

# Reality or wishful thinking: do bicycle helmets prevent facial injuries?

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**Abstract.** Standard bicycle helmets are designed to protect the cranial vault. Numerous studies have demonstrated the beneficial effect of standard bicycle helmets on craniocerebral trauma, but their protective effect on facial injuries remains unclear. Therefore, this study used data obtained by an accident research unit to investigate the protective effect of standard bicycle helmets on facial injuries. A total of 31,634 bicycle accidents were registered between 1999 and 2015; of these, 7004 met the study requirements. Demographic characteristics, technical information (relative collision speed, collision type, collision partner, helmet use), and clinical data (injury type) relating to these accidents were analyzed. Of all affected cyclists, 1005 (14.3%) had a facial injury (fracture and/or soft tissue injury). Bicycle helmets were worn in 11.8% of accidents. Of these, 75.4% involved males and 24.6% involved females. The bicycle helmet did not protect against facial injuries. Furthermore, sex and the type of collision partner were found to be risk factors for facial injuries. In the future, helmet designs should be modified to improve facial protection, and better education should be provided to the public regarding the benefits of bicycle helmets.

Key words: cyclist; bicycle helmet; facial injury; midface fracture.

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The anatomical and functional recovery of maxillofacial injuries is surgically challenging. An accurate reconstruction is necessary for aesthetic and functional results. Facial injuries are rarely life-threatening, but they are often associated with severe morbidity, loss of function, disfigurement, mental illness, and a significant financial burden on the healthcare system<sup>1–3</sup>. In particular, facial injuries are a risk factor for impaired quality of life,

as measured 6 months after a bicycle accident<sup>4</sup>.

Road crashes are the most common cause of maxillofacial fractures in Europe, particularly those that involve cyclists<sup>1,5</sup>. In Germany in 2017, cyclists accounted for 14.8% of all victims of road accidents (86,460/583,208), of whom 91.8% were injured ( $n = 79,346$ ). Furthermore, cycling accidents accounted for 0.4% ( $n = 382$ ) of mortalities<sup>6</sup>.

Various studies have demonstrated the protective effect of bicycle helmets on head injuries<sup>7–10</sup>. However, the potential of a bicycle helmet to prevent facial injuries is controversial. Older studies report a protective effect of bicycle helmets against facial injury. In case-control studies performed by Thompson et al., the helmet was found to exert a protective effect on the upper and midface in 65% of cases<sup>8,11</sup>. In 1993 and 1995, McDermott

et al. described a reduction of facial injuries by 24.9–28.0% resulting from the use of a bicycle helmet<sup>7,12</sup>. In both of these studies, the authors failed to mention which facial injuries were recorded. In 2000, Thompson et al. performed a meta-analysis for the Cochrane Collaboration<sup>9</sup>, including five studies on crashed cyclists. Overall, the review confirmed the positive effect of bicycle helmet use, but there was some criticism of bias in their work<sup>13,14</sup>. Another meta-analysis based on 16 studies investigating the effect of a bicycle helmet on head, face, and neck injuries reported a reduction of facial injuries by 27%<sup>13</sup>. Elvik criticized these results in 2011, proposing the influence of publication bias and time-trend bias<sup>14</sup>. A recent meta-analysis by Hoye reported that helmet use lowered the risk of facial injuries by 28%<sup>15</sup>, and a meta-analysis by Fitzpatrick et al. suggested that bicycle helmets may offer a protective effect against facial injuries<sup>16</sup>. However, as recognized by the authors of these publications, the number of studies on this topic is small and the results are heterogeneous, suggesting a need for further research<sup>16</sup>.

Only a few studies have found no effect of bicycle helmets in preventing facial injuries. In a case-control study, Hansen et al. demonstrated a protective effect of hard-shell bicycle helmets on head injuries but not on facial injuries<sup>17</sup>. Fortunately, despite the fact that German law does not require road cyclists to wear helmets, the German In-Depth Accident Study (GIDAS) has reported that the number of helmet users in Germany is increasing (Fig. 1).

The standard bicycle helmet is usually designed without facial protection features such as a chin guard or face shield. Nevertheless, numerous studies have reported a protective effect of helmets on facial injuries<sup>7,10–12,18,19</sup>. As recent investigations have suggested that the results reported in some of these publications were subject to publication bias and time-trend bias, the conclusions drawn should be interpreted with caution<sup>13,14</sup>. Nevertheless, due to the proven protective effect of helmets against head injuries, the belief held by the general population is that wearing a helmet also protects the face.

Considering the controversy in the literature regarding this topic, further research and better education of the public are needed. Due to the lack of facial protection, it was hypothesized that standard bicycle helmets do not prevent facial injuries. This study was performed to analyse the data obtained from the GIDAS in order to investigate the protective effects of helmet use against facial injury.

## Materials and methods

An analysis was performed using data from the GIDAS, a collaborative project of the German Federal Highway Research Institute and the Research Association of Automobile Technology. Traffic research units at the University of Dresden and the University of Hannover collected data on a random selection of road accidents involving personal injury from 1999 to 2015. In the case of a road accident, the research

team (technicians and medical specialists) arrived on the scene to analyze the accident using photography, stereoscopic photography, three-dimensional laser techniques, and clinical injury documentation. The case was completed at the hospital after a clinical examination and an analysis of the computed tomography scan by a craniomaxillofacial surgeon.

The GIDAS registered 31,634 accidents during the period 1999 to 2015. Of these accidents, 29,499 could be technically reconstructed completely. A total of 7004 datasets for cyclists involved in traffic accidents met the requirements of the present study and were included. In all cases, the collision partner (car, utility vehicle, motorized two-wheeled vehicle, bicycle, pedestrian, or fall), collision type (technical description of the collision event), collision speed (relative speed of the collision partner in kilometres per hour (km/h)), age, sex, helmet use, and the presence of a facial injury (soft tissue injuries and fractures) were analysed retrospectively.

IBM SPSS Statistics version 23.0 (IBM Corp., Armonk, NY, USA) was used for the statistical analysis. For the data overview, a descriptive analysis was performed. A binary logistic regression model was used to detect risk factors for facial injuries and specifically to look for a relationship between bicycle helmet use and the occurrence of facial injuries. The level of significance was set at  $P \leq 0.05$ .

## Results

Of the total 7004 cyclists included in this study, 1005 (14.3%) experienced a facial injury. The distribution of the injuries is shown in Figs 2 and 3.

Overall, 58.9% of all cyclists were male and 41.1% were female (male to female ratio, 1.4:1), but the ratio of male to female cyclists in the group with facial injuries was higher (1.8:1) (Table 1). Logistic regression analysis and the  $\chi^2$  test revealed a significant correlation between sex and facial injury, with male cyclists displaying an increased risk of facial injury (Table 2).

The mean age of all accident patients was 39.6 years (standard deviation (SD) 20.1 years; median 37 years, range 2–92 years). Of all cyclists, young adults between 21 and 30 years of age were the most frequently involved (Fig. 4, Table 1).

The most common collision partners were cars (64.8%), objects including falls (15.3%), and other cyclists (8.2%). Logistic regression analysis revealed a significant correlation between the collision

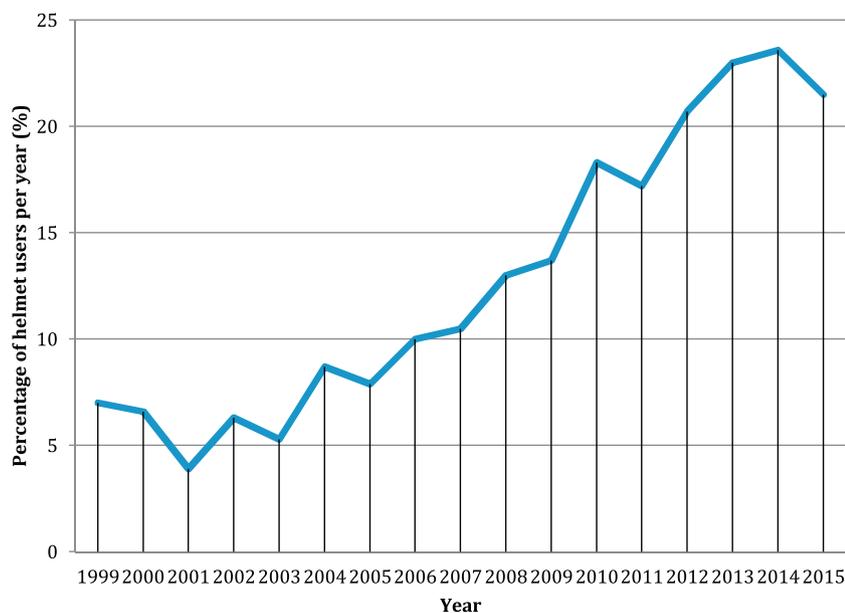


Fig. 1. Number of helmet users as a percentage of all cyclists involved in accidents from 1999 to 2015.

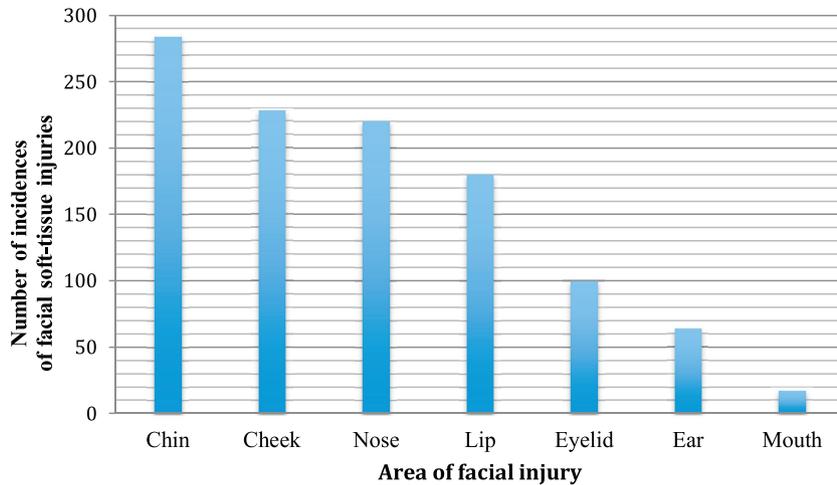


Fig. 2. Number of soft tissue injuries in cyclists involved in collisions, categorized by facial area.

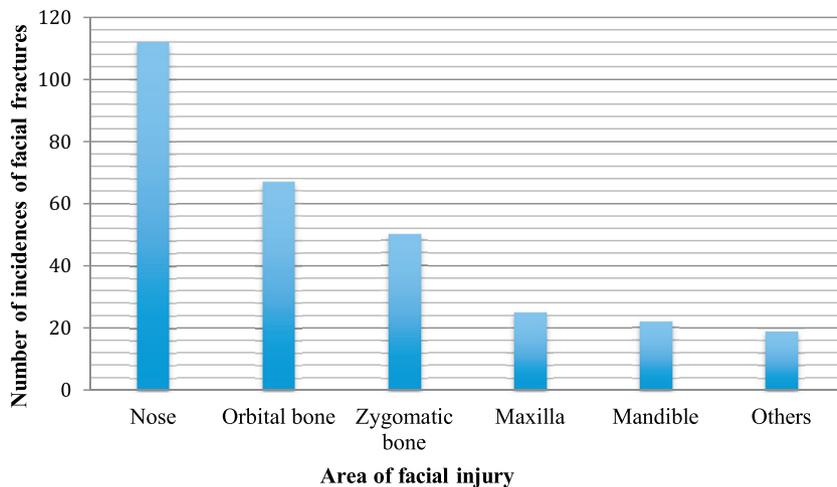


Fig. 3. Number of facial fractures in cyclists involved in collisions, categorized by facial area.

Table 1. Demographic overview of the 7004 bicycle collision victims included in the analyses.

	Facial injury (n = 1005), n (%)	No facial injury (n = 5999), n (%)	Total (N = 7004), n (%)
Sex	(n = 1004)	(n = 5980)	(n = 6984)
Female	360 (35.9)	2507 (41.9)	2867 (41.1)
Male	644 (64.1)	3473 (58.1)	4117 (58.9)
Age, years	(n = 990)	(n = 5963)	(n = 6953)
0–10	34 (3.4)	229 (3.8)	263 (3.8)
11–20	177 (17.9)	982 (16.5)	1159 (16.7)
21–30	176 (17.8)	1140 (19.1)	1316 (18.9)
31–40	151 (15.3)	905 (15.2)	1056 (15.2)
41–50	137 (13.8)	900 (15.1)	1037 (14.9)
51–60	110 (11.1)	672 (11.3)	782 (11.2)
61–70	111 (11.2)	654 (11.0)	765 (11.0)
>70	94 (9.5)	481 (8.1)	575 (8.3)
Helmet			
Yes	125 (12.4)	701 (11.7)	826 (11.8)
No	880 (87.6)	5298 (88.3)	6178 (88.2)
Mean age (years)	40.2 (SD 20.6)	39.5 (SD 20.0)	39.6 (SD 20.1)
Mean speed (km/h)	17.7 (SD 15.9)	16.7 (SD 12.9)	16.9 (SD 13.2)

SD, standard deviation.

partner and the probability of a facial injury (Table 2). The highest risk of facial injury occurred from collision with a motorcycle, and the lowest risk occurred from collision with a pedestrian.

The mean speed of the collision partner at the time of collision in the group without a facial injury was 16.7 km/h (SD 12.9 km/h) and in the group with a facial injury was 17.7 km/h (SD 15.9 km/h). Statistically, the speed at the time of collision had no significant influence on the severity of a facial injury (Table 2).

Overall, 11.8% (824/7004) of cyclists involved in accidents were wearing a helmet. Of these, 75.4% were male (621/824) and 24.6% were female (203/824). The percentage of helmet users was highest in children and decreased significantly with age, up to the age of 51 years (Fig. 4). A binary correlation test showed a significant correlation between the use of a helmet and sex and age. Overall, no significant association was observed between helmet use and the likelihood of a facial injury (Table 2). However, significant associations were observed between the probability of a facial injury and the type of collision partner and the sex of the cyclist (Table 2).

**Discussion**

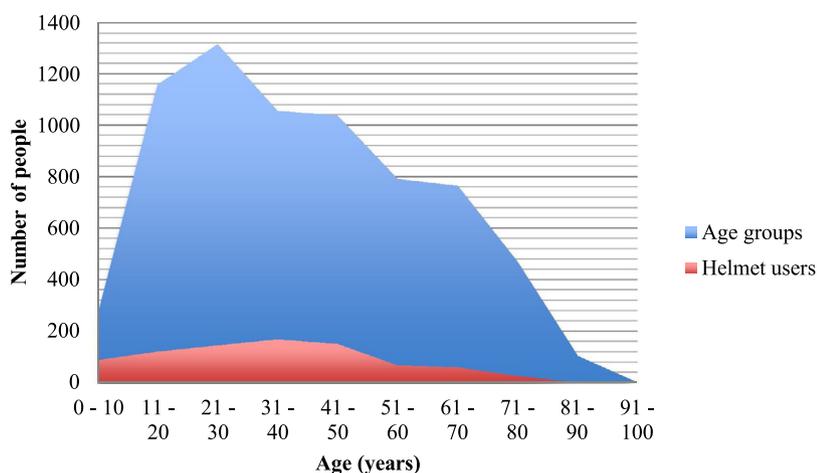
In this study, a detailed analysis was conducted of the technical and medical data of 7004 cyclists involved in road accidents. Sex and the type of collision partner were found to be risk factors for facial injuries. In contrast to the results reported in the literature, it was found that the standard bicycle helmet did not protect against facial injuries.

The increasing number of road cyclists will lead to a greater need for treatment of bicycle-related injuries. According to the literature, the main known causes of bicycle accidents include cycling too fast, inattentiveness (including the increasing use of mobile phones while riding a bicycle), poor driving conditions, limited visibility, and mechanical failure<sup>20,21</sup>. Most of these accidents occur in road traffic and include collisions of cyclists with cars, other cyclists, and pedestrians<sup>20</sup>. The findings of the present study are in accordance with these previous results; cars (64.8%), objects including falls (15.3%), and other cyclists (8.2%) were the most common collision partners found in this study. However, other studies have claimed that most bicycle accidents occur due to falls<sup>11,17,22,23</sup>. This conflict in findings is probably due to the fact that the present study included data only from traffic accidents, while the previous studies cited

**Table 2.** Binary logistic regression analysis: association between the collision partner, collision type, mean speed of the opponent, age, sex, and helmet use (independent variables) and the occurrence of facial injuries (dependent variable).

	Regression coefficient	SD	P-value	OR	95% CI for OR	
					Lower value	Upper value
Collision partner	0.144	0.025	0.000	1.155	1.099	1.213
Collision type	0.025	0.023	0.269	1.026	0.981	1.073
Mean speed (km/h)	0.005	0.003	0.056	1.005	1.000	1.011
Age (years)	-0.001	0.002	0.793	0.999	0.996	1.003
Sex (male/female)	-0.199	0.080	0.013	0.820	0.701	0.960
Helmet use (yes/no)	0.028	0.117	0.813	1.028	0.818	1.292

CI, confidence interval; OR, odds ratio; SD, standard deviation.



**Fig. 4.** Distribution of age groups and helmet users within the total number of bicycle collision victims included in the analysis.

included data from all bicycle accidents. Furthermore, Rivara et al. suggested that the speed at the time of the crash is a risk factor for serious head, face, and neck injuries<sup>18</sup>. Speed at the time of the collision was found not to have a significant influence on the occurrence of facial injury in the present study; however, in a previous study by the present authors' research group it was found that speed at the time of collision has a significant influence on serious injuries (fractures)<sup>24</sup>.

Of all cyclists, 14.3% had a facial injury. The supporting literature reports a rate of occurrence of facial injury in the range of 7.1–34.5%<sup>5,10,22,23,25</sup>. In the present analysis, lacerations were shown to be more common on the lower face, and fractures of the midface were more common than those of the mandible. Conversely, the supporting literature reports higher incidences of mandible fracture<sup>22,23,25,26</sup>.

Analysis of the age distribution demonstrated that the largest proportion of accidents occurred in young adults aged 21–30 years. However, a study by Yamamoto

et al. demonstrated a higher incidence of accidents in children and teenagers aged 10–19 years<sup>27</sup>, while other studies reported that the majority of accidents occurred in patients aged 10–40 years<sup>22,25</sup>. Furthermore, the risk of a serious facial injury has been found to increase with age<sup>24</sup>. This could be attributed to the increased risk of bone fractures in the elderly population due to decreased reaction speed, poor perception, and lower bone density<sup>28</sup>.

The study analyses revealed that male cyclists had a significantly higher risk of facial injuries from bicycle accidents than female cyclists and were more commonly involved in bicycle accidents. This may be due to their increased likelihood of partaking in risk-taking behaviour<sup>1,29</sup>. Nonetheless, the study data also suggest that male cyclists are more likely to wear a helmet than female cyclists (male to female ratio 2.1:1), in agreement with some studies reported in the literature<sup>10,30,31</sup>. Speculatively, this could be because women are more concerned about fashion and hairstyle. Furthermore, the increased use

of helmets in male cyclists coupled with the increased risk of facial injury in males could also suggest the ineffectiveness of bicycle helmets as protection against facial injuries.

Compared to the existing literature, the percentage of helmet-wearers in this study is relatively low (11.8%). In a meta-analysis by Hoye, it was found that the average percentage of helmet-wearers in countries without helmet legislation is 26%<sup>15</sup>, while the percentage in countries with helmet legislation is 52.5–89%<sup>9,18,32</sup>. The percentage is lowest in developing nations (2.1–6%)<sup>25,33</sup>. The percentage of helmet users in the present study decreased with age and was highest (33.2%) among children younger than 10 years of age. While some existing publications support this finding<sup>30,34</sup>, others have conversely demonstrated a positive correlation between age and helmet use<sup>31,35</sup>.

The literature presents various reasons for not wearing a helmet, including appearance, comfort, and social stigma<sup>36,37</sup>. Social norms, perceptions of control, and past behaviour significantly predict intentions for helmet use<sup>38</sup>. Furthermore, an investigation by Ritter and Vance found that household demographics, residential location, and riding patterns are also significantly correlated with helmet use<sup>30</sup>. In addition, urban residency, household income, and the presence of children in the household have a positive effect on the probability of helmet use. A study by Popa et al. showed that helmet use is associated with riding patterns and demographic characteristics (sex, age, geographical area, average number of kilometres cycled per week, type of bicycle, past crash involvement, and frequency of bicycling)<sup>31</sup>.

Another known problem is that a large number of cyclists wear their helmet incorrectly and/or wear the wrong size of helmet<sup>39,40</sup>. The most common error is the helmet sitting too far back on the head<sup>39</sup>. The results of the study by Romanow et al. showed an increased risk of facial injury when the helmet had come off during a crash and also when the helmet was tilted back at the time of the crash<sup>39</sup>. Furthermore, Ching et al. reported that, after an accident, a large proportion of helmets have a damaged rim, particularly at the front of the helmet<sup>41</sup>. Therefore, to improve the design of the helmet to protect the upper face, the helmet could extend further down the face, and additional liner material could be added to the rim<sup>41</sup>.

As the rate of helmet usage was low, this study is vulnerable to coincidence and bias. The data did not specify the type of

helmet worn (e.g., soft shell or hard shell), thus the superiority of one helmet type over the other could not be determined.

In conclusion, this study found no protective effect of a standard bicycle helmet with regard to facial injuries following an accident. The rate of helmet-wearing cyclists is low in Germany compared to other countries, especially for female cyclists. To gain better acceptance of helmet-wearing, it is suggested that helmets should be light, modern, and stylish. The helmet should extend further down, with additional liner material on the rim. Also, an additional chin guard should be designed for mandible protection. If such modifications can be incorporated by helmet manufacturers, there is a possibility that bicycle helmets will offer greater protection against facial injuries. However, it is speculated that the number of helmet-wearers would drop in countries with no legislation for helmet-wearing if the helmets were to have a chin guard or face shield. Therefore, there is a need for general helmet legislation. Furthermore, improved education is required to inform the public of the benefits of bicycle helmets and the necessary design changes for facial protection.

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### Competing interests

No conflicts of interest.

### Ethical approval

No ethical approval needed.

### Patient consent

Not required.

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