European Road Safety Observatory

Road Safety Thematic Report – Seat belt and child restraint systems

This document is part of a series of 20 thematic reports on road safety. The purpose is to give road safety practitioners an overview of the most important research questions and results on the topic in question. The level of detail is intermediate, with more detailed papers or reports suggested for further reading. Each report has a 1-page summary.

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Seat belts and child restraint systems are among the most effective measures to protect occupants of motorized vehicles from road injuries. They are designed to prevent or minimize injuries of occupants when a crash occurs. Wearing a seat belt reduces the risk of fatal or serious injuries by around 60%. Moreover, wearing a seat belt also impacts the safety of other occupants since unrestrained occupants can become a projectile: rear seat passengers who do not wear a seat belt double the risk of injuries for restrained front seat occupants. Appropriate and correctly used child restraint systems can reduce the risk of children being killed or injured by around 55 to 60%.

While the effectiveness of seat belts and child restraint systems has been scientifically proven, there are still a number of occupants that do not use a restraint system or use it incorrectly. Especially for child restraint systems (which are more complex to use than a seat belt), there is a high prevalence of incorrect use or the use of systems that are not adapted to the size of the child. While the percentage of non-use of seat belts is relatively low, these non-users have a higher crash risk than seat belt users and an increase in seat belt use could therefore save many lives. New data on the use of restraint systems are expected in 2022 as part of the EU project “Baseline” on key performance indicators.

Countermeasures

The use of seat belts and child restraint systems on all seats in vehicles equipped with seat belts has been made obligatory in all EU countries by European legislation. Studies have shown that enforcement of this legislation is an effective measure to increase the correct use of restraint systems, especially in combination with awareness campaigns. However, since police checks are difficult to automate, enforcement is relatively expensive and road users in the EU have a very low chance of being checked.

There are different measures in the field of vehicle technology that can induce the (correct) use of restraint systems. Studies have indicated that both seat belt reminders and seat belt ignition interlocks can have a great impact on seat belt use. While a seat belt reminder gives a sound signal when the seat belt is not fastened or unbuckled during the trip, seat belt ignition interlocks will prevent a vehicle from starting or accelerating. The acceptance level of seat belt ignition interlocks among road users is much lower than that of seat belt reminders. Seat belt reminders on all front and rear seats in cars and vans and on all front seats in buses and trucks have become compulsory from 1 September 2019 for new vehicle types and from 1 September 2021 for all new vehicles.

ISOFIX is a system for attaching child restraint systems in a vehicle without using a seat belt. These systems reduce the risk of incorrect installation of child restraint systems. From 2014, this system has been compulsory in all new vehicles in the European Union.

1 Highlights

- The seat belt wearing rate in front seats is more than 95% in most EU countries, while the seat belt wearing rate in the back seats is generally lower, varying between 70 and 98%.
- An estimated 25% to 50% of fatally injured car occupants were not wearing a seatbelt.
- Observational studies show that only one third (between 20 and 50%) of children are correctly restrained.
- Not wearing a seat belt also increases the injury risk of other occupants because unrestrained occupants can become a projectile in the event of a collision.
- It is estimated that 900 deaths per year could be avoided in the EU if 99% of car occupants were wearing seat belts.

2 What is the problem?

2.1 Restraint systems

Seat belts are one of the most effective measures to protect occupants of motorized vehicles from road injuries. They are passive or secondary safety devices, which means they will not prevent the occurrence of a crash but are designed to prevent or minimize the injuries of the occupants when a crash occurs (FIA Foundation for the Automobile and Society, 2009).

Because the stature of children is different from that of adults, the safety belt is not sufficient for them. Children are not only smaller, the relative proportions of their body parts and the development of their bones and muscles are different from adults. Hence, they need a system that is more adapted to their size and weight. There are different types of systems depending on the size or weight of the child. Integral systems, which are designed for babies and toddlers, have their own belt system with straps. These systems can be forward- or rearward-facing. Child restraint systems for older children are designed to guide the seat belt over the child's body. These are non-integral systems (i.e. booster cushions).

FIA (Foundation for the Automobile and Society, 2009, p.7) summarizes the main features of seat belts and child restraint systems as:

- "*Reduce the risk of contact with the interior of the vehicle or reduce the severity of injuries if this occurs;*
- *Distribute the forces of a crash over the strongest parts of the human body;*
- *Prevent the occupant from being ejected from the vehicle in an impact;*
- *Prevent injury to other occupants (for example in a frontal crash, unbelted rear-seated passengers can be catapulted forward and hit other occupants).*"

2.2 Incorrect use of restraint systems

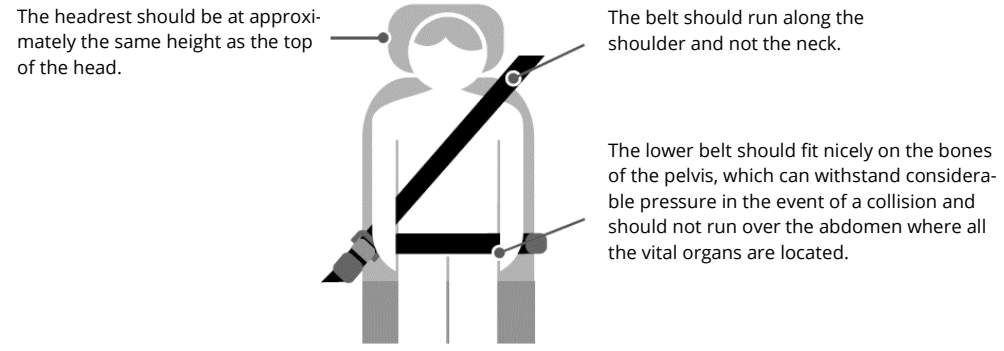
While the effectiveness of seat belts and child restraint systems in preventing injuries has been scientifically proven (see Section 5), there are still many vehicle occupants who do not use a restraint system or use it incorrectly (see Section 3). Studies have shown that incorrect use or use of an inappropriate restraint system can reduce or even eliminate the safety effectiveness of the restraint system, resulting in increased risk of fatal or serious injuries (Brown & Bilston, 2007; Kapoor et al., 2011; Lesire et al., 2007).

The correct use of a three-point seat belt is illustrated in Figure 1. Research about incorrect use of seat belts is mostly limited to children. The most common types of misuse are (Schoeters et al., 2017):

- The seat belt is placed away from the shoulder, even put under the arm or behind the back.
- The seat belt is twisted.
- There is slack in the seat belt.

When observed with children, these types of misuse often result from discomfort and can be avoided by using booster cushions, i.e. child restraint systems that guide the seat belt over the child's body.

Figure 1 Correct use of the three-point seat belt. Source: www.assureurs-prevention.fr



The most common types of incorrect use of child restraint systems are different depending on the type of system that is used. For integral systems (which have their own set of straps), the most common misuses are (Schoeters et al., 2017):

- Incorrect use of the straps, such as too much slack, twisted straps or the child's arms are outside the straps.
- Incorrect attachment of the child restraint system to the vehicle by means of the vehicle's seat belt.
- Installed in the wrong direction: child restraint systems designed for babies and some systems for toddlers should be installed facing rearward.

For non-integral systems, the most common misuses are (Schoeters et al., 2017):

- Incorrect position of the seat belt on the child's body (see above).
- The seat belt goes above or behind the arm rests of the booster cushion instead of below them.
- The back support of the booster cushion is not adapted or the seat belt guide is not used.

Apart from installation errors, children are often secured in a system that is not appropriate for their size or weight, which can also lead to serious injuries. Child restraint systems are homologated according to different weight classes (ECE R44) or according to the size of the child (ECE R129) (see Section 6.1), which means that these systems have been tested in crash tests using child dummies with different sizes to ensure that they give the best level of protection.

3 What is the prevalence of (correct) use of restraint systems?

3.1 Seat belt use in European countries

Table 1 Seat belt wearing rate of car drivers from national observational studies[1].

Country	Year	Seat belt wearing rate – Car drivers	Year	Seat belt wearing rate – Rear passengers in cars
Austria	2020	95%	2020	95%
Belgium	2018	95%	2018	86.3%
Denmark	2018	97%	2018	93%
Finland	2020	95%	2020	90%
France	2019	99.4%	2019	86.2%
Germany	2020	98.1%	2020	98.5%
Hungary	2019	95%	2019	71%
Ireland	2018	96%	2018	90%
Italy	2018	62.7%	/	/
Norway	2019	97.8%	/	/
Poland	2020	97%	2020	85%
Portugal	2017	96%	2017	77%
Slovenia	2018	94.8%	2018	78.1%
Sweden	2020	97.6%	2017	94%
Switzerland	2019	96%	2019	77%

Source: OECD, 2021

Table 1 shows the percentage of seat belt use in all European countries for which results of a recent observational study were available in the IRTAD database (2021). The comparison shows that the seat belt wearing rates for car drivers are very close: in most countries, more than 9 out of 10 drivers wear a seat belt. For rear seat passengers, the seat

[1] The figures should be interpreted with caution, since the observation and measurement methods used may vary between countries.

belt wearing rate in most countries is lower than for front seat passengers. The results show more variation and range between 98.5% in Germany and 71% in Hungary. In general, the seat belt wearing rate has increased substantially over the past twenty years.

A second data source on seat belt use is self-reported data. During the ESRA survey conducted in 20 European countries in 2018, respondents were asked how often they had worn a seat belt as a car driver or as a rear seat passenger in the previous 30 days. 83% of European respondents said they had always worn the seat belt as a driver in the previous 30 days. Ireland has the highest scores: 9 out of 10 respondents say they had always used the seat belt as a driver during the previous 30 days. Greece has the lowest scores: less than 7 respondents out of 10 say they had always used the seat belt as a driver in the previous 30 days. The study also confirms that seat belt use in the rear is less frequent: only 63% of the European respondents say that they had always used the seat belt as a back-seat passenger in the previous 30 days. The highest percentages are found in Denmark, Germany, and France, where almost 8 out of 10 respondents say they had always worn the seat belt when travelling in the back seat in the previous 30 days. The ESRA-survey did not contain questions about incorrect seat belt use (Nakamura et al., 2020).

3.2 Use of child restraint systems in European countries

The ESRA survey asked respondents if they had ever transported children in the car who were not restrained in a child restraint during the previous 30 days. On average 85% of European respondents said that they had always transported children in child restraints in this period. The highest percentage was found in Slovenia where more than 9 out of 10 respondents said they had always done so in the previous 30 days, while the lowest percentage was found in Denmark (69%) (Nakamura et al, 2020).

However, simply buckling children into a child restraint system is not enough to ensure their safety: it must also be done correctly. Several national and international observational studies (Lesire et al., 2013; Ledon, 2010; Brown et al., 2010; Hummel et al., 2010; Timothy, 2009; Piot, 2008; Decina & Lecoco, 2005; Roynard, 2012; Roynard, 2015; Schoeters & Lequeux, 2018) investigated the prevalence of incorrect (use of) child restraint systems. In this study, the installation of children in the car was observed in real-life conditions. In general, the observational studies showed that only one third (between 20 and 50%) of children were correctly restrained (without misuse) and that 15 to 30% were installed in an inappropriate system.

4 What are the causes for non-use or incorrect use of restraint systems?

4.1 Factors associated with non-use of seat belts

Different studies have identified factors that are associated with not using a seat belt:

- Type of vehicle: the seat belt wearing rate is lower amongst passengers of vans and trucks compared to car passengers (Goetzke & Islam, 2015; ETSC, 2017).

- Age: younger occupants are less likely to wear a seat belt than others (Goetzke & Islam, 2015; Webster & Norbury, 2019).
- Gender: male occupants are less likely to wear a seat belt compared to female car occupants (Goetzke & Islam, 2015; Webster & Norbury, 2019).
- Seat belt use of the driver: the seat belt wearing rate of front-seat passengers is higher when the driver wears a seat belt (Nambisan & Vasudevan, 2007).

A recent British study (Webster & Norbury, 2019) summarized the potential reasons for the non-use of seat belts as “lack of habit or forgetting; feeling safe without a seat belt, especially in the back seat; belief that seat belts can be dangerous; discomfort; peer pressure; sensation seeking; rebellion/libertarian attitudes and perceived lack of enforcement”.

4.2 Factors associated with incorrect use of child restraint systems

Observational studies which investigated the use of child restraint systems have identified several characteristics that have a strong association with incorrect use (CHILD, 2005; Hummel et al., 2010; Lalande, 2003; Ledon, 2010; Piot, 2008; Roynard, 2012; Roynard et al, 2014; Roynard, 2015; Vesentini, 2007; Schoeters & Lequeux, 2018):

- The age of the child: children require different types of child restraints at different stages of their development and some types are more likely to be misused than others.
- The size of the child: children between 110 and 130 cm in height have a relative high risk of being incorrectly restrained (Piot, 2008). Parents would more easily allow them to only use a safety belt instead of a booster cushion, because they consider the children already "big enough" not to have to sit in a child restraint system. Another risk group are children who are switched too quickly to a forward facing system.
- The type of trip and its duration/distance: on regular and short trips of less than 15 minutes (school, nursery, supermarket) where there is often a certain time pressure, there is a greater chance that the child is not properly secured. Journeys that last longer than 45 minutes and journeys at night also have a very high prevalence of improper securing because of the discomfort that children experience.
- Seat belt use of the driver: drivers who do not wear their seat belt are more prone to not securing their children or doing it incorrectly (Leopold, 2014).
- The level of education of the parents: a lower level of education is related to a higher rate of incorrect use (Piot, 2008).
- The presence of an ISOFIX system: an ISOFIX system significantly reduces the rate of incorrect use (Roynard & Lesire, 2012).

Child restraint systems are more complex to use than adult seat belts because there are numerous opportunities for errors, both in choosing an appropriate system and in installing it correctly (Brown et al., 2010). Lack of knowledge and awareness are identified as an important cause of incorrect use or non-use of child restraint systems. In observational studies performed in Belgium, it appeared that the majority of drivers were not

aware of the installation errors and about half of them minimized the importance of correct use for the child's safety (Roynard et al., 2014; Schoeters & Lequeux, 2018).

5 How dangerous is non-use or incorrect use of restraint systems?

While the percentage of non-use of seat belts is relatively small in most European countries, there is still a major proportion of car occupant fatalities where no seat belt had been worn. A study from the United Kingdom shows that more than a quarter of car occupants killed in 2017 were not wearing seat belts (ETSC, 2019), and a Norwegian study (Ringen, 2019 in Elvik, 2020) showed that between 2005 and 2010 45% of car occupants that died had not worn a seat belt. Høye (2016) estimated that the risk of having a fatal crash in Norway is more than 8 times higher for unbelted drivers compared with drivers wearing a seat belt. This difference in crash risk is further explained by the fact that not using seat belts correlates with other risk factors such as drink-driving, speeding, nighttime driving, and previous traffic offences.

ETSC (2017) estimates that 900 deaths per year could be avoided in the European Union if 99% of car occupants wore seat belts.

5.1 Effectiveness of seat belts

Table 2 Effectiveness of seat belt use in light vehicles, results of a meta-analysis.

	% difference in number of fatalities	
Use of seat belt	Best estimate	Confidence interval 95%
Drivers	-70%	[−81; −50]
Front seat passengers	-58%	[−60; −56]
Front seat occupants	-60%	[−66; −53]
Rear seat occupants	-44%	[−58; −27]
All occupants	-61%	[−69; −52]

Source: Høye (2016)

According to a meta-analysis by Høye (2016), wearing a seat belt reduces the risk of being killed by 60% for front seat occupants and by 44% for rear seat occupants compared to not wearing a seat belt (Table 2). The studies included in the meta-analysis have controlled for crash severity and other risk factors that are related to seat belt wearing such as drink-driving, speeding, and crashes at night.

Furthermore, not wearing a seat belt, especially for rear seat occupants, increases the injury risk of other occupants, especially front seat occupants. In a collision, rear seat occupants who are not restrained can become a projectile and increase the injury risk of front seat occupants either directly (by increasing the load on the front seat occupant) or indirectly (by pushing the front seat closer to the dashboard). As shown in Table 3, a meta-

analysis by Høye (2016) shows that unrestrained rear seat passengers more or less double the risk of fatalities and injuries among front seat passengers wearing a seat belt. There is very little effect (of unrestrained rear seat passengers) on front seat occupants who do not wear a seat belt.

Table 3 Effect of seat belt non-use among rear seat occupants of light vehicles, results of a meta-analysis.

Effect of unrestrained rear seat occupants	% difference in number of fatalities and injuries	
	Best estimate	Confidence interval 95%
Restrained front seat occupant fatalities	+119%	[+46; +230]
Unrestrained front seat occupant fatalities	+4%	[−3; +11]
Restrained front seat occupant injuries	+69%	[+26; +126]
Unrestrained front seat occupant injuries	+5%	[−8; +21]

Source: Høye (2016)

Only a few studies have examined the effectiveness of seat belts in heavy goods vehicles and buses. A summary by Høye (2013a) shows that for truck drivers the risk of being injured in a crash is reduced by 42% and the risk of being killed by 47%. In-depth studies of bus and coach crashes indicate that most injuries of bus occupants could have been avoided by using seat belts.

5.2 Effectiveness of child restraint systems

The effectiveness of child restraint systems in reducing the risk of injury to children has been demonstrated through scientific studies. The results vary depending on the age, the restraint system used, and the severity of the injuries. A meta-analysis by Høye (2013b) shows that in general children who are correctly restrained in an appropriate child restraint system have around 55% to 60% lower risk of being killed or injured than children who are not restrained at all.

The effectiveness of a child restraint system is highly dependent on the correct use of the seats. Scientific research has shown that incorrect use or use of an incorrectly adapted seat can have very serious consequences. It can reduce or even eliminate the safety effectiveness of a system, resulting in an increased risk of fatal or serious injuries (Brown & Bilston, 2007; Kapoor et al., 2011; Lesire et al., 2007).

This is confirmed by the meta-analysis by Høye (2013b). When comparing correctly restrained children with children who are incorrectly restrained or using an inappropriate restraint system, the risk of death or injury is around 30% to 40% lower. When a child between 1 and 6 years is restrained only by a seat belt, the risk of injuries is reduced by about 40% compared to children that are not restrained at all. However, when a child is correctly restrained in an appropriate restraint system, the risk of injuries reduces by about 60% compared to being restrained by the seat belt only. Table 4 shows these figures.

Table 4 Effectiveness of the use of child restraint systems and seat belts by children in passenger cars, results of a meta-analysis.

	% difference in number of fatalities or injuries	
	Best estimate	Confidence interval 95%
Correctly restrained vs. not restrained		
All - Fatalities	-59	[-65; -51]
All - Injuries	-56	[-65; -44]
Correctly restrained vs. incorrectly restrained		
Baby – Serious injuries	-43	[-55; -29]
All - Fatalities/ Injuries	-34	[-46; -20]
Correctly restrained vs. seat belt only		
1-6 years - Injuries	-61	[-85; +2]
Seat belt only vs. not restrained		
All - Injuries	-39	[-47; -29]

Source: Høye (2013b)

6 Which measures help to increase the (correct) use of restraint systems?

6.1 Regulation

Since 1991, the use of a seat belt is compulsory in vehicles below 3.5 tonnes that are fitted with restraints according to European legislation (Directive 91/ 671/EEC). In 2003 this obligation was extended to all vehicles (Directive 2003/20/EC). The same directive made the use of child restraint systems which are appropriate according to the size and weight of children obligatory for children less than 1.35 m in height. Many EU countries have adopted stricter regulations and have made child restraint systems obligatory up to 1.50 m (WHO, 2018).

The technical requirements of child restraint systems are defined in two UN ECE regulations. Within the UN R44 regulation there are five weight classes in which child restraint systems can be approved:

- Group 0: for children weighing less than 10 kg;
- Group 0+: for children weighing less than 13 kg;
- Group 1: for children between 9 and 18 kg;
- Group 2: for children between 15 and 25 kg;
- Group 3: for children between 22 and 36 kg.

The new standard UN R129 aims to increase the effectiveness of child restraint systems by implementing stricter technical requirements and by improving their user-friendliness

so as to reduce the risk of incorrect use. This new regulation is being introduced in several phases and is currently running in parallel with the R44 standard (Directive 2014/37). The first phase was completed in 2013 and includes a new generation of integral child restraint systems called "i-Size". The most important innovations are (United Nations Economic Commission for Europe, 2016):

- I-Size seats are approved according to the height of the child instead of the weight.
- Children up to 15 months of age are obliged to be installed rearward facing. This position offers better protection for babies and young toddlers.
- I-Size seats can only be installed with an ISOFIX-system, as this has been proven to reduce the risk of incorrect installation.
- I-Size seats offer better side protection.

Since 1 September 2021 no new child restraint systems can be type-approved according to the R44 standard. As of 1 September 2024, these child restraint systems will no longer be sold in the EU, and then only child restraint systems according to the R129 standard will be on the market.

6.2 Enforcement

Enforcement of seat belt and child restraint system legislation is based on police controls and punishment. The intention of enforcement is to make occupants of vehicles comply with the legislation and thereby increase the (correct) use of restraint systems (Alfonsi et al., 2017).

A meta-analysis by Høye (2020) shows that seat belt use increased by 19% during a period of increased enforcement and by 15% in the period after. These effects depend on the current levels of seat belt use. When seat belt use is low, an increase in enforcement can lead to a 30 to 45% increase in seat belt use. However, when seat belt use is already above 90%, an increase in police controls does not appear to have a measurable effect.

Furthermore, different studies show that enforcement actions are more effective when combined with awareness campaigns and information in the media (Høye, 2009; Nuyts & Vesentini, 2006; Kaiser et al., 2017; Alfonsi et al., 2017). Accordingly, many police departments undertake prevention and awareness actions in addition to checks. In this respect, the American "click it or ticket" campaign has served as a model for different European countries (Elvik, 2009).

However, the ESRA-survey has shown that only 26% of car drivers have a high probability of being checked by the police for wearing a seat belt on a typical journey (Nakamura et al, 2020). Enforcement of seat belt and child restraint legislation is labour-intensive and relatively expensive since seat belt checks are difficult to automate (Alfonsi et al., 2017).

Punishment of non-seat belt use can consist of fines or a combination of fines and demerit point system penalties. Different studies have shown an increase in seat belt use after the introduction of a demerit points system (Zambon et al., 2007; Gras et al., 2014). However, research has also shown that the effects can only be maintained when enforcement levels remain sufficiently high (Goldenbeld, 2017).

6.3 Education and information

The purpose of campaigns is to raise awareness about the importance of restraint systems and to motivate road users to use them. Campaigns can also inform road users about the correct use of seat belts and especially child restraint systems. The effect of campaigns is difficult to estimate, since they are mostly linked to the introduction of new legislation and to enforcement (Kaiser et al, 2017).

In a literature review by Phillips et al. (2011), different factors are identified that are important for a campaign to be effective. These are: using personal communication and roadside media (billboards and road signs); combination with enforcement (see Section 6.2); and short campaign duration (less than one month).

6.4 Vehicle technology

6.4.1 Seat belt reminders

Seat belt reminders are alarm systems that detect whether a seat belt is not fastened or unbuckled while driving and give visual and audible warnings. Studies have shown that these systems have a significant influence on seat belt wearing rates (Høye, 2016). According to ETSC (2006), seat belt reminders which meet Euro NCAP criteria[2], can induce up to 99% of drivers to wear their seat belts.

Under Regulation (EC) No 661/2009, seat belt reminders were made compulsory for the driver seat in all new passenger cars from 2014 in implementation of UN Regulation No. 16, which established the relevant technical provisions. As a result of the amendment of that UN Regulation to take account of technical progress, it is obligatory to fit all front and rear seats of passenger cars and vans, as well as all front seats of buses and trucks, with seat belt reminder systems from 1 September 2019 for new types of motor vehicles and 1 September 2021 for all new motor vehicles.

6.4.2 Seat belt ignition interlock

Seat belt ignition interlocks are systems that prevent a vehicle from starting unless all occupants are wearing their seat belt. While currently not available in cars, experiments have shown that these systems can have a great impact on seat belt use (Van Houten et al., 2014 in Høye, 2016). However, acceptance of these systems by users is much lower than for seat belt reminders (Kidd et al., 2014).

6.4.3 ISOFIX

ISOFIX is a standard system for attaching a child restraint system to the vehicle without using the seat belt (Figure 2). The seat is clicked directly into the anchorage holes of the car using attachment hooks. This system is designed for ease of use and to reduce the risk of incorrect installation. When a seat is attached using the seat belt, the routing of the belt is not always clear and the installation can require some work. There is also a risk

[2] The Euro NCAP criteria for seat belt reminders include (a) the device should not be easy to deactivate, and (b) it should give a loud and clear sound for at least 90 seconds (Høye & Elvik, 2015).

of slack in the belt during installation, which could prevent the child restraint system from staying in place in the event of a collision. Studies have shown that incorrect use decreases when using ISOFIX (Roynard & Lesire, 2012).

The ISOFIX system can only be used in cars equipped with an ISOFIX anchorage system for which the technical provisions are determined in UN Regulation No. 145. Under Regulation (EC) No 661/2009 such a system is made mandatory in all new vehicles in the European Union since 1 November 2014, but many older cars are also equipped with it.

Figure 2 The ISOFIX anchoring system. Source: ANWB

ISOFIX

7 Further reading

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