European Road Safety Observatory

Road Safety Thematic Report – Serious injuries

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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Contents

Summary

Road traffic injuries

The number of road traffic fatalities has traditionally been the main indicator in monitoring road safety performance. However, road crashes also cause numerous injuries: in the EU it is estimated that, for every life lost, five more people suffer serious injuries with life-changing consequences. And the number of serious injuries has generally been declining at a slower pace than fatalities. Moreover, the EU Road Safety Policy Framework 2021-2030 sets a new target to halve - for the first time - the number of serious injuries (in addition to deaths) on European roads by 2030.

A new common definition of a serious injury has been established which defines a serious road injury as a road traffic casualty with an MAIS (*Maximum Abbreviated Injury Scale*) score of 3 or more (MAIS3+). EU Member States undertook to collect data on MAIS3+, as part of the 2017 Valletta Council conclusions on road safety. This relies on the use of hospital data instead of police data. As both data sources are limited in the information they contain, the preferred method of collecting injury data is by linking police and hospital records.

The most common types of injury differ by road user type and crash characteristics. Head injuries for example tend to occur among pedestrians, cyclists and car occupants, but less frequently among motorcyclists. Thorax injuries are more frequent among car occupants and motorcyclists.

Road traffic injuries, severe or not, can have a long-lasting impact on casualties' health. Long-term consequences appear to be greater for pedestrians and motorcyclists. Road traffic accidents also cause a substantial cost to society, with injuries accounting for a much larger share in total costs than fatalities.

Countermeasures

A number of measures that are effective in preventing fatalities can also reduce injury severity. However, crashes causing serious injuries might differ from fatal crashes, possibly requiring different countermeasures specifically aimed at tackling serious injuries.

Forgiving road designs and environments minimise the impact of a collision if a crash has become unavoidable. Examples are the installation of roadside barriers, motorcycle-friendly guardrails, forgiving cycle paths, and appropriate speed limits.

Protective equipment such as protective clothing and helmets provide additional protection to cyclists and powered two-wheelers, mitigating the risk of serious injury.

Many *vehicle-related passive safety measures* (seatbelts, frontal and side airbags, pop-up bonnets, pedestrian airbags, anti-whiplash systems, and child restraint systems) are regulated by European vehicle safety legislation. Consumers are informed about the safety performance of cars through programmes such as EuroNCAP.

Monitoring developments in the number of persons seriously injured according to the MAIS3+ definition requires collecting new injury data for many countries.

1 Highlights

- For every life lost, it is estimated that in the EU five more people suffer serious injuries.
- The number of serious injuries has generally been declining at a slower pace than fatalities and has stagnated during most of the last decade.
- Long-term consequences appear to be greater for pedestrians and motorcyclists.
- Cyclists in particular are overrepresented among MAIS3+ casualties compared to fatalities.
- About 90% of the total burden of road injury is attributable to the lifelong disability experienced by on average 25% of all MAIS3+ casualties.

2 What is the problem?

2.1 Definition and collection of injury data

In many countries, the number of road traffic fatalities is typically used for monitoring road safety performance. However, road crashes also cause numerous injuries. It is estimated that for every life lost, five more people suffer serious injuries (European Commission, 2020b). Generally, there are two main sources of data on injuries: police crash data and hospital trauma data registries. The definition of what constitutes a serious injury depends on the data source used.

2.1.1 Road traffic injuries in police crash data

Police crash data have traditionally been the main source of information on road traffic accidents and injuries. They provide the official data for most countries' statistics, at both the national (a country's own official statistics) and European level (the CARE Database). Even though there is no common international definition for a traffic injury, most European countries adopt the set of definitions developed by ITF/EuroStat/UNECE which classify road victims into three categories of injury severity: fatality, serious injury, and slight injury. According to these definitions, a fatality is a person who dies within 30 days following the crash as a result of the injuries suffered. A person seriously injured is defined as any person injured who was hospitalized for a period of more than 24 hours. The category of slight injuries then includes any other person injured excluding fatalities and those seriously injured (ITF/EuroStat/UNECE, 2019).

Nevertheless, other definitions of a serious road injury are also employed by several countries, for example definitions based on the type of injury, the inability to work, or the length of recovery. Such differences in definitions make comparisons between countries and target-setting at a EU level quite challenging since this could imply that an injury recorded as "serious" in one country might be recorded as "slight" in another country (Yannis et al., 2014).

Data collected by the police usually contain very detailed information about accidents. However, both underreporting and misreporting pose challenges to the completeness and accuracy of the data. Crashes could be missing from the official records since the police are not always alerted to the accident, either because there was no opponent, no one was (seriously) injured, or the parties involved reached a private settlement (Imprialou & Quddus, 2019; Nuyttens et al., 2018).

All countries experience under-reporting, though to varying degrees. Research shows that under-reporting mainly concerns characteristics such as injury severity and road user type (Imprialou & Quddus, 2019). Under-reporting seems to be higher for less severe accidents (Derriks & Mak, 2007), when no motorised vehicle is involved (Houwing, 2017), or when the casualty is a vulnerable road user (Nuyttens, 2013).

Under-reporting rates are also affected by injury misreporting (Yannis et al., 2014). Misreporting occurs when victims are incorrectly registered as slightly or seriously injured. Most information on the accident is gathered at the scene of the crash. However, the nature and the severity of the injuries are often not evident for the police, who are not medically trained. Many life-threatening injuries, such as injuries to internal organs, cannot be observed at the scene and require clinical diagnosis in hospital (ETSC, 2007). Although the medical dimension of the on-the-spot assessment can be later verified by the hospital, in practice this rarely happens (IRTAD, 2011; Nuyttens et al., 2018).

2.1.2 Road traffic injuries in hospital trauma data registries

Maximum Abbreviated Injury Scale (MAIS)

To harmonise the definition of “serious injury” across EU countries and in order to arrive at a more accurate total number of seriously injured traffic victims in the EU, a new common definition of a serious road injury was established by the High Level Group on Road Safety in 2013 (European Commission, 2013). EU Member States committed to collecting data on MAIS 3+, as part of the 2017 Valletta Council conclusions on road safety[1].

The new definition is based on the Abbreviated Injury Scale (AIS). AIS is a globally accepted anatomical-based trauma classification of injuries published by the Association for the Advancement of Automotive Medicine (AAAM). It is used by medical professionals to describe injuries and rank their severity on an ordinal scale from 1 (minor injuries) to 6 (non-treatable injuries). As one person can have more than one injury, the Maximum Abbreviated Injury Scale (MAIS) is the maximum AIS of all injury diagnoses for a person (ETSC, 2021). The High Level Group established the definition of a serious road injury as a road traffic casualty with an MAIS of 3 or more (MAIS3+) and identified three main methods to collect this data. All three methods are in one way or another based on hospital data (European Commission, 2013):

1. create a link between police and hospital data;
2. report the number of injured based on data from hospitals;
3. continue to use the police data but apply a correction coefficient derived from samples of hospital data.

[1] https://data.consilium.europa.eu/doc/document/ST-9994-2017-INIT/en/pdf

It was recommended that from 2015 all EU countries provide data on serious injuries based on this new definition. The SafetyCube project has published a study on serious road traffic injury data reporting practices which provides guidelines and recommendations for each of the three methods (Pérez et al., 2016; SafetyCube Consortium, 2016).

As MAIS is based on medical information, it substantially reduces the risk of misreporting (EC, 2013). Even so, hospital data are also unlikely to provide a perfect estimate of the actual number of MAIS3+ traffic victims due to flaws in the hospital's registration systems or simply because not all casualties go to the hospital after a road crash (Pérez et al., 2016). In addition, hospital data are likely to include only minimal information on the circumstances of a crash. Linking police and hospital records would therefore provide the most complete set of information on road injuries, reducing the risk of both under-reporting and misreporting. This is therefore seen as the preferred data collection method in the long term (European Commission, 2013).

Burden of injury

The health burden of road injuries can also be expressed in terms of Disability Adjusted Life Years (DALYs). This measure of population health loss combines mortality, expressed in Years of Life Lost (YLL), and disability, expressed in Years Lived with Disability (YLD). One DALY equals one healthy life year lost either due to premature death or due to a non-fatal injury (Murray, 1994).

The DALY approach originates from the field of public health and was originally developed by the World Health Organization and the World Bank to estimate the "Global Burden of Disease" (Murray & Lopez, 1996). In recent years it has also found its way into road safety research. Studies on the burden of road injuries have been carried out in Sweden (Tainio et al., 2014), the Netherlands (Weijermars et al., 2016), Belgium (Dhondt et al., 2013), and France (Lapostolle et al., 2009). Within the European SafetyCube project, YLDs have been calculated in six European country locations[2] (Weijermars et al., 2016).

2.2 Reported serious road traffic injuries in the EU

The numbers of seriously injured casualties registered according to countries' national definitions are not comparable, because both the definitions and the levels of under-reporting vary widely between countries. The figure below therefore indicates the percentage change in the number of seriously injured, taking the numbers registered in 2010 – based on countries' national definitions – as a starting point (ETSC, 2021).

During most of the previous decade, the number of serious road traffic injuries has stagnated. Progress overall in reducing this number has been considerably less than is the case with road fatalities. Over the period 2010-2020, the EU27 collectively reduced the number of road deaths by 37%, while serious injuries showed only a smaller reduction estimated by ETSC at around 14%. However, both results are distorted by a considerable reduction in 2020 (Figure 1). This is likely a consequence of Covid-19 lockdowns and travel restrictions across Europe in 2020.

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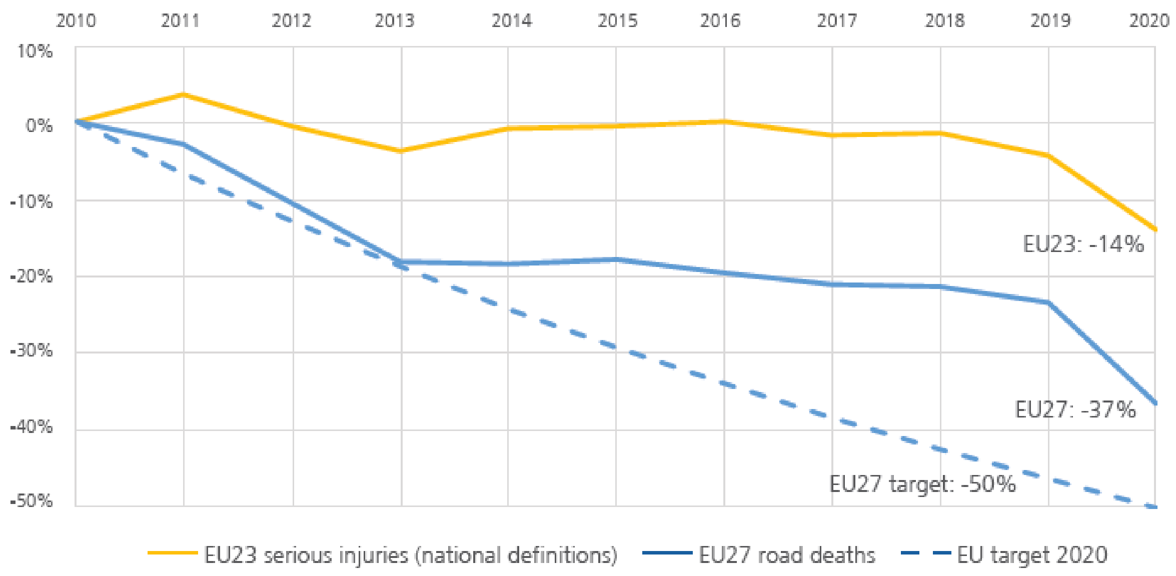
[2] Austria, Belgium, England, The Netherlands, Rhône region in France, and Spain

Figure 1 Reduction in the number of road deaths in the EU27 since 2010 plotted against the EU target for 2020 and reduction in the number of serious road traffic injuries in the EU23* based on countries' national definitions.



**EU23: EU27 excluding IT, FI and IE due to inconsistent data trend and LT due to lack of data. EU23 reduction in serious road traffic injuries is an ETSC estimate as serious injury data for 2020 were not available for some countries at the time the report went to print.*

Source: ETSC (2021)

With effect from 2015, EU Member States started to report data on serious injuries based on the new common MAIS3+ definition. According to an estimate by the European Commission, 120,000 people were seriously injured on Europe's roads in 2019. This means that for every life lost, five more people suffered serious injuries (European Commission, 2020b).

Although it is too early to use this data to compare the number of seriously injured between countries (due to different data collection methods and varying quality of the data), the first estimates indicate that the majority of those seriously injured were vulnerable road users, i.e. pedestrians, cyclists, and drivers of powered two-wheelers (European Commission, 2016). Based on data from the Netherlands, the Rhône region in France, Spain, and England, there is a strong indication that cyclists in particular show a high number of MAIS3+ casualties compared to the number of cyclist fatalities (Reed et al., 2017).

The proportion of MAIS3+ casualties within the total number injured increases as a function of age. Older road users are more prone to serious injury due to their physical vulnerability (Airaksinen et al., 2020; Leo et al., 2021; Weijermars et al., 2014). However, younger road users also take up a high proportion of MAIS3+ casualties, relative to the number of younger fatalities (Reed et al., 2017). These younger casualties are commonly pedestrians and, to lesser extent, cyclists (Aarts et al., 2016; Reed et al., 2017). Also important to highlight is the high proportion of youngsters among severely injured car occupants. This is in contrast to fatal car crashes in which adults have generally been found to dominate within the data (Aarts et al., 2016; European Commission, 2020a).

The distribution of seriously injured casualties by gender differs depending on the travel mode. For example, Aarts et al. (2016) investigated severely injured persons in the Netherlands, the Rhône region in France, Spain, and England: they found approximately equal proportions of male and female pedestrians in all countries, while on the other hand cyclists showed large variations in terms of predominant gender, from around half male in the Netherlands to more than 80% male in the Rhône region, Spain and England (Aarts et al., 2016; Reed et al., 2017). Seriously injured motorcyclists, drivers of other powered two-wheelers as well as car occupants are dominantly male (Aarts et al., 2016).

In 2018, the European Commission announced a new 50% reduction target for road deaths and, for the first time, also for serious injuries between 2020 and 2030. The new target is based on the MAIS3+ definition and is part of the EU road safety policy framework 2021-2030 (European Commission, 2020b).

3 Injury patterns and mechanisms

The different injury patterns and mechanisms for each road user type are discussed below. These are common findings of studies conducted in different European countries. Although there are still some country-specific differences which could result in particular crash characteristics, these findings can be considered quite representative for the entire EU. Insights into injury patterns and mechanisms assist in identifying and evaluating effective measures to prevent or limit frequently occurring serious injuries. (For a detailed discussion on injuries sustained by senior road users, see *Thematic Report Seniors, EC, 2021*.)

3.1 Pedestrians

Pedestrians most often sustain serious injuries to the head or neck, the thorax, and both upper and lower extremities, though the order of prevalence differs between countries (Aarts et al., 2016; Airaksinen et al., 2020; Leo et al., 2021; Saadé et al., 2020). Aarts et al. (2016) found that the lower extremities particularly suffer injury when the pedestrian is hit by a car or on 30 km/h roads, whereas injuries to the head are more prevalent in collisions on roads with a speed limit above 30 km/h and in collisions with heavy goods vehicles. The lower extremities are often the first point of impact in a pedestrian-car collision. When a pedestrian is hit at a lower speed, the collision is of the type “hit and fall over”. In collisions at higher speed, pedestrians are also likely to hit their head against the bonnet or windscreen before falling to the ground. Hence higher speeds are associated with “hit and thrown”. In addition to speed, the type of opponent is also a determining factor: in a collision with a heavy goods vehicle or SUV, the initial point of impact will be higher up on the body (Aarts et al., 2016; Saadé et al., 2020).

3.2 Cyclists

Cyclists suffer severe injury mostly when they are hit by a car, though in some countries single bicycle crashes are also very common. For example, in the Netherlands almost 4 out of 5 cyclists are injured in crashes without a motorised vehicle being involved (Reed et al., 2017). The comparable figure across the EU for fatal cyclist accidents not involving a motorised vehicle is estimated to be one quarter of all cyclist fatalities (EU CARE database, n.d.; Schepers et al., 2017).

The most frequently injured body regions of MAIS3+ cyclists are the head, followed by the lower extremities, and the thorax (Aarts et al., 2016; Airaksinen et al., 2020; Foley et al., 2020; Leo et al., 2021) with traumatic brain injuries and bone fractures as the most prevalent types of injury (Helfen et al., 2017; Leo et al., 2019).

The lower extremities are frequently injured in single bicycle crashes and in crashes with lower impact speed, e.g. in urban areas or when the cyclist is hit by another cyclist (Aarts et al., 2016; Weijermars et al., 2016a). However, there is no clear profile for certain types of crashes where head injuries are more common. Head injuries are found to be more prevalent in single bicycle crashes in a Finnish study by Airaksinen et al. (2020), whereas Dutch data indicate that head injuries are most prevalent in cyclists injured in a crash with a motorised vehicle (Reed et al., 2017; Weijermars et al., 2016a).

3.3 Motorcyclists

The thorax and the lower extremities are the most frequently injured body regions in MAIS3+ motorcyclists, followed by head injuries and injuries to the upper extremities (Aarts et al., 2016; Airaksinen et al., 2020; Forman et al., 2012). Thorax injuries are most frequently the result of single motorcycle crashes and collisions with fixed objects. Lower extremity injuries are particularly prevalent in crashes with a passenger car. As with pedestrians and cyclists, the first impact point on the body when hit by a passenger car are the legs. The collision can lead to the motorcyclist falling down and landing awkwardly. Impact with the ground may cause further injury, depending upon how the motorcyclist falls (Aarts et al., 2016).

Noteworthy is the lower percentage of head injuries among MAIS3+ motorcyclists compared to MAIS3+ pedestrians and cyclists. This can be attributed to the protective effect of helmets, which are worn by almost all motorcyclists in the EU, as opposed to a much lower helmet user rate among cyclists (Aarts et al., 2016). Motorcyclists are more likely than other road user types to suffer a pelvic injury (part of the lower extremities). An Australian study shows that the most frequent cause of this type of injury is the pelvis hitting the motorcycle's fuel tank during the collision (Meredith et al., 2016).

3.4 Car occupants

MAIS3+ car occupants most frequently suffer injuries to the thorax, the head and the lower extremities (Aarts et al., 2016; Airaksinen et al., 2020). Aarts et al. (2016) found indications that thorax injuries occur more often in crashes with another car and when a seatbelt is used but the car has no (functioning) airbag. Thorax injuries can also be the result of seat belts and airbags that press on or hit the upper part of the body with great force when the car crashes at high speeds (Aarts et al., 2016). Car occupants often suffer head injuries in collisions with a fixed object or with a heavy vehicle, due either to intrusion of the object into the car occupant's space or to partial ejection of the head through the window onto the object. There are indications that injuries to the lower extremities occur mostly in car-to-car crashes, crashes with a fixed object, or crashes at lower speeds (e.g. 50 km/h roads). Most occupants suffer this injury due to impact with the interior of the vehicle during the collision (Aarts et al., 2016; Reed et al., 2017).

Although spinal cord injuries occur less frequently, these injuries often result in long-term disabilities (Reed et al., 2017). Reed et al. (2017) found that spinal cord injuries are more common among car occupants than among any other road user. Rollover crashes appear to be the main type of crash causing these injuries due to contact with an intruding roof.

4 Consequences of road traffic injuries

4.1 The long-term health impact of road traffic injuries

Studies have consistently shown that road traffic injuries can have a substantial and long-term negative impact on the life of the casualties. Many people report negative functional consequences, including pain, fatigue, mobility problems, and problems carrying out daily activities. For example, a French case study showed that three quarters of MAIS3+ casualties have not fully recovered three years after the crash (Weijermars et al., 2016). Furthermore, a burden of injury study using data from six European country locations[3] showed that about 90% of the total burden of road injury is attributable to lifelong disability which is experienced by on average 25% of all MAIS3+ casualties (Weijermars et al., 2016).

The risk of long-term impairment is found to increase as a function of injury severity. However, it should be noted that less severe injuries are much more prevalent than serious injuries and can also involve a risk of permanent impairment. As a consequence, the vast majority of non-fatal injuries leading to medical impairment are slight to moderate injuries. One out of three less severely injured casualties have not fully recovered three years after the crash, making them just as relevant from a health impact perspective (Weijermars et al., 2016).

Long-term consequences appear to be greater for pedestrians and motorcyclists. Cyclists on the other hand, though also vulnerable road users, often report better recovery and appear less likely to experience persistent functional limitations (Weijermars et al., 2016).

[3] Austria, Belgium, England, The Netherlands, Rhône region in France, and Spain

4.2 The social cost of road traffic injuries

The total cost of road crashes in Europe is estimated at €280 billion (van Essen et al., 2019; Wijnen et al., 2017). This corresponds to almost 2% of EU GDP[4]. However, this is still likely to be an underestimate of the true total cost caused by traffic accidents since many countries do not correct accident numbers for under-reporting. It is estimated that, if unreported casualties and crashes are taken into account, the total costs are in the order of magnitude of at least 3% of GDP (Wijnen et al., 2017).

Crash cost estimates indicate that within total costs the proportion taken up by injuries is on average 2.4 times higher than the proportion taken up by fatalities (Wijnen et al., 2017). However, these results differ substantially between countries and can be explained by differences in the definition of a serious injury and in reporting rates.

5 Countermeasures

Most measures aimed at preventing fatal accidents can also be effective in reducing injury severity. However, relying on these measures alone might not be sufficient since they are likely to have a stronger effect on the number of fatalities than on the number of seriously injured (Reurings et al., 2012). Crashes resulting in serious injuries may differ in terms of crash characteristics compared to fatal crashes, which would require different countermeasures (Aarts et al., 2016; Reed et al., 2017). This chapter lists measures which, in the event of an accident becoming unavoidable, will mitigate the consequences of the accident in terms of injuries. Examples of measures that are explicitly aimed at serious injuries are anti-whiplash systems and protective clothing for powered two-wheelers (PTW).

5.1 Infrastructure

One way to minimise the consequences of injury crashes through road infrastructure is to design forgiving roads. Forgiving road designs and environments offer sufficient time and space to regain control of the vehicle should the driver leave the road and minimise the impact of the collision if a crash has become unavoidable. Examples of such infrastructural interventions to lessen injury severity are:

Roadside barriers
Roadside barriers are widely used to mitigate the effects of crashes and to prevent vehicles from leaving the road surface and hitting roadside hazards or crossing into the path of oncoming vehicles. Some studies have indicated that the presence of safety barriers results in a reduction in the severity of crashes (Botteghi et al., 2017).

Motorcycle-friendly guardrails
For motorcyclists, the risk of being killed or sustaining serious injuries is usually increased by colliding with side railings (Høye, 2014). One way to prevent this is by fitting a safety board at the bottom of the guardrail which prevents a motorcyclist from sliding

[4] EU27 + Iceland, Norway, Serbia, Switzerland and the UK.

underneath the railing (Slootmans et al., 2017). The technical requirements for these safety systems are regulated by several European norms (e.g. CEN/TS 17342:2019).

Forgiving cycle paths
Similar to forgiving road designs for motorised vehicles, forgiving cycle paths entail, amongst other things, an obstacle-free environment and forgiving road edges and curbs. Forgiving cycle paths may help avoid single bicycle crashes, which in several countries are the main cause of serious injuries among cyclists (SWOV, 2020). For more information on cyclists and related measures, see *Thematic Report Cyclists, EC, 2021*.

Appropriate speed limits
Not only will lower speeds prevent accidents but a lower impact speed will also reduce injury severity when an accident cannot be avoided (Aarts et al., 2016; Saadé et al., 2020). Speed limits should be credible and suited to the type of road, the nature of the road users, and potential conflicts between different types of road users (Nuyttens et al., 2018). For more information on the impact of speed and related measures, see *Thematic Report Speed, EC, 2020*

5.2 Road users

For cyclists and powered two-wheelers (PTW), it is especially important to be well protected, since their own vehicle does not offer them any protection (Weijermars et al., 2014). Protective equipment consists of protective clothing and helmets.

Protective clothing for PTW is designed to mitigate the risk of injury from contact with another vehicle, the road surface, or other road furniture. It provides protection through impact resistance, abrasion resistance, or by distributing mechanical loads on the body. For example, armoured leather trousers can enclose a leg fracture and prevent more serious open fractures or wounds, which can then speed up recovery and improve long-term health outcomes. In a best case scenario, the mechanical load is distributed by armoured parts to such an extent that injury can be avoided altogether (Reed, 2017c).

Cycle and PTW helmets provide additional impact protection for the head. Literature shows that both cycle and PTW helmets are associated with reduced risk of serious injuries to the head and face compared to not wearing a helmet. Meta-analyses have shown a reduction in the risk of serious head injuries by approximately 60% for PTW helmets (Høye, 2016) and cycle helmets (Høye, 2018) . However, despite the overall positive protective effect, there is evidence that in some circumstances, injuries to the neck may not be reduced by wearing a helmet (Reed, 2018a, 2018b). Furthermore, in some cases cycle helmets may increase the risk of brain injury due to increased rotational acceleration in the brain during impacts. However, such injuries are rare and this risk is outweighed by the injury-reducing effects (Høye, 2018).

5.3 Vehicle related

5.3.1 Passive safety measures

Many vehicle-related measures are aimed at improving the passive safety of vehicles. Passive safety means in this context systems and features of the vehicle which, in the event of an accident, are designed to prevent or reduce injury to the vehicle occupants or other parties involved in the accident. This is in contrast to active safety measures which are meant to prevent accidents altogether (Nuyttens et al., 2018; Weijermars et al., 2014).

Seatbelts

The main function of a seatbelt is to reduce the risk of injury and the risk of being ejected from the car by restraining the occupant to the vehicle. Using a seat belt reduces the risk of being killed or injured by approximately 60% among drivers and front seat passengers and by 44% among rear seat passengers (Andersson, 2017). The use of seatbelts is obligatory in all EU countries. For more information on seatbelts, see *Thematic Report Seatbelts and Child Restraint Systems, EC, 2021*.

Frontal and side airbags

The purpose of airbags is to protect the head, neck, and chest in frontal and side collisions. Studies indicate the significant benefits of airbags, showing a reduction of injuries and injury severity. The effect on less severe injuries is probably limited since airbags do not deploy below a certain impact severity. Moreover, the protection level depends on seat belt usage. Regulations regarding frontal load limits make it difficult to purchase a passenger car without a frontal airbag (Johannsen, 2018). Side airbag systems are also widely available, though in some vehicle models they are not fitted as standard but offered as an option to the customer (Jänsch & O'Connell, 2017).

Pop-up bonnets and pedestrian airbags

Pop-up bonnets lift up in the event of a collision and absorb part of the impact energy. This technology helps to meet the safety requirements for energy absorption of the bonnet. Pop-up bonnets are often installed alongside pedestrian airbags. These airbags deploy on the outside of the vehicle from the gap made by the pop-up bonnet at the base of the windscreen, offering additional protection to pedestrians and cyclists. Studies show that either of these technologies on their own can reduce serious head injuries but that much larger benefits accrue when these technologies are combined (Høye, 2017b; Reed, 2017a). As from 2022, a new regulation will enlarge the current head impact zone for pedestrians and cyclists by means of improved energy absorbing measures, notably including the front windscreen (European Union, 2019).

Anti-whiplash systems

Whiplash injury to the neck is one of the most frequently reported injuries on European roads. A whiplash injury, though considered as less severe, often leads to long-term impairment with approximately 50% of patients reporting neck pain symptoms 1 year after their injuries (Carroll et al., 2009). Whiplash can occur in all impact directions, though the injury is most frequently observed in rear-end collisions (Leopold, 2016). Research indicated that anti-whiplash systems such as the vehicle seat and the head restraint are the principal means of reducing neck injury (D'Elia & Newstead, 2021; Farmer et al., 2003; Svensson, 2017).

Child restraint systems

Child restraint systems aim to reduce injuries to children in motor vehicle crashes by providing both additional impact protection and optimal restraint. Research has shown that the appropriate and correct use of child restraint can reduce the risk of fatal and serious injuries as compared to inappropriate use (30% to 40% lower risk) or no use of a restraint system at all (over 50% lower risk) (Høye, 2013; Reed, 2017b). For more information on child restraints, see *Thematic report Seatbelts and Child Restraint Systems, EC, 2021*.

5.3.2 Vehicle safety legislation

In Europe, all new cars must meet a number of safety requirements to protect both vehicle occupants and vulnerable road users. One key vehicle safety standard that has recently been introduced is a new mandatory type of side impact crash test that focuses on a vehicle side collision with a rigid narrow pole. Side impact crashes are a type of crash that often leads to serious injuries in car occupants (Aarts et al., 2016). This pole side impact test requires better protection in the head strike area of car occupants with interior parts of the vehicle. Another new type of crash test that will also be added focuses on improving restraint systems (i.e. airbag and safety-belt combinations) to encourage adaptive restraints which protect a broader demography of occupants. The new regulations will be effective from 2022 (European Union, 2019).

5.3.3 Consumer information programmes

Consumer information programmes provide potential car buyers with objective information about the safety performance of cars and encourage manufacturers to implement evidence-based safety designs beyond legislative norms (European Commission, 2021a). One example of such a test programme is the European New Car Assessment Programme (EuroNCAP). EuroNCAP aims to assess a car's safety performance before it is used on the road, giving an overall safety rating of up to five stars (European Commission, 2021b). Ratings are based on (crash) testing and visual inspections (European Commission, 2021b). EuroNCAP tests are complementary to regulatory tests but the requirements for obtaining five stars are significantly stricter than the minimum requirements for cars to be approved (Høye, 2017a; Martin, 2017). Though results differ between studies, in general the risk of injury is found to decrease by approximately 5% for each star in the overall assessment (Høye, 2017a).

5.4 Data collection

Achieving the EU target of a 50% reduction in serious injuries will require statistics on serious injuries based on the common EU definition. In this regard, the European Transport Safety Council (ETSC) has formulated the following recommendations (ETSC, 2021):

- Set national reduction targets for serious injuries based on MAIS3+ alongside the reduction of deaths in national road safety strategies for the period post-2020.

- Collect serious injury data according to the MAIS3+ definition with an exchange of MAIS3+ recording practices between Member States supported by EU institutions, and continue collecting data based on national definitions.
- Include effects on numbers of serious injuries in the impact assessment of road safety measures.

The SafetyCube project provides practical guidelines for collecting serious injury data according to the MAIS3+ definition (Pérez et al., 2016; SafetyCube Consortium, 2016).

6 Further reading

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