SWOV Fact sheet

Bicycle helmets

Summary
One third of the cyclists who are admitted to hospital with serious injury after a road crash are diagnosed with head or brain injury. Approximately three-quarters of the head and brain injuries among cyclists are caused by crashes that do not involve motorized traffic; as many as nine out of ten young children who sustain head/brain injury, do so in crashes not involving motor vehicles. These are mostly cyclist-only crashes. This type of crash is difficult to prevent, but it is possible to limit the severity of the head and brain injury by wearing a bicycle helmet. According to the most recent and sound estimate, the risk of sustaining head injury is reduced by as much as 42% when a good bicycle helmet is worn correctly; the risk of sustaining brain injury is then reduced by 53%. Research in other countries has shown that the use of bicycles sometimes declines, particularly during the first few years after the introduction of mandatory helmet use. The longer-term effects or the significance of these results with regard to the situation in the Netherlands are not known.

Background and content
Bicycles are very popular in the Netherlands, among 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, this is usually done by recreational cyclists, mountain bikers and young children. There is no public support in the Netherlands to make the bicycle helmet compulsory (Kemler et al., 2009). 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 bicycle use. 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, especially the prevention of bicycle crashes deserves serious consideration, rather than the reduction of injury once a crash has already occurred. This Fact sheet aims to present the scientific facts about bicycle helmets. More general information regarding the safety of cyclists and possible measures can be found in the SWOV Fact sheet *Cyclists*.

How many cyclists sustain head/brain injury?
Annually, in the Netherlands, approximately 67,000 casualties of cycling crashes are treated at a first-aid department (Source: Injury Information System LIS), 8,000 cyclists are admitted to hospital (Source: National Medical Registration LMR), and 190 people die as a consequence of a cycling crash[1] (Source Statistics Netherlands – Unnatural deaths). Of the seriously injured bicycle casualties[2] admitted to hospital, a third were diagnosed with head or brain injuries (32%) (LMR 2005-2009; see also *Table 1*). Head injury is the general category and generally implies brain injury, but sometimes there is head injury without brain injury. *Table 1* contains data about head/brain injury among cyclists during the period 2005-2009;

- Of the cyclists with serious injury who are admitted to hospital following a crash with motorized traffic, almost half (47%) are diagnosed with head/brain injury. After crashes not involving motorized traffic this is the diagnosis for just under one third (29%) of the cyclists.
- Proportionally, head/brain injury occurs most frequently among children and young people. In crashes with motorized traffic more than 60% of the young seriously injured cyclists (0-17 years old) have sustained head/brain injury; in the case of crashes not involving motorized traffic, the percentages range from 33 to 56% for these age groups (compared with the 29% average).
- Approximately three-quarters of all head/brain injury sustained by are the result of crashes not involving motorized traffic. For young children (0-5 years old) as many as nine out of ten head/brain

[1] Due to the extensive underregistration of (cyclist-only) bicycle crashes in the official National Road Crash Register (BRON), this Fact sheet will henceforth only contain hospital data of the LMR. Deaths due to head/brain injury are not included.
[2] Serious injury is defined as a minimum score of 2 on the Maximum Abbreviated Injury Scale (MAIS). Head and brain injury are always given a minimum injury severity of 2 on the MAIS scale.

injuries are the consequence of bicycle crashes not involving motor vehicles. These are mostly cyclist-only crashes, i.e. crashes without another road user being involved, or crashes into an object.
- The risk of head/brain injury in crashes not involving a motor vehicle is particularly high for children in the age groups 0-5 and 6-11 years old; for cyclists over 65 the risk increases rapidly as they get older.

Age	After collision with motor vehicle			After collision not involving motor vehicle		
	Annual number of cyclists with head/brain injury	Percentage of all cyclists with serious injury	Risk (number of cyclists with head/brain injury per billion. kilometres cycled)	Annual number of cyclists with head/brain injury	Percentage of all cyclists with serious injury	Risk (number of cyclists with head/brain injury per billion. kilometres cycled)
0-5	15	67%	32	154	56%	338
6-11	53	66%	64	170	38%	204
12-14	73	60%	56	108	33%	83
15-17	74	63%	60	115	44%	93
18-24	70	51%	52	160	45%	115
25-34	51	43%	32	178	37%	112
35-44	68	46%	32	238	31%	115
45-54	78	37%	37	332	31%	155
55-64	90	40%	52	318	25%	174
65-69	39	37%	70	127	23%	205
70-74	43	41%	111	125	21%	308
75-79	50	47%	235	102	17%	411
80-99	49	47%	431	103	17%	871
Total	**752**	**47%**	**54**	**2.229**	**29%**	**157**

Table 1. *Annual number of cyclists admitted to hospital with head/brain injuries as main or second diagnosis, and their share of all seriously injured cyclists admitted to hospital, and per distance travelled by bicycle, for different age groups and for the period 2005-2009.(Sources:* National Medical Registration LMR*; Statistics Netherlands, Mobility survey).*

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 grammes and consists of a hard plastic shell with a polystyrene foam liner. The helmet functions as a sort of crumple zone, similar to that of a car; it ensures that the force exerted by a fall is absorbed. Furthermore, the impact of the fall is also spread across a larger surface. Bicycle helmets sold within the European Union must comply with the European standards EN-1078 (helmets for adults) and EN-1080 (helmets for children). 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.

The European standard for bicycle helmets is not as strict as the standards in, for example, the US and Australia. At the present European standard the helmet is adequate in cyclist-only crashes, but offers insufficient protection in crashes involving other road users (Kemler et al., 2009). Therefore, the effectiveness of these non-European helmets cannot simply be compared with the helmets used in the Netherlands.

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. During the 1980s, hardly anyone in the Netherlands wore a helmet while cycling. 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 preceding 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. Experiences in other countries where helmets are sometimes mandatory for cyclists also played a role.
In 2010, the Dutch province of Zeeland started a large-scale campaign to promote voluntary use of bicycle helmets by primary school pupils in the province. The pupils received a free bicycle helmet, while at the same time education and information about helmet use is provided. The Ministry of Infrastructure and the Environment and SWOV are partners in the multi-year evaluation of the effects this project has on safety and behaviour.

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). On 31 May 2010, mandatory helmet use for children under the age of 10 was introduced in Austria, but no sanctions were placed on disobedience. Outside Europe, wearing bicycle helmets is mandatory in Australia, New Zealand, in twenty states of the USA, and in a number of Canadian provinces. In these countries the legislation generally 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?
Case-control studies give a good indication of the (maximum) effect of a bicycle helmet use. They compare the injuries of cycling casualties with and without helmets, including correction for differences in other characteristics of the cyclists (such as sex and age), and the crash circumstances. A recent meta-analysis of case-control studies gives the best indication of the injury reduction due to bicycle helmets (Elvik, 2011). This meta-analysis is an improvement of an earlier meta-analysis about the same subject which was carried out by Attewell et al. in 2001. The improvement consists of Elvik's study including more case control studies and correcting for the effects of what is known as publication bias as much as possible. Publication bias is a distortion which occurs when only the positive findings are published, while the negative or indecisive findings are ignored. *Table 2* summarizes the most important results of the meta-analysis.

Type of injury	Number of effect estimates	95% confidence interval of the effect	Best estimate of changes in odds ratios of injury or no injury occurring
Head injury	23	–55% to –25%	–42%
Brain injury	9	–71% to –25%	–53%**
Facial injury	13	–33% to +3%	–17%
Neck injury	4	+1% to +72%	+32%*
Head, facial- or neck injury	40	–26% to –2%	–15%

* Too few effect estimates (4) to allow correction for publication bias.
** This estimate is based on table 1 in Elvik (2011), the other estimates are based on table 2.

Table 2. *Overview of the injury reducing effect of bicycle helmets according to the best estimates in Elvik's meta-analysis (2011).*

In *Table 2* head injury is the most general injury category which may also include injury to the back of the head, face and brain (some studies consider facial injury as a head injury, other studies do not). Brain injury specifically refers to the brain, and facial injury specifically refers to injury to the face (chin, nose mouth, jaws, eyes, forehead, ears). Elvik compared the risk proportions of a specific injury occurring or not occurring. Bicycle helmets reduce the risk proportion of head injury occurring by about 42% and the reduction in risk proportion for the more specific category brain injury amounts to 53%. Bicycle helmet use reduces the risk proportion of facial injury by 17%, but this reduction is not significant. For neck injury the risk proportion increases by 32% due to wearing bicycle helmets, although this finding is based on only four effect estimates and is therefore less decisive than the other results. For all injuries together, including neck injury, a risk reduction of 15% was found.

What are the effects on helmet use and injuries of promoting bicycle helmets or making them compulsory?

An international review by Karkhaneh et al. (2006) showed that after being made compulsory, the use of bicycle helmets increased by an average factor of four. The increase in the use of helmets varied somewhat per region or state, depending on factors such as the original level of helmet use, the area's socio-economic background, and the amount of accompanying publicity and enforcement (with penalties/rewards).

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

The United States and Canada

On the basis of telephone interviews it was established that in the United States the percentage of children (aged 4-14) who always wear a helmet when cycling had increased from 25% to 48% during the period 1994-2003 (Dellinger & Kresnow, 2010). Karkhaneh et al. (2010) compared helmet use by cyclists in Alberta, Canada, at two moments in time: two years before and two years after helmet legislation was introduced for cyclists younger than 18. They found an increase in helmet use by children from 75% before to 92% after the introduction; for adolescents the increase in helmet use was from 30% to 63%. Helmet use by adults, whom the legislation did not apply to, remained almost the same: 52% before and 55% after the legislation was introduced.

Macpherson & Spinks (2007) examined safety effects after the introduction of legislation in the United States and Canada. They report that compulsory helmet use has generally had a positive safety effect. They have based this conclusion on three studies whose methods they judged to be good. The first two studies examined compulsory helmet use for children and youngsters up to the age of 17 in California. The first study only pertained to the Californian state of San Diego County and showed a non-significant reduction in head injuries among children. The other study pertained to the entire state of California and found an 18% reduction in the number of brain injuries amongst children and youngsters, but no reduction was found among adults for whom helmet use had not been made compulsory. Lastly, the third study was carried out in Canada. It also examined the effects of compulsory helmet use for both children and youngsters to the age of 17. In the Canadian provinces where such compulsory helmet use had been introduced, the number of head injuries among cyclists under the age of 18 declined by 45%. In the provinces where compulsory helmet use had not been introduced, there was a 27% reduction in head injuries.

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 general compulsory helmet use, there had been a decrease of 39% in the number of head injuries among cyclists who had been admitted to hospital. O'Hare et al. also cite a study by Schuffman et al. in 2000, which calculated that general compulsory helmet use in New Zealand coincided with a 19% reduction in the number of head injuries among cyclists over a period of three years. However, there are also less positive 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 bicycle helmets had increased by at least 40% in each of these countries/states. Robinson found that the decrease in head injuries amongst cyclists was very gradual, and that no clear trend break in the speed of decrease could be observed during the year in which compulsory helmet use was introduced.

In a response to Robinson's study, Hagel et al. (2006) for instance state, that it bases its conclusions on time series data without an adequate control group, and they say that this is 'weak evidence'.

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 younger than 15 coincided 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.

In summary, we can conclude that a number of well-carried out population studies indicate a positive effect of bicycle helmet use. However, on average this effect is somewhat smaller than could have been expected on the basis of case-control studies. Elvik (2011) gives two possible reasons for this discrepancy. Firstly, it could be possible that especially careful and safety conscious cyclists begin to use bicycle helmets when new legislation is introduced. In that case a selection effect occurs which is responsible for the figures being lower in actual practice than could be expected. In the second place it could be possible that helmeted cyclists display riskier behaviour so that the effects become smaller (see the following section). There is no conclusive evidence for either of Elvik's explanations.

Does the use of bicycle helmets lead to more crashes?
Beside the favourable effect of bicycle helmets on injuries, there are also some reports on the possibility of an (unfavourable) effect on the involvement in crashes due to behavioural adaptation. Robinson (2006), for example, reports that cyclists wearing helmets may possibly take more risks themselves, or are treated approached with riskier behaviour by drivers. It is not clear to what extent this is also the case in practice, as the research conducted into behavioural adaptation is too limited for generalization. Walker (2007) found that drivers displayed riskier behaviour towards cyclists wearing helmets than towards cyclists who were not: when overtaking drivers drove closer to cyclists wearing helmets than to cyclists without helmets. However, this study has not been repeated or confirmed in other countries. Recently, Philips et al. (2011) also found indications of behavioural adaptation (in a negative sense) among experienced helmet users during a 400 metre ride along a downhill bicycle track. They experienced less risk and cycled faster when wearing a helmet than they did when not wearing one. Among cyclists who had no experience wearing bicycle helmets, wearing or not wearing a helmet had no effect on the reported feeling of risk or on the speed that was cycled. On the other hand, there are also a few studies that indicate that young cyclists wearing helmets do not take extra risks (in Hagel et al., 2006).

Does compulsory helmet use lead to reduced 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 used their bicycles; in the second year this was 36% fewer in comparison with the situation before compulsory helmet use. Among adults the decline amounted to 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 the research methods applied before and after the introduction of compulsory helmet use were not easily comparable. 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 bicycle helmet and other safety measures?
Bicycle helmets do not prevent crashes, but 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 be 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 be aware of the fact that bicycle-bicycle crashes and bicycle-only crashes are difficult to prevent because infrastructural factors are not always easily identified and because the behavioural factor cannot always be influenced. As shown in *Table 1*, three-quarters of head and brain injuries (and as much as 90% among cyclists in the ages 0-5), are caused by crashes that do not involve a motor vehicle. These are mainly due to such bicycle-only and bicycle-bicycle crashes. It is difficult to prevent these crashes, even more so for the youngest cyclists (ages 0-5), because they fall frequently due to their limited bicycle control, often on pavements and in playgrounds.

Conclusions
One third of the cyclists who are admitted to hospital with serious injury after a traffic crash are diagnosed with head/brain injury. Approximately three-quarters of these cyclists sustain this head/brain injury in crashes not involving a motor vehicle. As many as nine out of ten young children who sustain head/brain injury, do so in crashes not involving a motor vehicle. In the majority of cases these are bicycle-only crashes.

Research has shown that a bicycle helmet provides protection against serious head and brain injury. The best estimates that are presently available indicate that the use of bicycle helmets decreases the risk proportion of sustaining or not sustaining head injury by 42%, that of sustaining or not sustaining brain injury by 53%, that of sustaining or not sustaining facial injury by17%, whereas the odds ratio for sustaining or not sustaining does on the other hand increase by 32%. These effect estimates are partly based on American and Australian studies, countries that use stricter standards for bicycle helmets than Europe.

An argument that is often heard against compulsory helmet use is that it would reduce the use of bicycles. International research indicates that this effect sometimes occurs, especially during the first couple of years after the introduction of compulsory helmet use. The long-term effects, as well as the significance of these findings for the Netherlands are unknown.

All in all, the SWOV concludes that a bicycle helmet is an effective means of protecting cyclists from sustaining head and brain injury in a fall with a bicycle.

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