

Accident configurations and injuries for bicyclists based on German In-Depth-Accident Study

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Introduction

Road traffic deaths, disabilities, and injuries are a major global public health issue. Worldwide, the number of people killed in road traffic crashes each year is estimated around 1.3 million (World Health Organization 2009). In addition, between 20 and 50 million people globally are estimated to be injured or disabled each year. In the European Union – with about 500 million inhabitants and 230 million motor vehicles – a total of 1,200,000 injuries and 34,500 deaths occur every year from road crashes (European Commission 2012a). Vulnerable road users – in particular bicyclists - play an important role in this context: in the European Union, of all journeys, 20-40% are travelled by cycle or on foot (European Commission 2012b).

Bicycle riding is becoming a popular means of transportation: the bicycle is used for short trips to shops and for leisure purposes; however, cycling is also a common way for commuting. The reasons of this phenomenon are several: the sharp increase in traffic in urban areas, a greater awareness among people about the environmental risk of pollution, economic reasons, health promotion.

Given this popularity, it is not surprising that cycling injuries and fatalities can and do occur: of all traffic fatalities in Europe, the proportion of bicyclist fatalities is about 6% (European Commission 2012b).

Moreover, 80% of vehicles striking cyclists are four-wheeled motor vehicles, as passenger cars, trucks, buses (European Commission 2012b), with a high risk of death as well as of severe injuries for the cyclist (Boström and Nilsson 2001). Indeed, bicyclists rank among the most exposed participants in traffic, who suffer injuries in case of an accident: compared to cars, bicycles have reduced visibility, are less stable, and offer less protection to the driver. Considering the unprotected body in comparison to the passenger car, the bicyclist usually separates from his bicycle and hits the hard, non-deformable structures of other vehicles or infrastructures, and suffers the most severe consequences.

The majority of bicycle-related injuries are head injuries (Lustenberger et al. 2010, Styrke et al. 2007) and extremities fractures (Bostrom e Nilsson 2001, Eid et al. 2007, Lustenberger et al. 2010, Richter et al. 2005, Richter et al. 2007, Rosenkranz e Sheridan 2003).

Aim of the present study is to evaluate which are the most common types of accident involving bicycles and to compare the frequency of injuries, in order to understand which are the most dangerous situations for bicyclists and to suggest appropriate preventive actions.

Materials and methods

Data sources and data collection

The data source was the German In-Depth Accident Study (GIDAS) database.

GIDAS is the largest in-depth accident study in Germany. The project is supported by the Federal Highway Research Institute (BAST) and the German Association for Research in Automobile Technology (FAT). The research institutes involved are the Medical University of Hannover and the Dresden Technical University.

Within the study, a sample of accidents occurring in the areas of Hannover and Dresden is investigated. In the both areas, the respective police, rescue services, and fire department headquarters report all accidents continuously to the research team. The team then selects accidents according to a strict selection process and investigates these cases following detailed procedures contained in a handbook and coding manual.

Accident investigation takes place daily during two six-hour shift following a 2-week cycle in order to cover all periods of the day throughout the whole year:

- first week: from 12:00 a.m. to 06:00 a.m. and from 12:00 a.m. to 6:00 p.m.
- second week: from 6:00 a.m. to 12:00 p.m. and from 6:00 p.m. to 12:00 p.m.

During each shift, a team consisting of two technicians, a doctor and a coordinator is on duty, equipped with special emergency vehicles. When an accident occurs the team goes on the accident site and collects information on:

- environmental conditions
- road design
- traffic control
- accident details
- crash information
- vehicle damages and deformation
- impact contact point for passenger and pedestrians
- technical vehicle data
- information about the people involved.

The information collected “on the scene” is complemented by more detailed measurements of the vehicle (collected usually on the following day), further medical information about injuries and treatment and an extensive accident reconstruction generated from evidence collected at the accident scene. The accident is then reconstructed using in-depth approach, reconstruction methodologies, and hoc software.

Both teams – Hannover and Dresden - function in the same manner using the same system, procedures and collecting data in a common database.

Each year in every investigation region approximately 1,000 traffic accidents are documented (GIDAS, 2012).

Sample

Cases consist of bicycles and their riders that were involved in accidents with injuries and transported to an emergency ward, stored in the GIDAS database and occurred in the years 2000-2010.

Injuries analysis

The injury situation was described according to the Abbreviated Injury Scale (AIS). The AIS is an anatomically-based global severity scoring system that classifies each injury by body region according to its relative importance on a six-point ordinal scale (from 1=minor to 6=maximal) (American Association of Automotive Medicine, 2012). For each rider all injuries were classified according to body region (head, face, neck, thorax, abdomen, spine, upper extremities, lower extremities) and AIS score. The whole bodily injury severity is classified as maximum AIS (MAIS), the maximal severity of all injuries of the body. All riders with $MAIS \geq 3$ were classified as severely injured riders.

Accident configurations analysis

Each accident was jointly reconstructed and analysed by a team of experts. Based on the results of the reconstruction, all the accidents were classified into different configurations, depending on the situation which led to the accident. The type of vehicle against which the bicycle had an impact was also taken into account, as it is an important factor for rider consequences on health.

Statistical analysis

All the study variables were described using the usual descriptive statistics: mean and standard deviation for continuous variables and percentages for categorical ones. In particular, frequencies of collision partner, of maximum AIS body region, and of accident configuration were calculated.

Accident consequences – percentage of injured, severely injured and died riders – by collision partner and accident configurations were also calculated.

Finally, the impact of the most frequent accident configurations - in terms of percentage of involved riders, injured riders, severely injured riders and died riders – was evaluated.

Results

Sample description

In total, 4928 bicyclists involved in an accident occurred in the years 2000-2010 were analyzed. The majority of them (59.4%) was men and the mean age was 38.3 (± 20.1) years (data not shown). In the majority of the accidents (63.8%), the bicycle impacted with a passenger car; 13.6% of cases was single accidents; in the other cases the bicycle impacted with another bicycle (11.0%), a heavy vehicle (truck, bus, tram) (6.6%), a motorcycle (1.2%) (Figure 1).

Accident consequences

As regards the accident consequences, they were known for 4770 riders. Among these, 92.8% reported injuries following the accident. And, among the injured riders, 5.5% was severely injured (Table 1) and 1.0% died following the accident. The percentage of injured riders shows a descendant trend from impact with heavy vehicles to lighter ones: more than 99% when the bicycle impacted with a four-wheeled motor vehicle (passenger car or heavy vehicle), 85.7% in accidents with a motorcycle, 67.2% in accidents with another bicycle, and 51.4% in accidents with a pedestrian. A similar trend is observed focusing on severe injuries: the percentage of severely injured riders is higher (9.2%), in accidents with an heavy vehicle and decreases in accident with a car (4.9%), a motorcycle (4.2%), a bicycle (3.6%), and a pedestrian (0.6%). In single accidents 93.3% of riders was injured and, among these, 8.5% was severely injured (Table 1).

Figure 2 shows the distribution of the maximum AIS by body region: the most severe injuries were more frequent on the head (29.2% of riders) and on the extremities (26.8% upper extremities and 20.1% lower extremities).

Accident configurations

The ten most frequent accident configurations were (Table 2):

1. Conflict between a non priority car and a bicycle with priority coming from a bicycle path (19.8%)
2. Conflict between a car and a bicycle coming from a parallel bicycle path which is turning into or crossing the road (6.7%)
3. Conflict between a bicycle and a car: a non priority vehicle and a priority vehicle coming from the left, not overtaking (6.5%)
4. Conflict between a bicycle and a car a non priority vehicle and a priority vehicle coming from the right, not overtaking (5.7%)
5. Conflict between a car turning off to the right and a bicycle from a special path/track going to the same or opposite direction (5.0%)
6. Conflict between two head-on encountering bicycles (3.4%)
7. Single accident on a straight road, without influences by road width or lateral gradient (3.1%)

8. Conflict between a car turning off to the left and a bicycle from a special path/track going to the same or opposite direction (3.0%)
9. Conflict between a bicycle and a car: a vehicle turning off to the left and oncoming traffic (2.6%)
10. Conflict because of opening a car door (2.4%).

Consequences by accident configuration

In the most common configuration - accident between a non priority car and a bicyclist with priority coming from a bicycle path - the percentage of injured rides was 99.5% and, among these, 3.1% was severely injured and 0.1% died following the accident. The configurations presenting the highest percentages of severely injured riders, higher than the average (5.5%), were: the accident between a car and a bicycle from a parallel bicycle path which is turning into or crossing the road (8.9%); the single accident on a straight road without influences by road width or lateral gradient (8.6%); the accident between a bicycle and a car: a non priority vehicle and a priority vehicle from the right, not overtaking (8.3%); and the conflict because of opening a car door (6.1%). The configurations presenting the highest percentages of rider fatalities, higher than the average (1.0%), were: the accidents between a bicycle and a car: a non priority vehicle and a priority vehicle from the right or the left, not overtaking (2.3% and 1.7% respectively); the conflict because of opening a car door (1.7%); and the single accident on a straight road without influences by road width or lateral gradient (1.4%) (Table 3).

Table 4 shows the impact of the first most frequent, the five most frequent and the ten most frequent configurations, in terms of percentage of riders involved, injured riders, severely injured riders and died riders. The accident between a car and a bicycle with priority from a bicycle path represented alone almost 19.8% of involved riders and 21.5% of injured riders. The five most frequent configurations represented 43.7% of involved riders and 46.7% of injured riders. The ten most frequent configurations represent 58.2 of involved riders, 61.0% of injured riders, 55.4% of severely injured riders, and 43.2% of died riders.

Discussion and conclusions

The main findings of the present research can be summarized as follows:

- in the majority of accidents the bicycle impacted with a passenger car, followed by single accidents;
- the percentage of injured riders was higher if the bicycle impacted with an heavy vehicle and decreased when the bicycle impacted with lighter vehicles;
- a high percentage of injured and severely injured riders in single accidents was observed;
- the most severe injury was more frequently on the head and on the extremities;

- ten most frequent configurations represented about 60% of involved riders and more than 60% of injured riders;
- five most frequent configurations represented more than 40% of involved riders and more than 45% of injured riders;
- the accident between a car and a bicycle with priority from a bicycle path represented alone almost 20% of involved riders and more than 20% of injured riders.

The results obtained allow to make some considerations about the phenomenon of road accidents involving bicycles and some suggestions for preventive actions.

The findings of this study indicate that the risk of sustaining injury or death in an accident is inversely proportional to the weight and solidity of the vehicle partner in the accident, consistently with previous findings (Orsi et al. 2009). These results are therefore supportive of recommendations to prioritise plans for protective interventions for bicycle riders.

The dangerousness of single accident is in accordance with results of previous studies, for instance Orsi et al. (2009). As these accidents occur without the intervention of other vehicles, the consequences are probably due to the impact with some infrastructure, suggesting that attention should be paid to infrastructure, to make the vulnerable road users safer. Moreover, these accidents are probably attributable to distractions, illness, falling asleep, often brought on by excess of food, alcohol, pharmaceuticals, and drugs. Therefore, injury prevention for bicycle riders should also include education and training about safe riding habits and accident risk factors.

The results of this research indicate that the most severe injury was more frequently on the head and on the extremities, in accordance with previous studies (Bostrom e Nilsson 2001, Eid et al 2007, Lustenberger 2010, Richter et al. 2005, 2007, Rosenkranz e Sheridan 2003, Styrke et al 2007). This evidence underlines the importance of wearing a helmet as preventive measure for accident consequences. Indeed, it is known that helmets reduce bicycle-related head and facial injuries for bicyclists of all ages involved in all types of crashes including those involving motor vehicles (Attewell et al. 2001, Airaksinen 2010, Amoros 2011, Thompson 2000). Consequently, helmet promotion and education on its use should be an integral part of bicycle injury prevention strategies.

The evidence that few configurations cause the majority of injured riders indicates that it is possible to address the preventive actions focusing on the most common situations. As the most frequent configuration is the accident between a car and a priority bicycle from a bicycle path, educational interventions should be addressed not only to bicycle riders but also to other vehicles drivers. A possible cause of these accidents could be a low bicycle and rider conspicuity: increased use of high-visibility helmets and clothing could be a simple intervention that may have a large impact on the safety of cycling.

In conclusion, it is reasonable to assume that in-depth investigations and accident reconstruction give most detailed data for specific research questions and decision making. It is possible to infer that training education programme to improve some riding ability and knowledge of the risk annexed to riding, could protect bicycles riders maybe by helping them in the detection of oncoming passenger cars and other road vehicles and the prediction of their manoeuvres. Moreover, a visibility enhancement system should be suggested on the bicycle and on the rider, for example on the helmet. Finally, to reduce the potential for accidents to happen at all it is desirable a proper road design, the use of traffic calming, mobility management, and more adherence to traffic laws.

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Figure 1. Accident collision partners

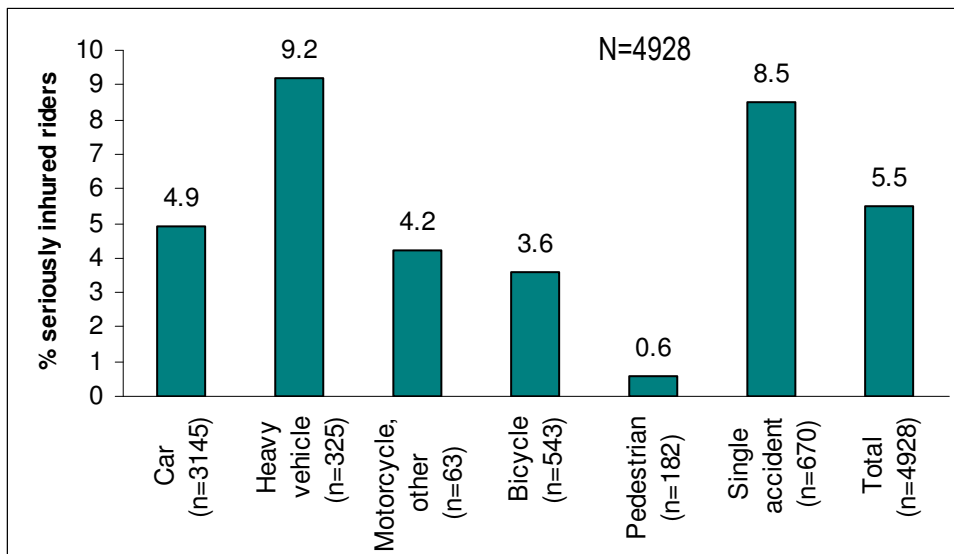


Table 1. Accident consequences by collision partner

Collision partner	N (total)	Injured		MAIS \geq 3	
		N	% (among total)	N	% (among injured)
Passenger car	3042	3019	99.2	147	4.9
Heavy vehicle	311	305	99.1	28	9.2
Motorcycle, other	56	48	85.7	2	4.2
Bicycle	534	359	67.2	13	3.6
Pedestrian	181	93	51.4	1	0.6
Single accident	646	603	93.3	51	8.5
Total	4770	4427	92.8	242	5.5

Figure 2. Maximum AIS body region

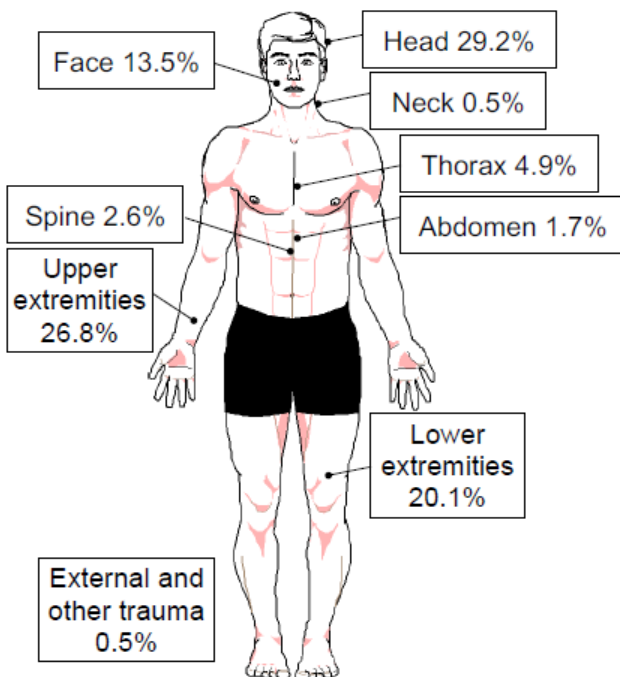


Table 2. Most frequent accident configurations

	Accident type	N	%
A non priority car and a bicycle with priority coming from a bicycle path		977	19.8
A car and a bicycle coming from a parallel bicycle path which is turning into or crossing the road		331	6.7
A bicycle and a car: a non priority vehicle and a priority vehicle from the left, not overtaking		318	6.5%
A bicycle and a car: a non priority vehicle and a priority vehicle from the right, not overtaking		281	5.7%
A car turning off to the right and a bicycle from a special path going to the same or opposite direction		248	5.0%
Two head-on encountering bicycles		169	3.4%
Single accident on a straight road, without influences by road width or lateral gradient		152	3.1%
A car turning off to the left and a bicycle from a special path going to the same or opposite direction		148	3.0%
A bicycle and a car: a vehicle turning off to the left and oncoming traffic		126	2.6%
Conflict because of opening a car door		117	2.4%

Table 3. Accident consequences by accident configurations

Accident type	N	Injured		% severe injured (among injured)	% of fatalities (among injured)
		N	%		
A non priority car and a bicycle with priority coming from a bicycle path	977	955	97.2	3.1	0.1
A car and a bicycle coming from a parallel bicycle path which is turning into or crossing the road	331	320	95.2	8.9	0.6
A bicycle and a car: a non priority vehicle and a priority vehicle from the left, not overtaking	318	302	94.3	6.7	1.7
A bicycle and a car: a non priority vehicle and a priority vehicle from the right, not overtaking	281	267	94.7	8.3	2.3
A car turning off to the right and a bicycle from a special path going to the same or opposite direction	248	240	94.8	0.9	0.0
Two head-on encountering bicycles	169	164	69.2	2.6	0.0
Single accident on a straight road, without influences by road width or lateral gradient	152	143	92.1	8.6	1.4

A car turning off to the left and a bicycle from a special path going to the same or opposite direction		229 uncertain if 221-225	148	144	95.3	5.0	0.7
A bicycle and a car: a vehicle turning off to the left and oncoming traffic		219 uncertain if 211-215	126	121	95.2	3.3	0.0
Conflict because of opening a car door		589 Side uncertain	117	115	98.3	6.1	1.7

Table 4. Impact of most frequent accident configurations

	% of involved riders	% of injured riders	% severely injured riders	% of died riders
1 most frequent configuration	19.8	21.5	12.0	2.3
5 most frequent configurations	43.7	46.7	41.7	31.8
10 most frequent configurations	58.2	61.0	55.4	43.2