS	20	18	31	7
<i>Booster cushion</i>	6	7	11	2
<i>Booster seat</i>	10	10	16	4
<i>Forward-facing CRS with harness</i>	4	1	4	1
Restraint unknown	1			1
Seatbelt only	1	10	9	2
Unrestrained	19	8	22	5
Unknown	1	5	5	1
Total	58	41	79	20

The 16 fatally injured children in a **rear-facing CRS**, all in age group 0–3 years, are shown in Table 3. All cases, except one, were categorized as non-survivable. In one case, the attachment separated, which contributed to the faulty outcome. If the CRS attachment had not failed, the child was estimated to have survived. The attachment detached due to the very high severity crash, beyond any standardized test. 12 of the non-survival cases were high severity crashes. In about half of the crashes (n=7), the child's car crossed the center line resulting in head-on (n=4) or side (n=3) impacts with oncoming traffic (heavy goods vehicle (n=4), bus (n=2), car (n=1)). In one case, the child traveled in a car frontally impacted the rear of a heavy goods vehicle standing still in the lane. The rest of the high

severity crashes were single vehicle crashes (n=4); one frontal impact with a moose and three rollover crashes. Three additional single vehicle crashes included post-crash events such as fire or submersion in water, which were determined to be the cause of the fatal injury, reducing the likelihood of survival with an alternative CRS (Table 3).

Table 3. Estimated survival possibility for the children using a **rear-facing CRS**. In case of high severity crash, the collision counterpart is noted.

Estimated survival possibility	Age 0-3
Non-survival	n
Drowning accident /fire	3
High-severity crashes	12
<i>Heavy Goods Vehicle</i>	5
<i>Bus</i>	2
<i>Moose</i>	1
<i>Car</i>	1
<i>Singe vehicle crash (roadside objects)</i>	3
Likely survivable with rear-facing CRS	1
Total	16

Table 4 shows the 38 children using a **forward-facing CRS**, where of 20 were under the age of 4. It was estimated that twelve of these 20 likely could have survived with a rear-facing CRS, based on the assessment of the crash and the injuries sustained. Among the 18 children in the age group 4-6 years, four were categorized as likely survivable, and additionally three children were categorized as potentially survivable if they had used a rear-facing CRS (considering their size and stature). In total, 19 of the cases were classified as non-survivable; for eight children aged 0-3 years, a rear-facing CRS would not have altered the outcome. The majority of the non-survival crashes were high severity crashes (n=15). Most of the high severity crashes (0-3: n=5/4-6: n=5) involved the child's car crossed the center line resulting in a frontal (0-3: n=1/4-6: n=2), side (0-3: n=3/4-6:n=2) or multiple (0-3:n=1/4-6: n=1) impacts with oncoming traffic (heavy goods vehicle (0-3: n=1/4-6: n=4)), bus (0-3; n=1/4-6: -)), car (0-3: n=3/4-6: n=1)). Additionally, two high-severity cases involved a crash in a crossing and one child traveled in a car frontal impacted into the rear of a standing still heavy goods vehicle. There were also two single vehicle crashes with roadside objects, and one moose collision. In total, three of the 11 non-survival cases involved 4-6 years old could have been using a rear-facing CRS due to their statue; but a rear-facing CRS were judged to hot have altered the outcome of the fatal crash due to the nature of the crash. Four of the children using a forward-facing CRS and classified as non-survivable were exposed to post-crash events such as submersion in water or fire.

Table 4. Estimated survival possibility for the children using a **forward-facing CRS**. In case of high-severity crash, the collision counterpart is noted.

Estimated survival possibility	Age 0-3	Age 4-6
	n	n
Non-survival	8	11
Drowning/fire	2	2
High severity crash	6	9
<i>Heavy goods vehicle</i>	1	5
<i>Bus</i>	1	-
<i>Car</i>	3	2
<i>Moose</i>	-	1
<i>Single vehicle crash (roadside object)</i>	1	1
Likely survivable with rear-facing CRS	12	4
Potential survivable with rear-facing CRS	-	3
Total	20	18

Among the eleven children that were restrained using **seatbelt only** it was estimated that a rear-facing CRS could potentially have altered the outcome up to four cases: one aged 0-3 and additionally 3 children aged 4-6 years (Table 5). The five seatbelt-only restrained children, categorized as non-survivable, were all aged 4-6 years. In all high severity crashes (n=3) the child's car crossed the center line resulting in a head-on (n=3) collision with oncoming traffic; in one case the car rolled over after impact.

Table 5. Estimated survival possibility for the children using **seatbelt only**. In case of high-severity crash, the collision counterpart is noted.

Estimated survival possibility	Age 0-3	Age 4-6
	n	n
Non-survivable	-	5
Drowning/fire	-	2
High severity crash	-	3
<i>Heavy good vehicle</i>	-	2
<i>Bus</i>	-	1
Likely survivable with rear-facing CRS	1	2
Likely survivable with forward facing CRS	-	1
Potential survivable with rear-facing CRS	-	1
Potential survivable with forward-facing CRS	-	1
Total	1	10

A total of 27 children aged 0–6 years were **unrestrained** (Table 6). Of them, 13 of the 19 (68%) children aged 0-3 years were classified as likely survivable if they had been using a rear-facing CRS (Table 6). Additionally, one in the age group 4-6 could likely have survived in a rear-facing CRS. In addition, two more children were estimated to potentially have survived if using a CRS. In total, 9 children were involved in such crashes that they were assessed not to survive the crash, even if using a CRS. All of them were high severity

crashes (n=9); in most cases (n=7), the child’s car crossed the center line resulting in a head-on (n=6) or side (n=1) impact with oncoming traffic, most often a heavy goods vehicle (n=5). In one case, an oncoming vehicle crossed the center line resulting in a head-on collision and, in the other, the driver of the child traveled in did not respect the stop sign resulting in a side impact followed by a roll over. Approximately half of the unrestrained children (53%) were ejected from the vehicle. If the ejected children had been using a rear-facing CRS, half of the children were estimated to have survived. Nearly one in three children who died in single-vehicle crashes were ejected from the vehicle, whereof 80% were unrestrained, 10% were improperly restrained, and 10% where the restraint use was unknown.

Table 6. Estimated possibility of survival among **unrestrained** children per age group. In case of high-severity crash, the collision counterpart is noted.

Estimated survival possibility	Age 0-3	Age 4-6
	n	n
Non-survivable	5	4
Drowning/fire	-	-
High severity crash	5	4
<i>Heavy goods vehicle</i>	5	2
<i>Bus</i>	-	1
<i>Car</i>	-	1
Likely survivable with rear-facing CRS	13	1
Likely survivable with forward facing CRS		2
Potential survivable rear-facing CRS	1	
Potential survivable forward-facing CRS		1
Total	19	8

In summary, when assessing the potential impact of rear-facing CRS on fatal outcomes, it was estimated that nearly half (47%) of the fatally injured children aged 0-3 years could likely have survived if restrained in a rear-facing CRS, and one more could potentially survive, i.e., 48% in total. Additionally, approximately one in six (17%) of the children aged 4-6 years were of such a stature that they were likely to have survived with a rear-facing CRS (Table 7). That is, it is estimated that additionally 27% of the aged 4-6 children could potentially survive (7 likely and 4 potentially). Moreover, for the children in size for a forward-facing CRS (i.e., with regards to stature/mass), it was estimated that for four of the 4-6 years old, a booster could have reduced the risk of fatal injury.

Table 7. Summary of estimated possibility of survival for all children per age group.

Estimated survival possibility	Age 0-3	Age 4-6
	n	n
Non-survivable	30	23
Likely survivable with rear-facing CRS	27	7
Likely survivable with forward facing CRS		4
Potential survivable with rear-facing CRS	1	4
Potential survivable with forward-facing CRS		3
<i>Total</i>	58	41

The rest of the cases (n=53) were classified as unlikely that a rear-facing CRS would have had an influence on the outcome, mainly due to the nature of the crash (Table 8). Many (40%) occurred in high-severity crashes, with 46% involving heavy goods vehicle, bus, train or moose. Furthermore, 69% of the non-survivable category took place on roads with posted speed limits exceeding 90 km/h, contributing to the high crash severity (see appendix). In approximately 20% of the cases, post-crash events such as fires or submersion in water further reduce the likelihood of survival, regardless of restraint type.

Table 8. Overview of main contributing crash factors to the child cases categorized as non-survivable. In case of high severity crashes, the collision counterpart is noted.

Contributing crash factor	Age 0-3	Age 4-6
	n	n
Drowning accident /fire	5	5
High-severity crashes	25	17
<i>Train</i>		1
<i>Heavy goods vehicle</i>	12	10
<i>Bus</i>	3	2
<i>Moose</i>	1	1
<i>Car</i>	4	3
<i>Single vehicle crash</i>	5	1
No seatbelt available		1
Total	30	23

The average age of the vehicle was 9.3 years (1992-2007: 8.8; 2008-2024: 11.2) with model years ranging from 1972 to 2013 (Appendix 1). The majority (71%) of the children were traveling in cars manufactured before 2003, cars which may not comply with ECE R94/95 safety. Notably, no child was fatally injured in a car manufactured after 2013. Many of the fatally injured children were traveling in cars with no rating in Euro NCAP (69%). However, a total of 64 fatally injured children traveled in a car rated in the Folksam Car Model Safety Ratings (based on Swedish real-world crash data). Among these, 11%

traveled in a vehicle that had received the grade 5 (top score); 37% had received the lower grade 1-2. In total, 15 cases (15%) involved newer cars, i.e., cars not manufactured before 2003 (Table 9). Of the ten children aged 0–3 years, four were restrained in a rear-facing CRS, three in a forward-facing CRS, and one seatbelt-only and two children were unrestrained. Five of these were assessed as likely survivable had they been restrained in a rear-facing CRS (Table 9).

Table 9. Restraint usage and estimated possibility of survival in cars manufactured in 2003 or later.

Restraint use	Age 0-3	Age 4-6
	n	n
Rear-facing CRS	4	
Forward-facing CRS	3	4
Seatbelt only	1	
Unrestrained	2	1
<i>Survivability estimation</i>		
Non-survivable	5	4
Likely survivable with rear-facing CRS	5	
Potential survivable <i>with</i> rear-facing CRS		1
Total	10	5

Discussion

CRS is a critical countermeasure within **Vision Zero** since it directly addresses the safety of one of the most vulnerable road-user groups: children. Rear-facing CRS usage has previously been identified as a main contributor to mitigate child fatalities as car occupants due to the extra support provided. Indeed, this study highlights the critical role of proper CRS use in preventing fatalities among young children in car crashes. The analysis indicates that up to 48% of fatally injured children aged 0–3 years likely could have survived if they had been restrained in a rear-facing CRS. As many as 12 of the 19 children (63%) under the age of four that were using a forward-facing CRS could have survived if the child had been using a rear-facing CRS. This reinforces the well-documented advantages of rear-facing orientation, which provides superior protection for the head, neck, and spine in frontal impacts, the most common and severe crash type. The protective principles of the seat shell provide optimal support for the child’s vulnerable neck, not only in frontal and side impacts but also in more complex crash scenarios such as rollovers and run-off-road incidents. It is also more forgiving for misuse, such as slack of harness and attachments [8]. During the 33 years period of this study (1992–2024) only 16 children in rear-facing CRS were fatally injured in car crashes in Sweden (with a population ranging between 8.6– 10.6 during these years). Nine cases occurred in frontal impact (all, except three) involving severe crashes with heavy goods vehicles and zero cases in rear-end impacts. The low relative numbers and the specific circumstances in which they occurred confirm that rear-facing CRSs are not only safe but also robust.

The Swedish tradition of keeping children rear-facing in cars started in the late 1960s and has since been strongly promoted as a shared national approach by all key stakeholders. In 2006, a national recommendation was introduced to counter a negative trend where more parents began turning children forward too early. By establishing a unified message, Sweden reinforces that rear-facing travel remains the safest option. However, despite generally high compliance reported in parental attitude surveys [4, 10], adherence among the fatally injured children was relatively low: the majority were not restrained in CRS types consistent with Swedish recommendations. In total, as many as 69% of fatally injured children aged 0–3 years were not restrained according to the Swedish recommendation to use a rear-facing CRS up to age four. The number of children aged 0–3 not restrained according to the Swedish recommendation has decreased (72% vs 58%). More than half (68%) of the unrestrained children were estimated to have survived if they had been restrained in a rear-facing. Among the unrestrained children, about half were ejected from the vehicle (53%). These findings emphasize the need for targeted interventions addressing both correct CRS installation and consistent use. Furthermore, this study also highlights that several in the 4–6 year old age group would have benefited from a rear-facing CRS; 27% of the 4–6 years old were of such a size that a toddler rear-facing CRS would be a good choice for them.

Another notable finding is the relation between vehicle age and fatal outcomes. Most crashes where CRS use were assessed as not to have altered the outcome occurred in cars manufactured before 2003, prior to the introduction of ECE R94/95 standards. No child fatalities in the 0–6 year old age group were recorded in cars manufactured after 2013. In some cases, the area in which the child was sitting was deformed and influenced the outcome of the crash. As for adults, children will benefit from improved vehicle crashworthiness, keeping the occupant compartment as intact as possible. Therefore, it is essential to analyze crashes from a Safe System perspective, addressing all contributing factors rather than focusing singular solutions. To move closer to Vision Zero, several parameters – such as infrastructure design, vehicle safety, restraint use, and post-crash care – should be considered in an integrated approach. In the present study, the main focus has been the use of CRS, but several factors could help prevent the outcome.

This study also highlights situations where the type of CRS is of less importance. In 40% of cases, the crash severity was high, or the car deformation was of such a character that the survivability was judged low regardless of CRS type. These cases often involved collisions with heavy goods vehicles, trains, or complex single-vehicle crashes. In 20% of cases, the children were exposed to post-crash events, such as fires or submersion. Almost half of the cases, the vehicle that the child was travelled in passed the center line and crashed into oncoming traffic. This highlights the importance of complementary measures, including speed management, infrastructure improvements, and continued advancements in vehicle crashworthiness to mitigate child fatalities.

An interesting question is whether rear-facing CRS would have provided greater benefits than forward-facing CRS in these cases; would as many children have survived if restrained forward-facing? Some of the estimated survivable cases involved unrestrained children, who might as well have benefited from being placed in a forward-facing CRS.

However, there were also cases involving forward facing children aged 0–3 years who sustained fatal head and/or neck injuries in high-severity frontal impacts. In such situations, a rear-facing CRS would likely have offered superior protection compared to a forward-facing CRS.

This study shows that only 99 children, of which 58 were under the age of four, have been fatally injured as car occupants on Swedish roads 1992–2024. A rather low number considering Sweden's population of 10 million, indicating Sweden's successful approach of keeping children safe. During some years there has even been no fatally injured child below 7 years old. However, this study shows that many of the fatally injured children were not restrained according to these guidelines. It clearly highlights the need for greater efforts to promoting and communicating the benefits of keeping children rear-facing. This study underscores the need for sustained efforts in strengthening compliance through education, enforcement, and, where appropriate, legislative action. It also emphasizes the importance of ongoing initiatives to improve crash safety, including infrastructure development and advancements in vehicle design, addressing Vision Zero.

Limitations

The study includes child car occupant fatalities between 1992–2024. During the time significant improvements have been made to the Swedish road environment and the overall safety of vehicles has improved which may influence the result. The method used is similar to e.g. Sherwood et al [11], in that, for each fatal crash, predictions were made regarding the possibility for restraint use to mitigate the fatal outcome. The predictions are limited to the information gained from the Swedish national in-depth crash database and this particular study, it did not include reconstruction of the accident or estimated delta-v. The judgement of survivability only considers alternative restraint use in the case the vehicle together with present safety equipment did not offer sufficient protection. Posted speed-limit was used as a proxy for crash severity. Moreover, the method does not account for the influence of changes of post-crash interventions, such as rescue, hospital care, and rehabilitation.

Conclusions

This case-by-case study of fatal accidents on Swedish roads between 1992 and 2024 shows that most of the fatally injured children were not restrained according to national recommendations. In total, 69% of children up to age 4 did not use a rear-facing CRS. It was estimated that potentially up to 48% of the children aged 0–3 years might have survived if using a rear-facing CRS, and additionally 27% of the 41 children aged 4–6 years. This study highlights the critical role of proper CRS use in preventing fatalities among young children in car crashes.

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Appendix 1

		Age 0-3 (n=58)	Age 4-6 (n=41)	
		No	No	
Car model	Old vehicle (Older than 2002)	38	32	
	Newer cars (2003 and later)	10	5	
	Unknown	10	4	
	Manufactured year (first)	1977	1974	
	Manufactured year (last)	2013	2013	
Crash event	Singel crash	25	9	
	Crash with another vehicle	33	32	
Counterpart	Car	12	11	
	Buss	3	2	
	Heavy goods vehicle	17	11	
	Light vehicle	1	1	
	Mini buss		1	
	Train		1	
	House		1	
	Rock	3	1	
	Tree	8	3	
	Ditch	12	1	
	Water	2	1	
	Moose	1	1	
	Crash type	Frontal	30	18
		Frontal + rollover	2	1
		Frontal + overturned	1	
Multiple		2	4	
Rear			1	
Rear + rollover		1	1	
Side		9	13	
Side + rollover		2		
Side + overturned		1	2	
Rollover		10	1	
Speed limit	Unknown	2	3	
	110 km/h	10	9	
	100 km/h	2	-	
	80 km/h	1	-	
	90 km/h	33	22	
	70 km/h	6	5	
	50 km/h	4	2	
<i>Ejected</i>	Ejected from vehicle	10	9	
	<i>Unrestrained</i>	8	6	
	<i>Restrained</i>		2	
	<i>Unknown</i>	1	1	
Restraint use	<i>Misuse</i>	1	-	
	Rear-facing CRS	17	-	
	Forward-facing CRS	19	18	
	Seatbelt	1	10	
	Unrestraint	19	8	
Seating direction	Unknown	2	5	
	Rearward			
	Forward	19	-	
	Horizontal	35	40	
	Unknown	4	-	
Seating position	Unknown		1	
	Front passenger seat	26	6	
	Rear passenger seat left	43	19	
Fatal injury	Unknown	3	2	
	Head injury	39	24	
	Neck injury	4	7	
	Multiple injury	6	4	

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Thorax	1	1
Abdomen	1	1
Drowning	3	1
Burn injuries	2	3
Unknown fatal injury	2	-