European Commission

Thematic Report

Road safety protective equipment

Mobility and Transport

This document is part of a series of 20 thematic reports on road safety. The purpose is to give road safety practitioners and the general public 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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1. Summary

Protective equipment such as helmets, seatbelts and child restraint systems have been shown to be very effective in protecting road users from injuries and fatality. However, their effectiveness greatly depends on occupants' willingness to use the equipment and whether the equipment is used correctly. If used correctly, helmets can reduce fatal injury to the head or brain by 71% on average for bicycle helmets, with motorcycle helmets reducing fatal accidents by about 42% and the chance of severe head injury by almost 70%. Seatbelts are shown to reduce risk of fatal incidents by 60% for occupants in the front of a vehicle and 44% for those in the rear. For child restraint systems, research shows that children who are correctly restrained are around 60% less likely to be injured or killed compared to unrestrained children.

While the effectiveness of these protective systems has been scientifically proven, their use is not yet ubiquitous. While compliance with legislation on drivers and passengers wearing a seatbelt is relatively high, some countries still face problems particularly with passengers in rear seats. Compliance with rules on the wearing of motorcycle helmets is also relatively high, though again with exceptions in some countries such as Greece. In contrast, bicycle helmets and child restraint systems have a high prevalence of incorrect or non-use.

Several causation factors are related to incorrect or non-use of protective systems. These factors often relate to perceived barriers such as discomfort, not matching an occupant's style, or lack of use among peer groups. For child restraint systems, the main factors of incorrect use relate more to a lack of knowledge or the relatively short lifespan of the child seat, e.g., child restraints are suitable only for children under a certain weight and height.

Programs focussing on education and reducing the perceived barriers to use can help to promote use of protective equipment. Legislation on mandatory use is positively associated with protective equipment use. It is important that any legislation is enforced in order to maintain its effects on the use. The perceived chance of being checked or fined for incorrect or non-use of protective equipment is relatively low in most EU countries.

2. What is the problem?

In this report, protective equipment is defined as helmets worn by cyclists and motorcyclists and restraint systems (seat-belts and child seats) for drivers and passengers of a motor vehicle. These are considered to be passive or secondary safety devices, meaning they do not help prevent a crash but help to reduce the injuries sustained during a crash. Protective clothing for (motor)cyclists can also be considered among protective equipment but is not discussed in this report but a number of interesting sources are provided in section 7. The purpose of this report is to give road safety practitioners and the general public an overview of the most important research questions and results on the topic in question.

2.1 Helmets

Helmets for cyclists and motorcyclists have been shown to protect from head and brain injuries (European Commission, 2021). Both bicycle helmets and motorcycle helmets have to comply with European standards but differ in what that standard entails. Bicycle helmets are tested less rigorously than helmets intended for motorcycle use.
While motorcycle helmets are mandatory in all EU countries, bicycle helmets are only mandatory in a low number of countries and often only for cyclists under a set age.
When helmets are worn they might be worn incorrectly, either due to an incorrect fit or due to incorrect fastening. This greatly reduces the protective effectiveness of the helmet.

2.2 Seatbelts and child restraint systems

Seatbelts are very effective means of protecting against road injuries for both drivers and passengers. Due to the smaller stature of children, a seatbelt for adults is not suitable for them. Children are not only smaller but also have different body proportions leaving a larger part of their abdomen uncovered by the pelvis or rib cage (Goodson et al., 1985). Therefore, children need a system that is adapted to their stature. Depending on the age and development of the child, different systems are suitable. At an early age, systems with integrated straps or seatbelts are used, such as forward- or rear-facing car safety seats. Older children require systems that allow for the correct placement of the seatbelt over the child's body (e.g., booster seats). These systems do not provide their own restraints.

FIA (Foundation for the Automobile and Society, 2009, p.7) summarizes the main features of seatbelts 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)."*

2.3 Incorrect use of protection equipment

While both helmets and restraint systems are effective at preventing injuries, their effectiveness is hindered by occupants not using or incorrectly using this equipment. The incorrect usage of helmets reduces the safety effectiveness and could even introduce additional hazards. The most common types of incorrect helmet use are discussed in section 4.1. The incorrect usage of restraint systems can reduce or even fully eliminate the safety effect. For adult occupants the correct use of a seatbelt requires the following:

- The belt should run across the shoulder and chest, with minimal slack.
- The lower belt should lie across the bones of the pelvis.
- The headrest should be at the same height as the top of the head.

For children, incorrect usage can often be a result of discomfort by the child. Usage of child restraint systems that help guide the seatbelt correctly, such as booster seats, can help to prevent discomfort. Common types of misuse of the system depends on the type of child restraint system and are discussed in section 4.3.

In addition to incorrect use of a system that is suitable for the child there are cases where the system used is not appropriate for the child's size or weight. Child restraint systems are built and tested with different weight and height classes in mind, meaning that using a system that a child has outgrown results in a reduced level of protection.

3. What is the prevalence of correct use of protective equipment?

3.1 Helmet use in European countries

3.1.1 Motorcycle helmet use

Observational studies in 12 European countries on motorcycle and moped riders and passengers show that, broadly speaking, there is very good compliance with the legislation: 95% or more of such road users wear helmets in Austria, Belgium, Czech Republic, Italy, Latvia, Malta, Poland, Portugal and Spain. However, in Bulgaria, Cyprus and particularly Greece the percentage is much lower, with Greece only showing 80% compliance for drivers. In almost all of the countries, the helmet-wearing rates for riders is slightly higher than for passengers (Yannis & Folla, 2022).

In addition to the observational studies there is data from the ESRA surveys conducted in 22 European countries in 2023. Of all European respondents, 24% indicated they had ridden a motorcycle without a helmet in the previous 30 days. Greece had the highest percentage with 42% indicating they drove without a helmet in the past 30 days. The lowest percentage was found in Luxembourg, with 7.1% (Vias Institute, 2024).

3.1.2 Cycling helmet use

Observational studies across 13 European countries show that between 14% and 90% of cyclists wear a helmet, with the lowest percentage found on urban roads in Latvia and the highest percentage found on rural roads in Spain (Yannis & Folla, 2022). Overall, rural roads showed higher percentages of helmet wearing compared to urban roads.

In addition to the observational studies there is data, from ESRA surveys of Road Users' Attitudes conducted in 22 European countries in 2023. Respondents were asked how often they had cycled without a helmet in the previous 30 days. Of all European respondents, 60% indicated they had cycled without wearing a helmet. The Netherlands had the highest percentage with over 88% indicating they had cycled without a helmet in the previous 30 days (Vias Institute, 2024).

3.2 Seatbelt use in European countries

Roadside observations in 15 European countries show more than half of the countries had seatbelt-wearing rates as high as 95% or higher

(Van den Broek et al., 2022). For passengers, the percentages are lower. Some countries show a seatbelt-wearing rate that is almost as high for both front and rear passengers as for the driver, such as Spain (94% front and 96% rear passengers) and Germany (96% front and 99% rear passengers). Other countries show a considerable difference between front and rear passengers, with front passengers wearing seatbelts more often (Van den Broek et al., 2022). In some countries the level of compliance for rear passengers is low, with Hungary at 57%, Greece at 52%, Italy at 41% and Bulgaria at 24%.
ESRA surveys from 2023 show that across 22 European countries, 15% of drivers indicated driving without seatbelt in the past 30 days, with Bulgaria scoring the highest at 34% and Luxembourg the lowest with 5.3%. For front and rear passengers, the percentage across the 22 European countries lies at 15% and 32% respectively (Vias Institute, 2024).

3.3 Child restraint system use in European countries

An observational survey looked at the extent to which child restraint systems are used (correctly) in 13 European countries. The highest percentages were observed in Austria and Germany (99% each) as well as in Poland (95%), while the values for Spain (36%), Bulgaria (46%) and Czech Republic (49%) were below half (Van den Broek et al., 2022).

ESRA surveys from 2023 show that across 22 European countries, 18.3% of drivers indicated transporting children without child restraint system in the past 30 days, with Bosnia Herzegovina scoring the highest at 33.4% and Luxembourg the lowest with 8.2% (Vias Institute, 2024).

4 Causes and prevalence of incorrect or non-use of protective equipment

4.1 Non-use or incorrect use of helmets

Factors for non-use of helmets have been identified in several studies. The most often identified factors for both motorcycles and bicycles are:

- Helmet making driver uncomfortable. This is especially often mentioned in combination with warm weather (Farag et al., 2023; Finnoff et al., 2001; Ledesma et al., 2019; Loubeau, 2000; Secginli et al., 2014; Skalkidou et al., 1999; Villamor et al., 2008).
- Perceived lack of functionality of helmets, especially at low speeds (Finnoff et al., 2001; Forjuoh et al., 2003; Ledesma et al., 2019; Loubeau, 2000; Secginli et al., 2014; Skalkidou et al., 1999; Villamor et al., 2008)
- Non-use of helmets in peer groups (Finnoff et al., 2001; Ritter & Vance, 2011; Villamor et al., 2008).
- Cycling helmets are considered to be ugly, to not match the driver's style or to negatively impact hairstyles (Forjuoh et al., 2003; Ledesma et al., 2019; Loubeau, 2000; Secginli et al., 2014; Villamor et al., 2008).

Incorrect choice of helmet or the incorrect fit of a good helmet can reduce the effectiveness of the helmet in case of a crash. Observational studies show that incorrect use of cycling helmets is around 15% (Hagel et al., 2010). The most common reasons for an incorrect fit were found to be the wrong size and incorrect adjustments (Thai et al., 2015).

Observational data on the incorrect use of motorcycle helmets is not available but data on motorcycle crashes shows that between 7% and 14% of crashes occurred with helmet ejection (Chinn et al. 2001). Loose helmet straps and poor fit have been indicated as causes of helmet loss during crashes (Thai et al., 2015). A study performed in Australia showed that two thirds of drivers were wearing helmets that were too big or too small according to manufacturer guidelines (Thai et al., 2015). Open-face motorcycle helmets were associated with a lower force required to move the helmet (Thai et al., 2015).

4.2 Non-use or incorrect use of seatbelts

Factors influencing the usage of seatbelts have been identified in several studies, with the most common factors being:

- The age of the driver or passenger, with younger people being less likely to wear a seatbelt (Goetzke & Islam, 2015)
- The location of the passenger, with the rear seat showing lower seatbelt usage than the front (Kargar et al., 2023)
- Gender, with male occupants showing lower likelihood of seatbelt usage compared to females (Goetzke & Islam, 2015; Kargar et al., 2023; Webster & Norbury, 2019)

A systematic review and meta-analysis from 2023 indicates type of vehicle and time of day as additional factors of interest for seatbelt usage (Kargar et al., 2023).

While research on incorrect usage of seatbelts is mostly limited to children there are some indications of common types of seatbelt misuse in adults:

- Not ensuring the seatbelt has no slack remaining.
- The seatbelt is placed away from the shoulder. This could be put under the arm, behind the back or across the neck.

4.3 Incorrect use of child restraint systems

Observational studies have identified several factors that are associated with incorrect use of child restraint systems. Some studies found that at least 50% of children were not correctly fastened (Roynard, 2012; Vesentini & Willems, 2007). The most common factors involved in incorrect use of child restraint systems are (Durbin and Hoffman, 2018; Schoeters et al., 2017):

- The age, height and weight of the child (Lalande et al., 2003; Roynard et al., 2014; Vesentini & Willems, 2007; Willis et al., 2004). Children around 110 to 130 cm are at increased risk, as are overweight children.
- Activities of the child during driving, with engagement in conversation and lap-based activities increasing odds of incorrect use by nearly 2,5 times (Cross et al., 2023)
- Lack of ISOFIX[1] module increases the incorrect use of restraint systems significantly (Roynard et al., 2014)

[1] The international standard for attachment points for child safety seats in passenger cars

- Where the system was purchased, with systems bought in specialty shops more likely to be used correctly (Roynard et al., 2014)
- Duration of the trip, (Decina & Lococo, 2005; Glassbrenner, 2005; Vesentini & Willems, 2007)

Because child restraint systems are more complex to use than seatbelts there is a higher likelihood for error.

5. How dangerous is incorrect or non-use of protective equipment?

5.1 Non-use or incorrect use of helmets

An analysis of 61 international studies shows that wearing a motorcycle helmet reduces fatal accidents by about 42%, and the chance of severe head injury by almost 70% (Liu et al., 2008).

A recent systematic review and meta-analysis found no difference in the occurrence or severity of facial injuries between the types of helmet used (full-face or open face) (Cavalcante et al., 2021). However, only a low number of studies was used in the meta-analysis, and some not-included studies do show that a full-face helmet offers better facial protection compared to other helmets (e.g.: Wu et al., 2019). Several studies show that wearing a motorcycle helmet incorrectly significantly reduces the protection it offers (Cavalcante et al., 2021; Yu et al., 2011).

Bicycle helmets have been shown to protect cyclists from head and brain injuries (European commission, 2021; European commission, 2024). For crash- or fall-related injuries a helmet has been shown to reduce fatal injury to the head or brain by 71% on average (Høye, 2018). Incorrect use of a cycling helmet increases the odds of head injury significantly (odds ratio of 3.38) compared to cases where the helmet fits very well (Romanow et al., 2014). For children, the risk of head injury in a crash doubles when wearing a poorly-fitting helmet (Rivara et al., 1999).

5.2 Non-use or incorrect use of seatbelts

A meta-analysis from 2016 shows that wearing a seatbelt reduces the risk of fatal incidents by 60% for occupants in the front of a vehicle and 44% for those in the rear, compared to not wearing a seatbelt (Høye, 2016). Estimates by the ETSC predict around 900 deaths could be

avoided in the EU if 99% of vehicle occupants wore seatbelts (ETSC, 2017). Data on seatbelt usage in 2021 shows that for incidents where the usage of seatbelt was known, over 26% of fatal incidents in cars had the driver or passengers not wearing seatbelts (European Commission, 2023).

A rear passenger not wearing their seatbelt not only increases their own risk of injury but also that of the other occupants of the vehicle. The 2016 meta-analysis shows that when a rear seat passenger is unrestrained, the injury and fatality risk of the front occupants almost doubles (Høye, 2016).

An incorrectly fitted seatbelt can result in a so called "seatbelt sign" where an impression of the seatbelt is visible on the skin of the person who wore it during a crash. This sign is often an indication that there are intra-abdominal injuries, which most likely would have been prevented had the seatbelt been worn correctly (Abbas et al., 2011)

5.3 Non-use or incorrect use of child restraint systems

The effectiveness of child restraint systems depends on the age of the child and the type of system used. A meta-analysis from 2013 shows that children who are correctly restrained in a suitable system have around 60% less risk of injuries or even fatality compared to unrestrained children (Høye, 2013). Incorrect use of the child restraint system can significantly impact its effectiveness, resulting in an increased risk of serious injury (Brown & Bilston, 2007).

A meta-analysis of the effect of booster seats reports on several studies showing different results regarding the effectiveness compared to seatbelts (Asbridge et al., 2018). Some of these studies show a positive effect of booster seats in reducing the risk of injury (e.g. Arbogast et al., 2009; Winston et al., 2000), while others show mixed results (House et al., 2012; Rice et al., 2009).

6. What can be done to help increase the use of protective equipment?

6.1 Helmet use

All EU countries have laws mandating the use of a motorcycle helmet (WHO, 2020). There are 15 EU countries that have some form of bicycle helmet laws. The vast majority of countries have laws for cyclists under a certain age only, with two countries mandating a helmet for all cyclists on certain roads (Esmaeilikia et al., 2018). Spain mandates the use of helmets when cycling on rural roads, except when cycling uphill while in Slovakia the law applies to urban roads. Spain shows the highest percentage of cyclists wearing helmets on rural roads with 90%, but only 33% of urban cyclists were found to be wearing helmets (Yannis & Folla, 2022).
Even when no laws currently exist in a country, belief in the existence of (bicycle) helmet laws has been shown to increase helmet wearing rates (Valero-Mora et al., 2020).
Perceived barriers (see also chapter 4.1) to helmet use can be in part mitigated by interventions that educate and focus on normative beliefs and peer influence, and on the reduction of those perceived barriers (Ledesma et al., 2019). The use of behaviour change campaigns together with education was successful in Denmark, resulting in an increase of cycling helmet wearing rates from 6 to 50% (Olsson, 2023).
With regard to incorrect use of helmet, the development of a "fit-index" to help find the correct helmet has been proposed (Ellena et al., 2016).

6.2 Seatbelt use

The use of a seatbelt in vehicles below 3.5 tonnes has been compulsory in the EU since 1991, and has been extended to all vehicles in 2003 (Directive 91/671/EEC; Directive 2003/20/EC). Enforcement of this legislation is based on police controls and automated systems. A review from 2021 indicates the need for effective enforcement to ensure legislation has the desired effect (Elvik, 2021). Combining enforcement with educational campaigns has been shown to increase the effectiveness (Alfonsi et al., 2017; Kaiser et al., 2017; Lourens et al., 2024). However, the perceived likelihood of being checked by the police for wearing a seat belt is relatively low in a number of European countries, with only 13% of people asked in Sweden indicating a perceived chance of being checked while Poland shows almost 55%

(Van den Broek et al., 2022).

Usage of a demerit system to punish non-use of seatbelts has shown potential in reducing its occurrence (Gras et al., 2014). However, recent research has shown that these gains in seatbelt use only last as long as enforcement levels remain high enough (Goldenbeld, 2017).

6.3 Child restraint system use

Legislation on the use of child restraint systems appears to be positively associated with their use, correct use and the reduction of injuries. However, the exact effects are unclear and differ depending on the type of legislation and across different populations (Sartin et al., 2021).
Different interventions to increase child restraint systems without legislation show mixed results with regards to increased awareness and knowledge (Glerum et al., 2019).
Since 2014 the ISOFIX system is mandatory in all new vehicles in the EU. This system has been shown to reduce the instances of incorrect use of child restraint systems (Roynard & Lesire, 2012).

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