

Bicycle helmets

Summary

More than a quarter of the injuries sustained by cyclists due to a road crash involve head and brain injury. Approximately three-quarters of the head and brain injuries are caused by crashes that do not involve motorized traffic; amongst young children this amounts to almost 90%. These are mostly cyclist-only crashes. This type of crash is difficult to prevent, however it is possible to limit the seriousness of the head and brain injury by wearing a bicycle helmet. According to a conservative estimate, the risk of head and brain injury is reduced by as much as 45% when a good bicycle helmet is worn correctly. Research in other countries has shown that the use of bicycles sometimes declines, particularly during the first few years after the introduction of compulsory helmet use. The longer-term effects or the significance of these results with regard to the situation in the Netherlands are not known.

Background

Bicycles are very popular in the Netherlands, amongst others for commuting, shopping, transporting children and recreation. However, cycling can also result in injury, often including serious head and brain injury. The bicycle helmet is intended to reduce the risk of this type of injury. In general, Dutch cyclists do not wear helmets. If a helmet is indeed worn, it is usually by recreational cyclists, mountain bikers and young children. The bicycle helmet has supporters and opponents worldwide. Part of the debate concerns proof of the protective effect of bicycle helmets. Another part is concerned with whether bicycle helmets lead to a decline in the use of bicycles. Lastly, the third part of the debate is whether promoting the use of helmets is the best way to improve cyclist safety. According to some, preventing cycling crashes takes precedence over preventing injury once a crash has already occurred. This Fact sheet aims to present the scientific facts. More general information regarding the safety of cyclists and possible measures can be found in the SWOV Fact sheet [Cyclists](#).

How many cyclists receive head/brain injuries?

Annually, in the Netherlands, approximately 67,000 casualties of cycling crashes are treated at a first-aid department (source LIS – Injury Information System of Consumers & Safety), 8,000 cyclists are admitted to hospital (source LMR – National Medical Registration), and 190 people die as a result of a cycling crash¹ (CBS – Central Bureau for Statistics – Unnatural Deaths). Of the casualties admitted to hospital, more than a quarter were found to have head or brain injuries (27.5%) (Ormel, 2009).

Amongst others, *Table 1* shows the following:

- Of the cyclists admitted to hospital following a crash with motorized traffic, approximately one third had head and brain injuries; this is somewhat less in the case of crashes not involving motorized traffic: approximately one quarter.
- Proportionally, head and brain injuries occur most frequently among children and young people. In crashes with motorized traffic, almost half of the injuries to young cyclists up to age 18 are head and brain injuries; in the case of crashes not involving motorized traffic, this is more than one-third for the same group.
- In actual fact, head and brain injuries result more frequently from crashes not involving motorized traffic than with motorized traffic. Approximately three-quarters of all head and brain injuries sustained by cyclists (in the case of young children almost 90%) are the result of a crash not involving motorized traffic. These are mostly cyclist-only crashes, i.e. crashes without another road user involved.
- Per kilometre cycled, head and brain injuries are most frequently sustained by children up to 12 years old and adults over 65. In the case of adults over 65, the risk of brain injury increases considerably the older they are.

¹ Due to the extensive under-registration of (cyclist-only) cycling accidents in the official National Road Accident Register (BRON), this Fact sheet will henceforth only contain hospital data of the LMR. Deaths due to head/brain injuries are not included.

Age	Following a crash with a motor vehicle		Crashes not involving a motor vehicle		Risk (number of head/brain injuries involving cyclists per billion kms)
	Annual number of head and brain injuries, 2003-2007	Percentage of all injuries	Annual number of head and brain injuries, 2003-2007	Percentage of all injuries	
0-3	6	67%	54	57%	193
4-7	15	43%	120	40%	314
8-11	35	49%	82	30%	213
12-15	81	45%	110	29%	112
16-17	35	45%	62	39%	118
18-24	51	34%	120	36%	127
25-64	210	31%	770	27%	130
65-70	36	30%	93	18%	230
71-75	33	33%	78	15%	285
76-80	28	31%	66	13%	448
81+	24	34%	52	13%	691
Total	550	34%	1600	25%	153

Table 1. Annual number of head and brain injuries under cyclists admitted to hospital during the period 2003-2007, and risk of head and brain injury following a bicycle crash over the same period for different age groups in the Netherlands (Sources: Ormel, 2009; CBS-MON).

What types of helmet are there, and how do they work?

There are bicycle helmets for children, adults, and special helmets for sport cyclists, touring cyclists and mountain bikers. Helmets are available in various sizes. The smallest size (for a head circumference of 48 cm) is suitable for babies aged approximately eight months. Most sizes can subsequently be adjusted slightly. A bicycle helmet weighs approximately 250 grams and consists of a hard plastic shell with a polystyrene foam liner. The whole article functions as a sort of crumple zone, similar to that of a car. The helmet ensures that the force exerted by a fall is absorbed. Moreover, the impact of the fall is spread across a larger surface. Bicycle helmets sold within the European Union must comply with the European standard EN-1078. This standard pertains to both children's and adults' bicycle helmets. For optimum effect, it is important that the helmet fits the head properly, and is securely fastened. It is also important that the helmet is undamaged and has not intercepted a hard blow previously.

What is the situation regarding the use of helmets in the Netherlands?

Bicycle helmets are not a familiar sight in the Netherlands, although there has been a slight increase in use during recent decades. Hardly anyone wore a helmet while cycling in the Netherlands during the 1980s. Bicycle helmets were also virtually unobtainable at the time. Since the mid-1990s, the demand for children's bicycle helmets in particular has increased markedly. It is estimated that two to three hundred thousand families with young children have purchased a bicycle helmet for at least one of their children during the last five years (Goldenbeld et al. 2003). According to these researchers, various circumstances regarding both supply and demand played a role in this increase. Possibly prompted by actions undertaken by schools and the media, parents for instance became more aware of the protection that bicycle helmets can provide. Retailers increasingly offered helmets for sale along with children's bicycles. The range of helmets also improved (choice, appearance, fit). In addition, bicycle helmets became a more common sight on the street due to the growing number of helmeted skaters and mountain bikers. A role was also played by experiences with cycling in other countries where helmets are sometimes mandatory.

What is the situation regarding the use of helmets elsewhere?

In Europe the use of bicycle helmets is currently mandatory in Finland (everyone everywhere), Spain (outside built-up areas), the Czech Republic (children < 16 years), Iceland (children < 15 years), and Sweden (children < 15 years). Outside Europe, wearing bicycle helmets is compulsory in Australia, New Zealand, in twenty states of the USA, and in a number of Canadian provinces. For these

countries the legislation usually applies to children and young people. The use of helmets is currently being promoted in a number of other (European) countries.

To what extent does a bicycle helmet reduce the risk of head/brain injury?

A good indication of the (maximum) effect of a bicycle helmet can be gained from case-control studies. Here the injuries of cycling casualties with and without helmets are compared, including correcting for differences in other characteristics of the cyclists (such as gender and age), and the crash circumstances. *Table 2* shows the results of two relatively recent reviews (meta-analyses) of case-control studies by Attewell et al. of 2001 and by Thompson et al. of 2004.

Type of injury	Attewell et al. (2001)			Thompson et al. (2004)		
	Number of studies	95% confidence interval*	Best estimate	Number of studies	95% confidence interval*	Best estimate
Head and brain injury	12	Min 45 - 71%	Min 60%			
Head injury				4	Min 63 - 74%	Min 69%
Brain injury	8	Min 33 - 74%	Min 58%	3	Min 58 - 77%	Min 69%
Facial injury	6	Min 27 - 61%	Min 47%			
Fatal injury	6	Min 29 - 90%	Min 73%			
Neck injury	3	Plus 0 - 86%	Plus 36%			

* This interval indicates the limits of the estimated reduction effect with 95% reliability.

Table 2. Overview of the injury reducing effect of bicycle helmets according to two reviews of case-control studies (Attewell et al., 2001; Thompson et al., 2004).

It is clear that both meta-studies report considerable reduction percentages for head and brain injuries. With regard to possible factors that interfere with the research, such as a publication bias resulting in the more frequent publication of studies showing positive results, and which are therefore overrepresented in the survey, it is perhaps advisable to opt for the conservative estimates. According to these studies, wearing a bicycle helmet would then result in a 45% lower risk of head/brain injury, 33% lower risk of brain injury, 27% lower risk of facial injury, and 29% lower risk of fatal injury. This would mean, for instance, that in the Netherlands almost a thousand fewer cyclists (-45%) per annum would be hospitalized with a diagnosis of head/brain injury if all Dutch people were to wear an undamaged bicycle helmet in the correct manner while cycling. The study carried out by Attewell et al. also shows a possible negative side effect of wearing a helmet, namely that the risk of neck injury would be greater for cyclists wearing a helmet. However, the effect was not statistically significant.

Curnow (2003) has criticized the results of case-control studies, especially as in his estimation, specific brain injuries and the specific mechanisms that cause brain injury are disregarded in these studies. An example of the latter is brain injury due to the angular acceleration of the head during a crash, where not only the speed, but also the head's direction of movement changes. In a riposte to Curnow, O'Hare et al. (2004) remarked that meta-analyses may disregard a number of possible nuances, but that this does not alter either the direction or the strength of the safety effects found. In other words, even if it is not precisely established *how* bicycle helmets work (mechanisms; types of injury), it has been established *that* they work.

A study resembling a case-control study was carried out in Norway (mentioned in Erke & Elvik, 2007). The voluntary use of helmets is relatively high in Norway. In 2006, 63% of children up to the age of 12, 25% of young people aged 12 to 17, and 34% of adults wore helmets. An analysis showed that the risk of sustaining fatal or severe injury is reduced by 25% when a helmet is worn.

What are the effects on brain injury of promoting bicycle helmets or making them compulsory?

Another way to establish the effect of bicycle helmets is the so-called population study. In this type of study, the injury patterns of cycling casualties before and after the introduction of a legal requirement, or before and after the promotion of voluntary helmet use are examined. For a safety effect to occur, it is conditional that the use of helmets must actually increase after having been made compulsory or being promoted. From a review by Karkhaneh et al. (2006), it was evident that after being made

compulsory, the use of bicycle helmets increased by an average factor of four by comparison. The rise in the use of helmets per region or state varied somewhat, depending on factors such as the original level of helmet use, the area's socio-economic background, and the amount of supporting publicity and enforcement (with penalties/rewards).

Voluntary promotion campaigns can also result in an increased use of bicycle helmets. Towner et al. (2002) reported the results of 19 studies on the voluntary promotion of bicycle helmets, 14 of which were carried out in the USA and Canada, most of which were aimed at children. The studies showed varied results, but the reviewers concluded that promotion campaigns generally resulted in a rise in the use of helmets, that the largest effect was achieved with young children and girls, and that in particular, discounts on the purchase price of bicycle helmets contributed positively to the purchase and use of bicycle helmets.

If helmets really do have the described effect of reducing injuries, it is to be expected that as more cyclists wear them, there will be proportionate reduction in head and brain injuries amongst cycling casualties. A number of studies have indeed shown such an effect.

The United States and Canada

Macpherson & Spinks (2007) examined experiences in North America. They report that on the whole, compulsory helmet use has a positive safety effect. They have based this on three studies whose methods were judged to be good. The first two studies examined compulsory helmet use for children and young people up to age 17 in California. The first study only pertained to the Californian state of San Diego County and showed an insignificant reduction in head injuries with children. The other study pertained to the entire state of California and found that there was an 18% reduction in the number of brain injuries amongst children and young people, but none amongst adults for whom helmet use was not compulsory. Lastly, the third study was carried out in Canada. It examined the effects of compulsory helmet use amongst both children and young people up to the age of 17. In the Canadian provinces where compulsory helmet use had been introduced, the number of head injuries amongst cyclists under the age of 18 fell by 45%. In the provinces where compulsory helmet use had not been introduced, there was a 27% reduction.

Australia and New Zealand

O'Hare et al. (2004) cite a 1995 study by Carr et al in the Australian state of Victoria. They found that in the four years after the introduction of compulsory general helmet use, there had been a decrease of 39% in the number of head injuries sustained by cyclists admitted to hospital as in-patients. O'Hare et al. also cite a study by Schuffman et al. in 2000, which calculated that compulsory general helmet use in New Zealand was responsible for a 19% reduction in the number of head injuries amongst cyclists over a period of three years. However, there are also less favourable results. Robinson (2006) studied the effects of compulsory helmet use in three Australian states, New Zealand and Nova Scotia (Canada) based on hospital data. After being made compulsory, the use of helmets increased by at least 40% in all these countries/states. Robinson observed that the decrease in head injuries amongst cyclists was very gradual, and that no clear trend break in the speed of decrease was perceived during the year in which compulsory helmet use was introduced.

This type of contradictory data brings us to the heart of the debate between supporters and opponents. Whilst Robinson has little faith in case-control studies, other researchers are suspicious of the data presented by Robinson. In a response to Robinson's study, Hagel et al. (2006) for instance state, that it examines time series data without an adequate control group, and they say that this is 'weak proof'.

Europe

In Europe hardly any similar population studies have been carried out, with the exception of Sweden. The increase from 5% to 31% in the voluntary use of helmets by children up to the age of 15 was coupled with a 43% decrease in head injuries amongst this group. Other injuries declined by 32% (Ekman et al., 1997). There was no indication that other factors, such as a reduction in the use of bicycles or an increase in the number of traffic safety measures could explain this effect.

To summarize, we can conclude that it is evident from a number of well-organized population studies that the effect of bicycle helmets is positive. However, on average this effect is somewhat smaller than could have been expected on the basis of case-control studies.

Does the use of bicycle helmets lead to more crashes?

Besides the favourable effect of bicycle helmets on injuries, there are also some reports on the possibility that there is an (unfavourable) effect on involvement in crashes due to changed behaviour. Robinson (2006) reports that cyclists wearing helmets may possibly take more risks, or are treated differently by drivers. It is not clear to what extent this is also the case in practice, as the research conducted is too limited for generalization. Walker (2007) found that drivers' behaviour was more risky towards cyclists wearing helmets than towards cyclists who were not; drivers drove closer to cyclists with helmets when overtaking than to cyclists without helmets. However, this study has not been repeated or confirmed in other countries. On the other hand, there are also a few studies that indicate that young cyclists wearing helmets do not take extra risks (stated by Hagel et al. 2006).

Does compulsory helmet use lead to reduce cycling mobility?

A different question is whether the compulsory use of helmets makes cycling less popular and leads to a decline in cycling mobility. There are few well-organized studies that can confirm or deny this (Macpherson & Spinks, 2007). Robinson (2006) refers to the data of large-scale counts in Australia (Melbourne and New South Wales), which show an unmistakable decline in the use of bicycles after the introduction of compulsory helmet use. This applied particularly to children and young people. In the first year after the use of helmets was made compulsory, 42% fewer children and young people were using their bicycles, and 36% less in the second year compared to before compulsory helmet use. Amongst adults there was a decline of 29% and 5% respectively. Robinson also reports a decline in the use of bicycles in the Canadian province of Nova Scotia after the introduction of compulsory bicycle helmet use, but adds that it was not easy to compare the research methods applied before and after the introduction of compulsory helmet use. On the other hand, Mapherson et al. (2001) found that in the Canadian province of Ontario, the use of bicycles by children aged 5 to 14 was not affected as a result of compulsory helmet use. The long-term effects are unknown.

It is difficult to relate these results to the Dutch situation. It cannot be ruled out that the effect of compulsory helmet use on the use of bicycles also depends on the way bicycles are used in a given country. In a country with a strong utilitarian cycling tradition such as the Netherlands, the effect of compulsory helmet use on the use of bicycles could be different to a country where bicycles are mainly used for recreational purposes. However, this has not been examined.

What is the relationship between the helmet and other safety measures for cycling?

Bicycle helmets do not prevent crashes. Rather, they are intended to limit the severity of the injury sustained during a crash. One may be of the opinion that it is more important to prevent crashes from happening altogether so that helmets would become superfluous (WHO, 2006). The prevention of crashes is indeed extremely important for the safety of cyclists (for a summary of the possible measures see SWOV Fact sheet [Cyclists](#)). However, we must realize that bicycle-on-bicycle crashes and cyclist-only crashes are particularly difficult to prevent. As shown in *Table 1*, three-quarters of head and brain injuries (as much as 90% for cyclists up to the age of 8), are caused by crashes that do not involve motorized traffic, and are due mainly to such cyclist-only and bicycle-on-bicycle crashes. It is difficult to prevent bicycle-on-bicycle and cyclist-only crashes, even more so amongst young cyclists, as they tend to cycle on pavements and in playgrounds.

Conclusions

More than a quarter of the injuries sustained by cyclists due to a road crash are head and brain injuries. Approximately three-quarters of head and brain injuries are caused by crashes not involving motorized traffic; amongst young children this is almost 90%. In the majority of cases these are cyclist-only crashes. Research has shown that a bicycle helmet provides protection against severe head and brain injury. According to conservative estimates, the maximum effect of a bicycle helmet (apparent from case-control studies) is approximately a 45% reduction of the risk of head and brain injury. In the opinion of the SWOV, case-control studies currently provide the best picture of the maximum injury-preventing effect provided by bicycle helmets, as they correct for possible interfering factors such as age, time of day, weather conditions etc. When the use of helmets increases amongst a population in practice, for instance due to compulsory helmet use, it is apparent that brain injury is indeed reduced amongst the target group in question, but to a lesser extent than would be expected on the basis of case-control studies. A few population studies found that there was no effect whatsoever.

An argument that is often heard against compulsory helmet use is that it would reduce the use of bicycles. Research shows that this effect occurs sometimes, especially during the first couple of years after the introduction of compulsory helmet use. The long-term effects are unknown.

All in all, the SWOV has concluded that a bicycle helmet is an effective means of protecting cyclists against head and brain injury.

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