A REVIEW OF ALL CHILD CAR OCCUPANT FATALITIES IN SWEDEN FROM 1992 TO 2024

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ABSTRACT

This study provides an overview of child fatalities in passenger cars in Sweden over the past three decades, based on the Swedish Transport Administration's national database of all fatally injured road users. Crashes involving child car occupants aged 0–14 years between 1992 and 2024 were analyzed. During this period, 221 children died in 181 crashes: a 78% reduction when comparing 1992–2007 with 2008–2024. Sweden recently recorded its first year with zero child car occupant fatalities, marking a major milestone.

About a quarter of the children were unrestrained, with proportion unchanged between the two time periods, although absolute numbers dropped from 42 to 9. Overall, 68% of the children were restrained, with no major change over time. However, the proportion restrained according to Swedish recommendation was higher in the later period with 56% (n=24) compared to the earlier period (42%, n=74). Examples of non-recommended restraint use included children aged 0–3 years placed on boosters and children aged 4–9 years using only a seat belt.

Ejection occurred mainly among unrestrained children, but five restrained children were also ejected, typically in crashes involving multiple events, a characteristic common to both groups. For restrained children, single-vehicle crashes accounted for 23%, while collisions with other vehicles accounted for 70% across all years. Among collisions with other vehicles, on-coming scenarios were most common, with about half resulting in side impact after loss of control. Most single-vehicle crashes involved road departure, with 59% including rollovers. These crashes were typically severe, causing extensive vehicle damage and compartment intrusion. Head injuries were the most common cause of death.

Although the findings demonstrate substantial progress and the success of current safety measures, moving forward in line with Vision Zero remains essential to ensure protection across all ages while continuing to address vehicle and infrastructure design.

Keywords: children, car occupants, fatalities, CRS, Vision Zero

INTRODUCTION

Road traffic injuries are a leading cause of death among children and young adults aged 5–29 years worldwide, with the majority occurring in low- and middle-income countries [1]. High-income countries have achieved substantial reductions in child occupant fatalities over recent decades, largely due to improvements in vehicle safety, child restraint legislation, and enforcement. For example, in the United States, child passenger deaths have declined by approximately 60% since 1975 [2]. However, the burden remains significant, and recent trends indicate a slowdown in progress. In the US, between 2007 and 2021, fatal injury rates among child occupants decreased by 36% (from 6.6 to 4.2 per 100 000), yet a 26% increase was observed between 2019 and 2021 [3]. Restraint use remains a critical factor; in 2023, 34% of fatally injured child occupants were unrestrained, and in 2020, this figure reached 42% [3].

A comprehensive Swedish study conducted in 2013 [4] examined all fatal outcomes among child car occupants aged 0–14 years, over a 55-year period (1956–2011). The analysis included trends and related them to improvements in vehicle and road safety as well as the implementation of child restraint systems (CRS). The number of fatalities based on normalized values adjusted for population per year is shown in Figure 1, for all car occupant fatalities and for those age 0–14 years old separately. Fatalities in the latest peak around 2010 were 83% lower compared to the peak levels observed in the 1960s and 1970s. Between 1992 and 2011, 194 crash-related fatalities were recorded, mostly occurring on high-speed roads. Head injuries accounted for 54% of the fatalities. Notably, 24% of the children were unrestrained, and 59% of those were ejected during the crash. Among restrained children, only 56% were appropriately restrained according to Swedish recommendations. Despite optimal restraint use in some cases, factors such as crash severity, complex crash scenarios, fire, and drowning contributed to fatal outcomes.

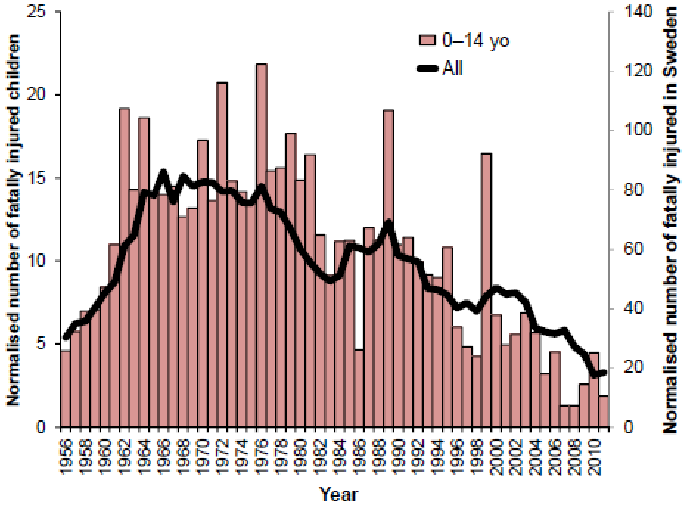

Figure 1 The normalized number of fatally injured passenger 0–14-year-old car occupants (primary axis, red bars) and all fatally injured car occupants in Sweden (secondary axis, solid black line) during the years 1956–2011. Normalization is expressed per 1 million inhabitants per year and accounts for the annual population size of this age group [4].

More recently a case-by-case analysis of fatal crashes in Sweden involving children aged 0–6 years (1992–2024) examined restraint use and the potential benefits of rear-facing CRS [5]. This study was based on a subset of data used in the current study. The analysis estimated that up to 48% of fatalities among children aged 0–3 years and 27% among those aged 4–6 years might have been preventable with rear-facing CRS use.

Sweden has a long-standing tradition of prioritizing child safety in vehicles. In 1964, Professor Bertil Aldman at Chalmers University of Technology presented the first rear-facing CRS prototype [6], inspired by the backward-facing position of astronauts during launch to withstand acceleration forces. A few years later, 1967, the seat came into production and was mainly sold in the Nordic countries. In 1975 there were three rear-facing CRS models available in Sweden, whereof at least one could accommodate children up to 6 years old [7]. In 1978, the world's first belt-positioning booster was introduced, also a Swedish invention [8].

Sweden's pioneering role in protection of children in cars, with its foundation in rear-facing CRS up to the age when a booster can be used, explains why the country never adopted forward-facing harness CRS for children aged 1-3 years, unlike many other nations. With the availability of the CRS and contributions from national campaigns in the 1970s and 1980s, use rapidly increased from 22% in 1976, to 75% in 1986 to 95% in 1990, remaining high since then [9–10].

Remarkably, this was before rulemaking was in place. In Sweden, seatbelt use became mandatory in front seats in 1975 and was extended to rear seats in 1986 for occupants 15 years or older, followed by children in 1988. It was not until 1998 the first Swedish Traffic Regulation mandating CRS for children when traveling in a car was introduced. Initially this regulation only applied to children up to and including 6 years of age. This was superseded by the regulation in 2007, stating that all children of height up to 135 cm must use a type-approved CRS according to their size. Since Sweden joined the European Union (EU) 1995, the country is aligned with the ECE standards on CRS type approval. In addition, the Swedish Plus Test, a voluntary assessment organized by the Swedish National Road and Transport Research Institute, was introduced in 2007 and revised in 2023 for use of Q-dummies. This is a voluntary test for assessing and promoting safe rear-facing CRS to ensure superior neck protection in high-severity frontal impacts. These laws and tests were complemented by strong national recommendations for extended rear-facing travel, up to at least age 4.

Recent studies confirm that CRS use in Sweden remains remarkably high in a global comparison. A recent survey showed that rear-facing CRS up to age three is still widely practiced, with 83% of children in this age group seated in rear-facing CRS [11]. Overall, 95% of children up to eight years use some form of CRS, reflecting strong compliance with Swedish recommendations for CRS use. However, CRS use declines among older children, particularly in the 8–10-year-old (yo) age group where 25% never use a booster or child seat and are restrained by seat belt only. An observational study by the Swedish Transport Administration (STA) [12] found that 97% of children seated in the rear were restrained by CRS or the seat belt only, underscoring the generally high level of restraint use in Sweden.

A unique feature of Sweden's approach is the unified voice among all safety advocates, including authorities, car and CRS manufacturers, restraint system manufacture, insurance industry, and consumer organizations, which consistently recommend rear-facing CRS up to at least 4 years, followed by boosters up to 140 cm and at least 10 years old. Equally important, Sweden benefits from high public trust in safety recommendations and a culture in which compliance is viewed as a social norm. In addition, strong social pressure among parents plays a significant role. Using rear-facing CRSs for infants as well as toddlers is widely regarded as the "right choice", and deviation from this norm is often socially discouraged. Together, these elements have enabled Sweden to achieve one of the highest levels of correct CRS use worldwide.

Despite these achievements, isolated cases of child fatalities still occur, making it valuable to examine them in detail to identify remaining challenges and opportunities for improvement. This study aims to provide an updated overview of child fatalities in passenger cars in Sweden over the past three decades, analyzing long-term trends, and exploring the circumstances and contributing factors behind these cases, with particular focus on restrained children.

METHODS

Data was analyzed from STA's national database on all fatally injured road users. For the current study, all children aged 0–14 years who were fatally injured as occupants in passenger cars in crashes occurring between 1992 and 2024 were included (N=221). Passenger cars were defined as vehicles with up to three seating rows, and a maximum of eight seats. Children up to 14 years, but not yet turned 15 years old, were included.

The in-depth case information was collected and analyzed through two different processes over the years:

- Between January 1, 1992, and June 30, 1997, the Swedish National Road and Transport Research Institute (VTI), conducted in-depth investigations of all child occupant fatalities, targeting to evaluate the technical performance of the CRSs, focusing on use, installation, and unexpected failures [13]. Information included police and rescue team reports, autopsy protocols, and photographs from newspapers. From this collection process, 79 child fatalities (aged 0–14) in 70 crashes occurring between 1992 and June 1997 were included in the current study.
- From 1997 and onward, all fatal traffic-related crashes in the national database have been investigated in-depth by STA's crash investigators. Since then, the database includes technical and medical information for each crash, such as police and rescue reports, vehicle-specific data, detailed on-site documentation of road and environmental conditions, photographs of vehicles and crash scenes, road surface and visibility conditions, injury details, and autopsy protocols. In some cases, STA crash investigators concluded that a crash involved excessive deformation, and they assessed an extremely low chance of survival, regardless of the restraint system used. When survivability is mentioned in the current study, it is based on this assessment. During 1997-2024, 142 fatally injured children (aged 0-14) were involved in 111 crashes in the current study.

To normalize the data, Swedish population statistics from SCB [14] was used to enable comparison of changes over the years. This was only used in Figure 2.

The Analyses

The data is presented in descriptive tables and graphs, supplemented by selected in-depth case examples. Due to the limited sample size, no advanced statistical analyses were performed. The factors collected and analyzed include age, sex, child weight and height, seating position, injury type, fatal injury, seat belt use, CRS use, crash description, collision counterpart, vehicle model and model year, crash event, impact direction, and posted speed limit.

The children were grouped into three age categories: 0-3yo, 4-9yo, and 10-14yo. The group 0–3yo includes children from birth to age 3 but not turned 4 years old. The group 4-9yo includes children aged 4 to 9, but not turned 10 years old, and the group 10-14yo includes children aged 10 to 14 but, not turned 15 years old. The groups were set based on the Swedish recommendation, which specifies rear-facing CRS up to at least 4 years, and belt-positioning boosters until the child reaches a height of 140 cm and at least 10 years old.

For each case, restraint use was assessed based on the child's age and size in relation to the Swedish recommendation. Restraint use was categorized as unrestrained, appropriately restrained, inappropriately restrained, or unknown. Children aged 0–3 years or children shorter than 105 cm were considered appropriately restrained when restrained rear-facing. Those who were larger than that and still shorter than 140 cm were considered appropriately restrained if using a booster cushion or a booster seat, together with the seat belt. In the current study, children aged 4-6 years in a forward-facing CRS with an internal harness were also considered appropriately restrained. When height was unknown, age alone was used for classification. Inappropriately restrained referred to cases where a restraint was used but was either of a non-recommended type or severely misused.

CRS types were classified as rear-facing CRS (including infant seats and larger rear-facing toddler seats), forward-facing CRS with harness and boosters (including both booster cushion and booster seat). There were no fatally injured children restrained on integrated boosters.

When information was available regarding misuse, which in this study included inappropriate seatbelt use, such as incorrect belt routing or restraining, it was noted in the results. However, all such cases were still classified under the category of restrained children.

To examine changes over time, the dataset was divided into crashes occurring during two time periods: one earlier period (1992–2007) and one later period (2008–2024). This approach enabled comparison of long-term trends and helped identify factors that may explain differences in child fatalities.

RESULTS

Overview

Figure 2 shows the number of fatally injured children, aged 0–14 years, as passenger car occupants, normalized to the Swedish child population per year. As shown, child fatalities have declined significantly over the last 33 years, with an average reduction of 78%. Specifically, the later period (2008-2024) shows 1.5 fatalities per 1 000 000 children normalized to account for the annual population size of this age group, compared to 6.8 fatalities per 1 000 000 children in the earlier period (1992-2007) (Figure 2).

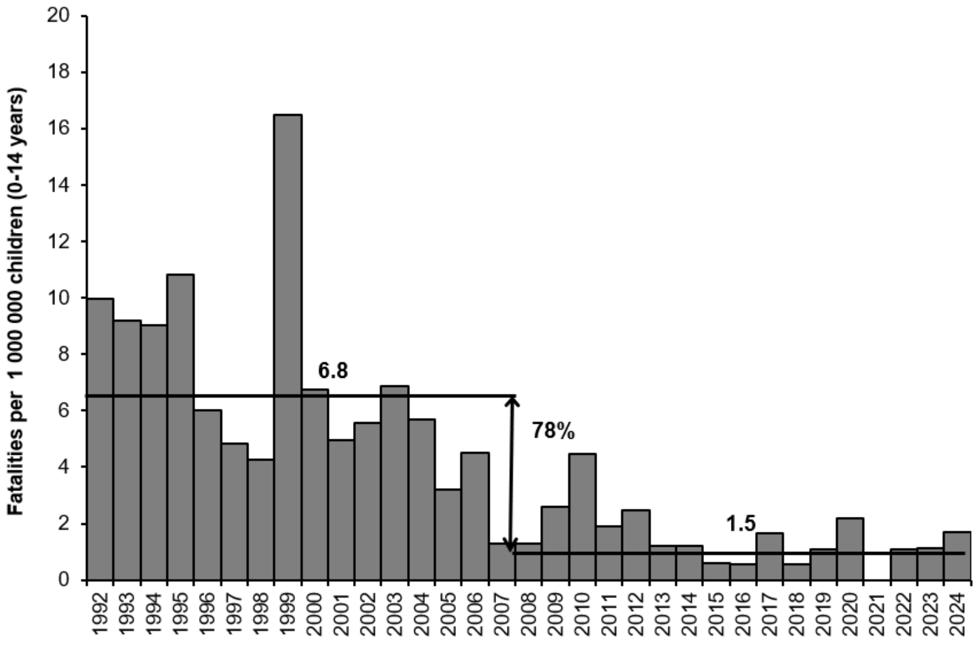

Figure 2 Fatalities per 1 000 000 children aged 0-14 years old.

In total, 221 children aged 0–14 years were fatally injured as occupants in a passenger car between 1992 and 2024, across 181 crashes. Figure 3 shows the number of fatally injured children per year, broken down by age group. In 2021, the first-ever year of zero child car occupant fatalities in Sweden was reached. Comparing the two time periods, the proportion of children across the same age groups was similar: in the earlier period, 26% were 0–3yo, 36% were 4–9yo, and 38% were 10–14yo; in the later period, the corresponding proportions were 28%, 35%, and 37% respectively (Appendix Table A1).

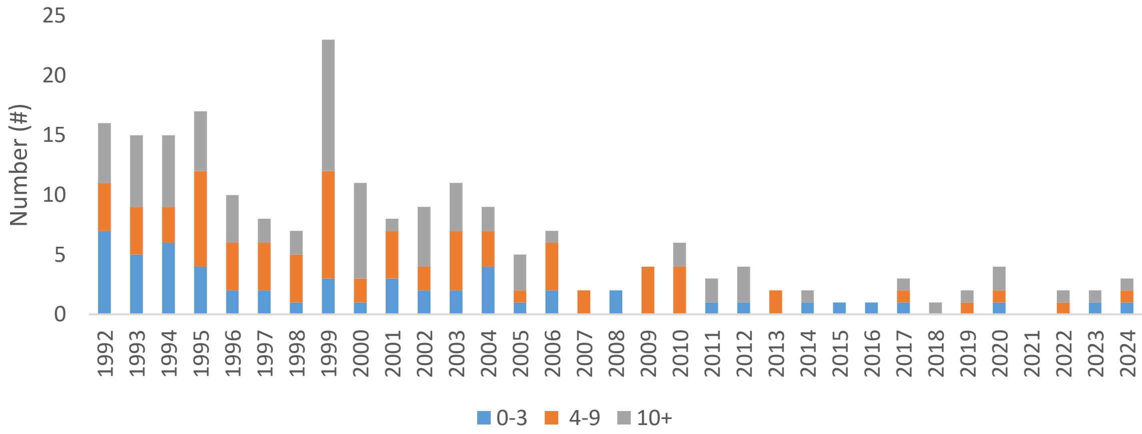

Figure 3 Number of fatalities per year and age group.

Figure 4 illustrates the seating positions in the car for the two time periods, respectively. In total 178 children were included in the earlier time period and 43 children in the later period. Approximately half of the children were seated in the second row for both periods. The front passenger seat was the most frequently used individual position. When all second-row positions were combined, the second row represented the most common seating location overall, with about half of the children. A small number of children were found in the driver's seat. One 4-year-old child was seated in the driver's lap, while the others were drivers, typically older children aged 13 to 14, who had taken or stolen the car. The seven children in the third row were seated in multi-purpose vehicle (1 crash, 1 child), large family car (2 crashes, 2 children) or minibus (1 crash, 4 children).

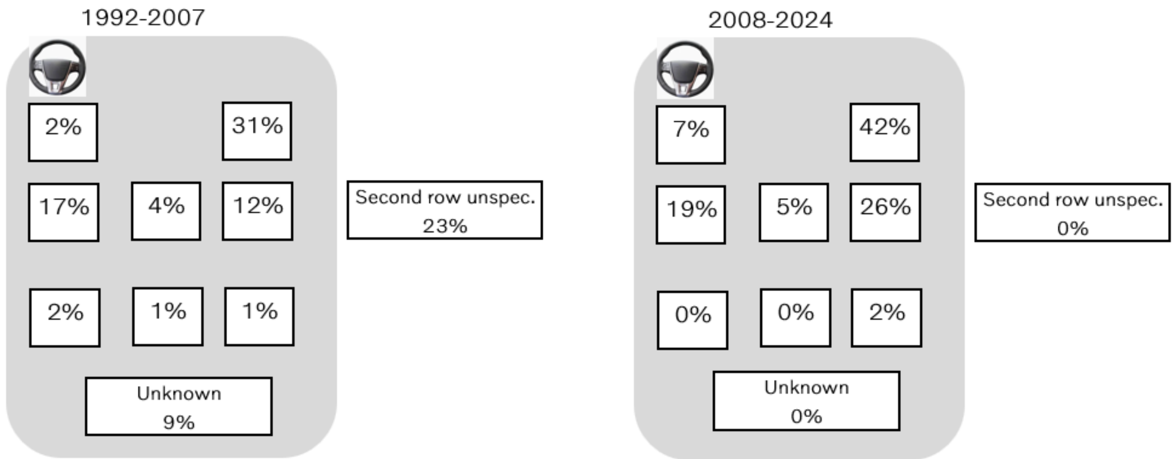

Figure 4 The distribution of the seating positions for the children in the earlier time period (left) and the later (right).

Among the 221 fatally injured children, 51 were unrestrained, 150 were using restraints and for 20 children, the restraint status was unknown. Among those restrained, 98 were categorized as appropriately restrained, 49 as inappropriately restrained and 3 children could not be categorized (***Table 1***). Figure 5 shows the distribution of these categories across the two time periods. Unrestrained children represented 24% and 21% in the two respective time periods, showing only limited relative improvements between the two time periods (Figure 5). However, in absolute numbers, a reduction from 42 to 9 children is seen. While most children were restrained to some extent, 67% in the earlier period and 72% in the later, the proportion of appropriately versus inappropriately restrained children changed over time. Among the restrained children the proportion of inappropriately restrained decreased from 36% to 20% for the two time periods, respectively.

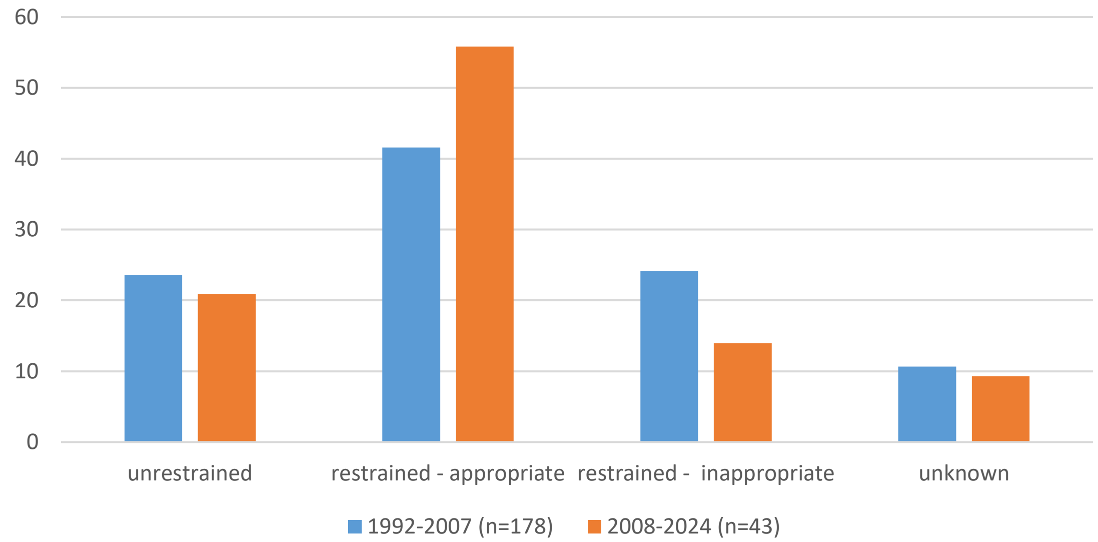

Figure 5 Distribution of restraint use for the two time periods.

The majority of the children died in crashes occurring on roads with posted speed limits of 70 km/h or higher; 89% in the earlier period and 88% in the later period. Five percent of the cases had unknown posted speed limit (Appendix Table A1). In the relatively few crashes that occurred on roads with lower posted speed limits, it was often assessed that the vehicles were traveling at speeds significantly above posted speed limit at the time of the crash.

With respect to the age of the car at time of the crash, most of the children travelled in cars that were more than six years old; 77% in the earlier period and 86% in the later period. The data shows a higher proportion of older vehicles involved in fatal crashes during the later time period (Appendix Table A1). The average age of vehicles in this dataset was 10 years, which aligns closely with the average age of passenger cars in the Swedish vehicle fleet in 2024, reported as 11 years [15].

A total of 33 fatalities occurred in crashes involving post-impact fires, with 29 of these during the earlier period. About one-third of the children involved in fire-related cases were in single-vehicle crashes. Among crashes involving another vehicle, 14 of the 33 involved a truck, bus, or minibus. In 17 of 33 fatalities, the fire was estimated to be the primary cause of death. One example involved two children traveling in a passenger car that skidded into the oncoming lane and collided with a minibus. All three occupants of the passenger car died at the scene, including a 9-year-old child in the front seat and a 6-year-old child in the rear seat. Both children were restrained, although it is unknown whether they were using boosters, which would have been appropriate for their size. The younger child sustained a severe neck injury; however, it was estimated that both children ultimately died because of the fire.

In total, eight fatalities were due to drowning, all in single-vehicle crashes during the first time period. The children's ages ranged from 3 to 14 years, with an average age of 8.6 years, slightly higher than overall average age of child fatalities. Most incidents occurred when parents were driving, lost control of the vehicle, veered off the road, and ended up in water. For example, a 9-year-old (with unknown seat belt use) was a front seat passenger when the car lost control in a left-hand curve, slid onto a bent guardrail, then rolled off and came to rest upside down in a narrow stream. The doors could not be opened until the car was lifted out. The driver and the child both died from drowning. One case involved a 15-year-old and a 14-year-old who had stolen a car, were pursued by the police, and drove at high speed before leaving the road and ending up in the water and both children drowned.

Restrained children

Table 1 presents the 150 restrained children per time period, age group, restraint type and whether the restraint was used appropriately or inappropriately. The number of children who died because of drowning or fire is indicated in brackets. When excluding those children, the number of restrained children adds up to 130.

Of these 130 children, 42% of the younger (0-3yo and 4-9yo) age groups (32 of 76) were not appropriately restrained. In the later period, among 18 cases, only six were categorized as inappropriately restrained.

In the age group 0–3yo, inappropriately restrained was primarily due to the use of a booster instead of a rear-facing CRS, which are recommended for this age. Two children in that age group were traveling in a forward-facing CRS with harness. In the age group 4–9yo, the most common form of inappropriate restraint was the use of a seat belt only.

Misuse was identified for three fatally injured children only. One child, aged 4 years old, had placed the shoulder belt under the arm. The other two, aged 8 and 10-years-old, were seated in the same car together with two other children in the rear seat. They pairwise shared the two outer seat belts. The fatally injured children were seated on the inboard positions, next to the buckle, while the two children who survived sat outboard, next to the doors.

Restraint failures were reported for two children. One of them was in a rear-facing CRS, whose attachment separated. The CRS was exposed to a very high severity crash, beyond any standardized test. The other child was using a seat belt, which had a production defect causing a separation between the webbing and seat belt tongue.

Table 1 The restrained fatally injured children categorized by appropriate/inappropriate restraint use, age group and time period. Information on type of restraint use is included. The number in brackets shows the children who died because of drowning or fire.

	1992-2007						2008-2024			
	0 -3yo		4- 9yo		10-14yo		0 -3yo		4- 9yo	10-14yo
Appropriately										
rear- facing CRS	11	(1)					3	(1)		
boosters			16	(1)					5	1
seat belt only			4		35	(7)			1	12
forward -facing CRS with harness									1	
In-appropriately										
boosters	11	(2)					3			
3pt seat belt only			12	(7)	3		1		2	
2pt seat belt only			2		1					
forward-facing CRS with harness	3	(1)								
Belted - Unknown			1		1				1	
Sum	25	(4)	35	(8)	40	(7)	7	(1)	10	13

The restrained fatally injured children were involved in single-vehicle crashes in 23% in both time periods. Most crashes involved collisions with another vehicle, representing 70% in both time periods (Appendix Table A2). Among these, oncoming collisions were the most common scenario. In contrast, crossings and following scenarios (where the case vehicle impacted the rear-end of another vehicle) were less frequent crash scenarios. More than half of all oncoming collisions were linked to loss of vehicle control, or skidding, which led to unintentional lane departures into oncoming traffic and resulted in both frontal and side impacts. Rear-end impacts were rare, only one child died in a rear-end impact. There were five crashes involving following scenarios. In four of these cases underride occurred, and the counterparts were trucks, three of them were stationary on the roadside. All the fatally injured children in these crashes were seated in the front passenger seat.

Figure 6 shows the distribution of crash types for the two time periods. Frontal or side impacts account for the most frequent crash types; however, the order is shifted between the time periods. In the early time period, frontal impacts account for the highest proportion, while the opposite is seen for the later time period. The multiple events included frontal impact with rollover (early n=8, later n=3), side impact with rollover (early n=11, later n=4), while the remaining cases included run-off road with multiple events and impacts with the environment, such as a ditch.

Fifteen out of 30 side impacted cars were exposed to an oncoming scenario, typically when the car lost control, skidded into the oncoming lane with the side toward the front of the oncoming vehicle. Other side impacts were involved collisions with trains (9 children), and six occurred at intersections.

For those exposed to frontal impacts, the majority (37 out of 42) occurred in an oncoming scenario, followed by single crashes (5 out of 42).

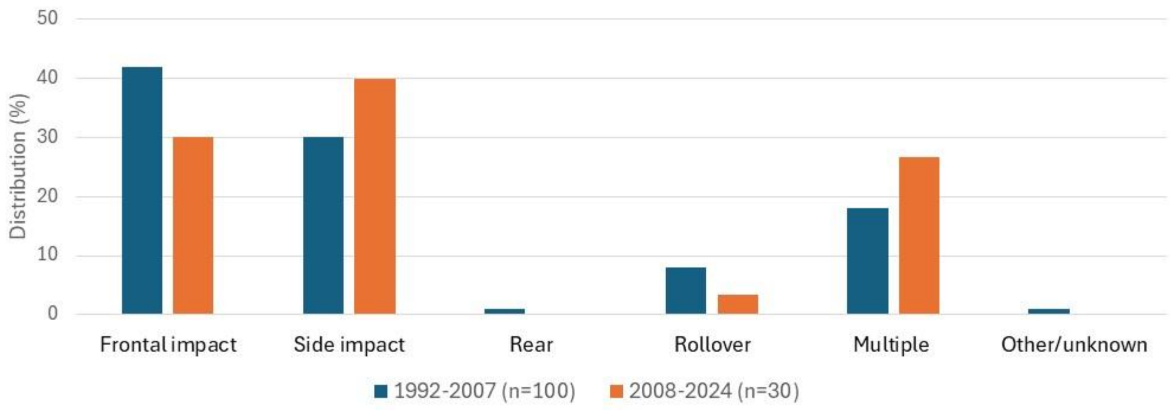

Figure 6 Distribution of crash types for fatally injured restrained children, excluding those who died from drowning or fire.

Figure 7 shows distribution of crash counterparts. The most common counterpart was another vehicle, with differences between the two time periods regarding vehicle type. For the later time period a relatively lower proportion was cars, while a higher proportion was heavy vehicles such as buses and heavy trucks. The category 'other' includes impacts to a rock wall and a house. Category 'multiple' included both multiple collisions (i.e. frontal impact followed by rollover, side impact followed by a rollover, run off road followed by tree impact, frontal impact followed by a side impact).

Three children were involved in crashes with large animal and died from head injuries. All were seated in the front passenger seat and were struck by a moose impacting the header and A-pillar area, resulting in significant car deformation in the area where they were seated.

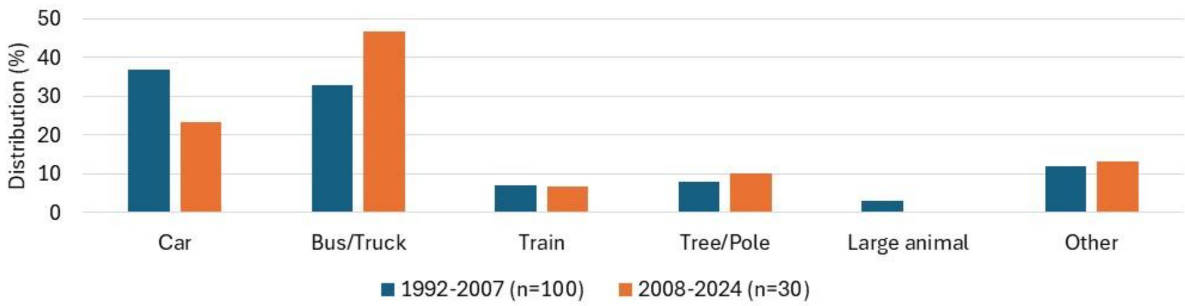

Figure 7 Distribution of crash counterparts for fatally injured restrained children, excluding those who died from drowning or fire

A total of 14 children aged 0-3 years were appropriately restrained in rear-facing CRS (***Table 1***). All were involved in high-severity crashes or significant deformation in the area where the child was seated. Type of restraint would not have influenced the outcome for any of these children. Eight of the children were exposed to frontal (n=5) or side (n=3) impact with oncoming traffic. One of them was involved in a frontal underride impact into the rear-end of a truck that was stopped on the roadside, resulting in substantial deformation of the whole compartment area. Another five children were involved in single events where the vehicle crashed into objects next to the road with a frontal impact (n=1), rollover (n=3), multiple crashes (n=2) or multiple events (n=5). One multiple-event crash involved both a rollover and impacts with several trees, while the second case included a rollover into a rock wall. No fatally injured child in a rear-facing CRS was exposed to a rear-end impact.

Among appropriately restrained children aged 4–9 years, 16 out of 27 were involved in crashes of such high severity that survival was deemed unlikely due to extensive vehicle deformation. The 26 cases included ten frontal impacts, eight side impacts, seven multiple-events, and one rollover. The outcome for two 4-year-old children was influenced by malfunction of the restraint system:

1. One of the 4-year-old children was seated in a forward-facing CRS with harness in the front passenger seat. The child was exposed to a frontal impact when an oncoming car skidded over the center line and impacted head-on. The child impacted the dashboard with the head and later died from head injuries. Investigation revealed that a production defect caused a separation between the webbing and seat belt tongue. The belt webbing routed only around the plastic part of the tongue, not through it. The plastic

broke in the crash, leaving the child and CRS unrestrained. The child was otherwise appropriately restrained.

2. The other 4-year-old child was seated on a booster cushion in the right rear seat, restrained with the seat belt that may have been incorrectly positioned. The car was involved in an oblique frontal impact, head-on with another vehicle at a traffic light. The child died the following day from abdominal injuries, indicating that the seat belt may not have been routed correctly, especially given the crash severity where such injuries are unexpected with correct belt routing.

In the 10–14yo age group with appropriate restraints, the vast majority were involved in crashes resulting in extensive vehicle deformation, as a result of high severity crashes and influenced by the car's structural integrity. Contributing factors included impacts with trucks or buses (n=17), collisions with another passenger vehicle (n=18), five children traveling in cars struck by a train, and the remaining cases involved objects such as ditches and poles. Most children were exposed to side impacts (n=20), followed by frontal impacts (n=14), multiple-impact crashes (n=11), and rollovers (n=3). Furthermore, 20 of the children were exposed to skidding prior to the crash, which is a major contributing factor when the vehicle ends up in an oncoming collision. Such pre-crash events may also influence occupants' posture and belt position prior to the impact. There were several cases in which a child traveled with a friend or older sibling who was driving at excessive speed, lost control of the vehicle, and subsequently became involved in various types of collisions.

Four examples of child occupant fatalities for this 10–14yo age group are included:

1. A 14-year-old child was correctly restrained in the front passenger seat. The car was traveling about 100 km/h on an icy road when it skidded, left the roadway, and entered a right-hand ditch, where it rolled over. The car came to rest about 70 meters later, lying on its roof. The child was trapped in the deformed vehicle and died from aspiration of blood into the airways due to extensive crushing injuries to the face and mouth. The car was equipped with summer tires despite winter conditions.
2. A 12-year-old child, restrained in the right rear seat, was involved in a frontal oblique impact, when traveling at excessive speed and crossed into the opposite lane into an oncoming vehicle. The child sustained fatal injuries to the head. The 59-year-old driver of the child's car was also fatally injured. Several friends of the child in the same car survived, but no further details were available.
3. A 14-year-old passenger was correctly restrained in the front seat. The crash involved a side impact on the driver's side followed by a rollover. The car, driven by a restrained 18-year-old at high speed, lost control, whereby the car skidded across the roadway, and collided with an oncoming tractor towing a trailer. Both occupants died instantly. The child sustained severe head and thoracic injuries, with head trauma identified as the cause of death.
4. An 11-year-old child, restrained by a seat belt in left rear seating position, was fatally injured in a rollover crash. The vehicle was deformed to a high degree, resulting in the child being trapped in the car and required extrication. The child died from severe abdominal injuries.

Among 18 **inappropriately restrained** children aged 0–3 years, 14 were using boosters, three in forward-facing CRS with harness and one restrained by seat belt only (Table 1). Twelve of the 18 cases were considered potentially survivable if rear-facing CRS had been used [5]. Of the seven cases classified as nonsurvivable, all involved high-severity crashes where rear-facing CRS would not have changed the outcome.

Among the 16 **inappropriately restrained** children aged 4–9 years, they were all restrained with seat belt only, two of them were using two-point belt only. Eleven out of 16 involved crashes of such high severity that survival was considered unlikely due to extensive vehicle deformation. Three frontal-impact cases where survival might have been possible with proper restraint were identified:

1. A 5-year-old child, restrained by a 2-point lap belt in the center rear seat, was exposed to a frontal impact, due to an oncoming car that crossed into the wrong lane, causing a head-on collision. The child died from severe thorax and abdominal injuries, while the restrained driver was seriously injured. It was winter and 18 m of skid marks were found behind the car.
2. A 4-year-old child restrained by the seat belt only, in the front passenger seat, was exposed to a frontal impact when an oncoming vehicle crossed into the wrong lane causing a head-on collision. The child sustained blunt head trauma and severe injury at the junction between the skull and cervical spine, including tearing of the brainstem. This injury pattern is representative of forward-facing children exposed to a high severity frontal impact. With a rear-facing CRS this child would have been provided an improved protection in this crash, due to the greater support over the head and torso reducing the risk for head impacts as well as loads to the neck.

3. A 6-year-old child was restrained by a two-point lap belt in the rear seat when exposed to a frontal impact. The car crossed into the oncoming lane and impacted head-on with another car. The child sustained injuries to the cervical spinal cord, brain, and abdomen, with the fatal injury assessed to be abdominal trauma.

Among four inappropriately restrained 10–14-year-old children, three were shorter than 140 cm but they were restrained with three-point seat belt only, and one was restrained with a two-point lap belt only. All four crashes were of very high severity, two were side impacts and two were frontal impacts. Three of these involved impacts with a truck. The remaining case involved a child restrained by a two-point belt, but the crash involved such extreme intrusion that the occupant space was compromised, making any restraint system ineffective.

Unrestrained children

The 51 unrestrained children were distributed over the three age groups: 18 children aged 0-3, 15 children aged 4-9 and 18 children aged 10-14 years old. Two of the 0–3-year-old children were positioned in a hard-shell carrycot, which in Sweden is not considered restrained, and they were therefore categorized as unrestrained.

Some cars included more than one unrestrained fatally injured child. For example, in one car, two unrestrained older children (12 and 13 years) were ejected from the rear seat when the car left the road at high speed, and the vehicle rolled over 105 meters off-road. In another car, three unrestrained children aged 2, 3, and 4 years old, along with unrestrained parents in the front seats, were involved in a frontal impact with a truck followed by a fire. There were also two cases where all occupants were restrained except one 1-year-old child, who was seated unrestrained on an adult's lap.

The number of unrestrained children was 39 in the earlier period and 10 in the later period. However, with respect to proportion, it was stable, accounting for 23% of all fatalities. Similarities for this group between the time periods were the proportion of single events, with 57% and 56% respectively (Appendix Table A3). With respect to crash type, frontal impacts and rollovers were most common during the first time period, while frontal and side impacts were most common in the later period.

In comparison to the restrained children, the unrestrained children were, to a higher degree, involved in single events, including multiple events and rollovers.

Children ejected from the car

In the earlier period, 17% of children were ejected, compared to 12% in the later period. Most ejected children were unrestrained; 80% in the earlier period and 60% in the later period (Appendix Table A1).

In total, 36 children were ejected, of which 31 were among the 51 unrestrained fatalities (31 in the earlier period, 5 in the later). Twenty-five of 36 cases involved a rollover or a complex crash sequence, often including multiple impacts.

In some crashes, survival would have been unlikely even with restraints due to extreme severity. However, there are cases where survival might have been possible if appropriate restraints had been used.

1. Two unrestrained children (12 and 13 years) sat in the rear. The car left the road in a right-hand curve, crossed into the oncoming lane, entered a ditch, struck a utility pole, and rolled approximately 105 meters. The vehicle caught fire, but the children were ejected before the fire. Witnesses reported very high speed.
2. A father and his two-year-old child, both unrestrained, were ejected in a run-off-road crash after failing to negotiate a left-hand curve following a long straight section of the road.

Not all ejected children were unrestrained. Five restrained children were ejected (see Appendix Table A1).

1. A 5-year-old on a booster cushion was likely ejected through the rear window during a skid and counter-skid sequence, landing on the road.
2. A 5-year-old on a booster cushion was ejected during a multi-impact crash involving water-induced loss of control. Two siblings remained inside; all three died.
3. A minibus carrying seven restrained children (ages 12–15) and two adults collided head-on with a truck after skidding into the oncoming lane. One child was ejected; all occupants died. The minibus caught fire after the crash.

Injuries

The head was primary injured body region and cause of death in 120 of the cases, followed by the neck and thorax. In 39 cases, multiple body regions were severely injured, making it difficult to determine the exact cause of death. Twelve of those involved both head and neck trauma and eight of them involved both head and thorax. Drowning was the cause of death to eight of the fatalities. There were 33 fire-related cases in total; in 17 of these, the fire was estimated to be the cause of death, while in the remaining cases the child was already fatally injured before the fire started.

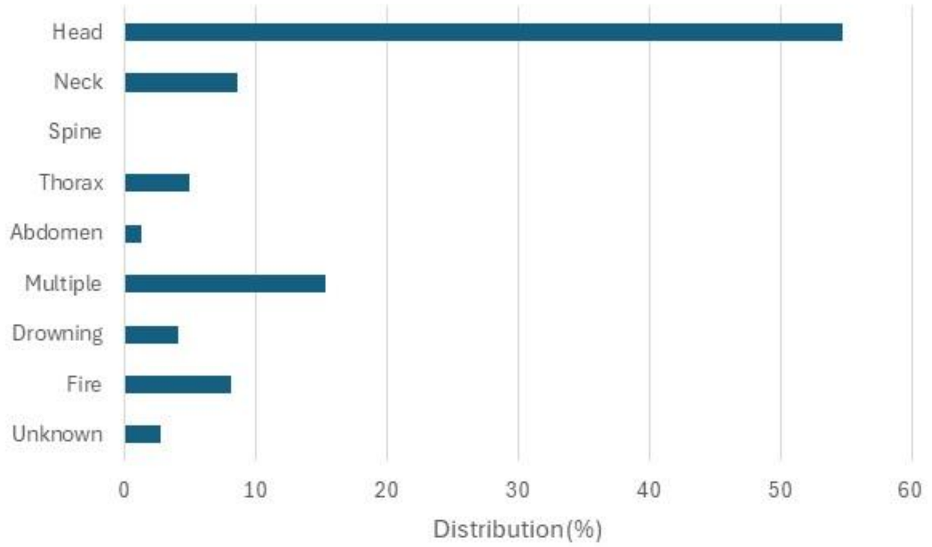

Figure 8 Primary injured body region as cause of death.

DISCUSSIONS

This study shows a substantial reduction in child car occupant fatalities over the past 33 years. Comparing the first 16-year period with the most recent 17 years, fatalities decreased by 78%, indicating continued progress in protection of children as car occupants in passenger cars in Sweden. These results align with the long-term trend reported by Carlsson et al. [4], who documented an 83% reduction in child car occupant fatalities over a 55-year period (1956–2011). The findings confirm that the downward trend identified in earlier research has continued, with an additional 13 years of recent data showing significant improvement.

This decline is consistent with trends observed in the United States, where fatal injury rates among child occupants dropped by 36% between 2007 and 2021 [3]. However, the reduction in Sweden is considerably greater. In absolute terms, Sweden now records approximately 1.5 fatalities per 1,000,000 children aged up to 14. Notably, in 2021 the country achieved a historic milestone - the first year with zero fatalities among children aged 0-14 traveling as occupants in passenger cars.

Changes Over Time – comparing 1992–2007 and 2008–2024

By comparing the two time periods, trends and factors that may explain differences in child fatalities over time provide insights into further measures. Although caution should be taken when comparing, since only 43 child car occupant fatalities occurred in Sweden during the later period (2008–2024), some observations can be noted in comparison to the earlier period (1992–2007).

The distribution of children across the three age groups was consistent, and seating position within the vehicle also remained largely unchanged. There was a slight increase in children positioned in the driver's seat during the later period. These cases typically involved older children who had taken or stolen a car, often driving at high speed, resulting in loss of control, and a severe crash. In four of these five instances, the children were also unrestrained.

The proportion of unrestrained children was similar in both time periods, at about one-quarter. However, the later period shows a higher proportion of appropriately restrained children as compared to the earlier period. One contributing factor may be the 2007 regulation requiring children to use a CRS until they reach a height of 135 cm. More importantly, the unified messaging from child safety stakeholders, speaking with ‘one voice’, has likely continued to help make the Swedish recommendations widely accessible to the public. Over the past decade, annual child restraint surveys [11,16] have consistently shown a marked improvement in CRS use among children aged 0–11 years in Sweden. For children shorter than 135 cm, appropriate CRS use increased from 55% in 2014 to 81% in 2024. Among children taller than 135 cm, booster use rose from 38% in 2014 to 51% in 2023, with a peak of 69% booster use recorded in 2018. These findings confirm a significant upward trend in CRS use over time, which has likely played an important role in the observed reduction in child fatalities.

Some trend changes were revealed when comparing the type of crashes the children were exposed to between the two time periods. In the later period, the children were more often exposed to side impacts, while in the earlier period, frontal impacts accounted for the largest proportion. Additionally, there was a relative increase in multiple crashes mainly involving an initial frontal or side impact followed by a rollover. In addition, the later period included a higher relative proportion of children exposed to crashes involving heavy vehicles, such as trucks and buses, also showing that the proportion of car-to-car crashes were relatively fewer in the later time period. This could indicate that passenger car improvements have enhanced protection of children in such crashes, while crashes involving heavy vehicles remain highly severe and continue to pose a challenge for occupant protection.

A high proportion of crashes still involve vehicles older than 10 years, and the trend indicates that vehicles in fatal crashes during the later period are, on average, even older than those in the earlier period. This may suggest that newer car models provide improved occupant protection, likely due to advancements in crash avoidance technologies, structural integrity, and restraint systems.

Moving forward, what still to focus

Being restrained is the most effective way to reduce the risk of injury or death in a car crash, and it remains one of the most critical areas of focus. Besides, being restrained is essential to fully benefit from the vehicle’s other safety systems. This study shows that approximately one quarter of the fatally injured children were unrestrained. The consequences of being unrestrained, even in a moderate crash, can be severe. The data shows a strong correlation between ejection and lack of restraint, moving forward this should not happen.

This study highlights the need for continued progress in appropriate restraint use across all age groups. Children aged 0–3 years should optimally use rear-facing CRS. However, 14 of 18 inappropriately restrained 0–3yo were restrained using a booster. Although a booster offers better protection than using the seat belt alone, it is not appropriate for this age group. Among the fatally injured children under the age of four, it is estimated that up to 48% of these fatalities could have been prevented with appropriate use of rear-facing CRS. This detailed survivability analysis was conducted by Klingegård et al. [5] using a subset of the Swedish child fatality data also used in current study. The subset included children aged 0–6 years, covering the period 1992–2024. For inappropriately restrained children aged 4–9 years, the main issue was being restrained with a seat belt only, without any CRS. Additionally, the inappropriately restrained children aged 10–14 years were still too short to travel safely without a booster. In total, about one third of the fatally injured children were assessed to use inappropriate restraints, according to Swedish recommendations. While several other factors may have contributed to these fatalities, besides inappropriate restraint use, this highlights the need for continued efforts to improve restraint use across all age groups and ensure appropriate CRS use throughout childhood. Although real-world surveys show that children in Sweden have a high CRS use [11], special attention is needed for older children, who often stop using boosters too early.

Only a few cases of misuse involving CRS or seat belts were explicitly identified in the crash data. However, it is likely that additional instances of misuse occurred but were difficult to detect post-crash. Observational studies suggest that misuse rates for booster cushions can be as high as 61%, while misuse [17] of rear-facing CRS was estimated at around 44% [18]. Importantly, the consequences of misuse in rear-facing CRS are generally considered to be less severe [19], contributing to their reputation as highly robust restraint systems. These findings highlight the need for continued development of restraint systems that are both easy to use and designed to minimize the impact of potential misuse. Future occupant monitoring systems may support caregivers ensure correct restraint use.

Another important aspect of these fatalities is the complexity of the crash scenarios, which often involve multiple phases – such as skidding, emergency braking, and loss of control – prior to the main impact. Some crashes also include secondary events like run-off-road or rollovers. All of these are dynamic events that can influence occupant kinematics and restraint performance. During these events, children may move around, potentially affecting shoulder belt positioning prior to the impact [20,21]. Managing complex crash sequences – including pre-impact events and multiple impacts – remains a challenge for keeping children properly restrained throughout the entire event.

High crash severity, often linked to excessive impact speeds and disregard for posted limits, is a common factor in these fatalities, emphasizing the importance of maintaining speeds in accordance with both speed limit and road conditions. Collisions with heavy vehicles such as trucks or buses further contribute to severe outcomes and significant intrusion, making crash avoidance the primary strategy. Many incidents from loss of control, where the passenger car veers into the path of heavy vehicles, something Electronic Stability Control continues to help prevent. In this study, four children were involved in underride impacts with trucks, underscoring the important role of heavy vehicles design in protecting occupants of lower vehicles. When crashes are unavoidable, improving crash compatibility becomes critical. While passenger cars have made significant progress in occupant protection, truck design could better account for compatibility through energy-absorbing front-end structures, underride protection, and alignment of crash zones to reduce intrusion and injury risk [22]. This work has been initiated under Swedish lead within Euro NCAP to be introduced in heavy truck crash testing in 2031 [23].

In addition to advancements in CRS and increased use rates, vehicle safety has evolved significantly, both in terms of collision avoidance and mitigation, and occupant protection. These developments have often been driven by consumer safety rating programs, in complement to regulatory requirements. In this study, there were cases with suspected driver impairment, including drivers falling asleep – though this is difficult to confirm when the driver also died. Detecting impairment is one function of collision avoidance systems that could provide significant safety benefits. Additionally, many crashes involved skidding on slippery roads, where vehicle-to-vehicle communication systems could have been beneficial by warning drivers about impaired road conditions. Furthermore, continuous improvements have been made to the road environment in Sweden. The STA actively pursues Vision Zero, with one key initiative being the conversion of high-risk road segments into 2+1 roads, a cost-effective design that helps reduce the risk of on-coming collisions between vehicles, contributing to overall traffic safety. Additional measures include setting safe speed limits, installing traffic safety cameras for traffic calming and reduced average speed, introducing roundabouts to lower crash energy, and consistently removing obstacles to create safer side areas. These interventions, gradually implemented since the introduction of Vision Zero in 1997, have likely contributed to the positive safety trend observed between the study time periods. Combined with advancements in with modern vehicle safety, these measures reflect Vision Zero key principle: a safe road system must account for human error and be designed to prevent fatal outcomes by respecting biomechanical tolerances.

Although a declining trend of child fatalities in passenger cars in Sweden, still on average 1.5 children yearly die as car passengers in recent years. Each individual child is one too many, which is clearly stated in Vision Zero. Moving forward, focus areas include using restraints and using appropriate restraint for the individual child's needs, in addition to vehicle and infrastructural design measures.

CONCLUSION

From 1992 to 2024, 221 children aged 0-14 years died as car occupants in Sweden. Comparing the earliest years (1992-2007) to the most recent period (2008-2024) shows a 78% reduction in child occupant fatalities. Notably, Sweden recently recorded its first year with zero child car occupant deaths in 2021: an extraordinary milestone.

Restraint use is essential for child safety. Twenty-three percent of fatal cases involved unrestrained children. While the overall proportion of restrained children has remained stable, age- and size-appropriate use has improved, likely supported by legal requirements and national recommendations. Still, appropriate use is critical. Many young child fatalities occurred because they were not rear-facing, and older children often lacked boosters. Closing these gaps is vital to further reduce fatalities and improve protection.

Several fatal crashes involved complex sequences such as skidding, braking, loss of control, and multiple collisions. High crash severity remains a major challenge, often linked to excessive speed and impacts with heavy vehicles. Infrastructure that separates oncoming traffic and side areas without obstacles is a key strategy to mitigate the consequences of high speeds. While crash avoidance is the primary goal, improving crash compatibility, including truck design enhancements, is vital to better protect occupants in passenger cars.

This latest update on child occupant fatalities in Sweden shows that, step by step, fatalities have been reduced over time. Addressing Vision Zero will require continued, coordinated efforts regarding restraint use, vehicle design, safe speeds and infrastructure.

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APPENDIX A.

Table A1 Distribution of ejected occupants, drowning, fire, age of car and posted speed limit.

		Early period 1992-2007		Later period: 2008-2024	
		#		#	
Number of crashes		142		39	
		Early period 1992-2007		**Later period: 2008-2024**	
Restraint use		#	%	#	%
	restrained	119	66.9	31	72.1
	unrestrained	42	23.6	9	20.9
	unknown	17	9.6	3	7.0
	Sum	178	100	43	100
Age of children	0-3yo	46	25.8	12	27.9
	4-9yo	64	36.0	15	34.9
	10-14yo	68	38.2	16	37.2
	Sum	178	100	43	100
Appropriately		74	64.3	24	77.4
	rear- facing CRS	*12*		*4*	
	boosters	*17*		*6*	
	seatbelt only	*45*		*13*	
	forward -facing CRS with harness	*0*		*1*	
In-appropriately		39	33.9	6	19.4
	boosters	*13*		*3*	
	3pt seatbelt only	*23*		*3*	
	2pt seatbelt only	*3*			
	forward-facing CRS with harness	*4*		*0*	
Belted - Unknown		2	1.7	1	3.2
	Sum	115	100	31	100
Ejected	Ejected from vehicle	31	17.4	5	11.6
	unrestrained	*25*	-	*3*	-
	restrained	*4*	-	*1*	-
	unknown	*2*	-	*1*	-
					-
Drowning		8	4.5	0	0.0
Fire		29	16.3	4	9.3
	fire cause of death	*16*		*1*	
Age of car	0-5 years	33	23.2	6	14.0
	6-10 years	51	35.9	11	25.6
	11-15 years	44	31.0	12	27.9
	16-20 years	13	9.2	12	27.9
	20+ years	1	0.7	2	4.7
	Sum	142		43	
Speed limit	30 km/h	0	0.0	1	2.4
	50 km/h	9	5.4	1	2.4
	60 km/h	0	0.0	1	2.4
	70 km/h	37	22.0	9	22.0
	80 km/h	0	0.0	3	7.3
	90 km/h	91	54.2	17	41.5
	100 km/h	1	0.6	3	7.3
	110 km/h	30	17.9	6	14.6
	Sum	168		41	
Seating position					
	driver	3	1.7	3	7.0
	front passenger	55	30.9	18	41.9
	2 row right	30	16.9	8	18.6
	2 row middle	7	3.9	2	4.7
	2 row left	21	11.8	11	25.6
	2 row unknown	40	22.5	0	0.0
	3 row left	4	2.2	0	0.0
	3 row iddle	1	0.6	0	0.0
	3 row right	1	0.6	1	2.3
	unknwon	16	9.0	0	0.0
	Sum	178		43	

Table A2 Distribution of crash scenario, crash type and counterpart for restrained occupants. The number in brackets shows the children who died as a result of drowning or fire.

		1992-2007		2008-2024		1992-2007	2008-2024
		#	(#)	#		%	%
Crash scenario							
	Single crash	23	(9)	7	(1)	23	23
	Crash with another vehicle	70	(10)	21		70	70
	Oncoming	*63*	*(10)*	*16*		-	-
	Crossing	*7*		*2*		-	-
	Following	*1*		*3*		-	-
	Train	7		2		7	7
	Sum	100	(19)	30	(1)	100	100
Crash type		**1992-2007**		**2008-2024**		**1992-2007**	**2008-2024**
	Frontal impact	42	(8)	9	(1)	42	30
	Side impact	30	(6)	12		30	40
	Rear	1		0		1	0
	Rollover	8	(2)	1		8	3
	Multiple	18	(2)	8		18	27
	Other/unknown	1	(1)	0		1	0
	Sum	100	(19)	30	(1)	100	100
Counterpart		**1992-2007**		**2008-2024**		**1992-2007**	**2008-2024**
	Car	37	(4)	7		37	23
	Bus/Truck	33	(6)	14		33	47
	Train	7		2		7	7
	Tree/Pole	8	(1)	3	(1)	8	10
	Large animal	3	(2)	0		3	0
	Water	0	(6)	0		0	0
	Other	12		4		12	13
	Sum	100	(19)	30	(1)	100	100

Table A3 Distribution of crash scenario, crash type and counterpart for unrestrained occupants. The number in brackets shows the children who died as a result of drowning or fire.

		1992-2007		2008-2024	1992-2007	2008-2024
		#	(#)	#	%	%
Crash scenario						
	Single crash	23	(2)	5	58	56
	Crash with another ve	17		4	43	44
	Oncoming	*15*		*4*	-	-
	Crossing	*2*		*0*	-	-
	Front to rear	*0*		*0*	-	-
	Train	0		0	0	0
	Sum	40	(2)	9	100	100
Crash type		1992-2007		2008-2024	1992-2007	2008-2024
	Frontal impact	13		4	33	44
	Side impact	1		4	3	44
	Rear	0		0	0	0
	Rollover	12	(1)	0	30	0
	Multiple	14		1	35	11
	Other/unknown	0	(1)	0	0	0
	Sum	40	(2)	9	100	100
Counterpart		1992-2007		2008-2024	1992-2007	2008-2024
	Car	7		1	18	11
	Buss/Truck/Mini bus:	11		3	28	33
	Train	0		0	0	0
	Tree/Pole	5		3	13	33
	Large animal	0		0	0	0
	Other	17	(1)	2	43	22
	Water	0	(1)	0	0	0
	Sum	40	(2)	9	100	100