# Bicyclist – bicyclist crashes
# – A Medical and Technical Crash Analysis

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**Background:** The purpose of this study was to analyse the actual injury situation of bicyclists regarding accidents involving more than one bicyclist. Bicyclists were included in a medical and technical analysis to create a basis for preventive measures and discovered repeating accident patterns and circumstances such as daytime, environment, helmet use rate.

**Methods:** Technical and medical data were collected at the scene, shortly after accident.
The population was compared focusing on bicycle versus bicycle accidents. Technical analysis included speed at crash, type of collision, impact angle, environment, used lane and relative velocity. Medical analysis included injury pattern and severity (AIS, ISS).

**Results:** Included were 578 injured bicyclists in 289 accidents from years 1999 to 2008, 61 percent were male (n=350) and 39 percent female (n=228). Sixty-seven percent ranged between 18 to 64 years of age, twelve percent each between 13 to 17 years of age and older than 65 years, eight percent between 6 to 12 years and one percent between 2 to 5 years.. Crashes took place in urban areas in 92 percent, in rural areas in 8 percent. Weather conditions were dry lanes in 97 percent and wet conditions in 3 percent. Eighty-three percent of all accidents happened during daytime, ten percent during night, and seven percent during dawn. The helmet use rate was only 7,5 percent in all involved bicyclists. The mean Maximum Abbreviated injury scale, Injury severity score was 1,31.

**Conclusion:** Bicyclists are still minimally- or unprotected road users. The helmet use rate is unsatisfactorily low. The incidence of bicycle to bicycle crashes is high. Most of these accidents take place in urban areas. The level and pattern of injuries is moderate. Most of the more severe injuries occur to the head and could have been avoided by frequent helmet use.

**Key Words:** Bicyclist, bicycle helmet, injury severity, technical analysis, medical analysis

## Introduction

Although there is a growing number of helmet-users, bicyclists are still minimally protected road users [1, 2, 3, 11, 18,]. Regarding pedestrians there average travelling speed is high and there reaction time is therefore lowered [2, 3]. The actual injury situation of bicyclist has already been investigated and published [4, 15], but there has not been any specific in-depth investigation regarding the bicycle to bicycle crash circumstances and the different injury pattern occurring to the opponents.
By using technical in-depth crash investigations in combination with medical data analysis the purpose of our study was to analyze the actual injury situation of bicyclists by setting our priorities on bicycle to bicycle crashes and there different injury patterns [6-10, 12, 14-20]. The target of our study was to create a basis for effective preventive measures regarding repeated injury patterns [14, 20].

## Methods

Since 1972, a local traffic research unit has collected prospective data in regard to all reported traffic crashes within Germany [13]. Specially trained documentation personnel are notified by police dispatchers and arrive on scene, often simultaneously with the rescue personnel. Thus, investigation of the crash (measurements by photography, stereophotography, three dimensional-laser technique), and clinical injury documentation is performed on site. This case report is then completed at the hospital, where all of the injured victims are taken, with proper documentation of X-ray examination, injury type, and severity [17, 22]. The monitoring includes demographic data, area of collision, environmental circumstances, injury pattern, Abbreviated Injury Scale (AIS), Maximum AIS (MAIS), Injury Severity Score (ISS) [5], incidence of serious or severe multiple injuries

n(polytrauma, AIS 3+ in two different body regions of the patient admitted to the hospital), incidence of serious (MAIS, 2-4) or severe injuries (MAIS, 5-6), and mortality.
Among the technical measurement techniques, the modern 3D-laser technique is a quick and exact method to document the exact position of all objects at the crash site. A 3D-data cube with a maximum size of $50m^3$ is generated from the data obtained by the 3D-laser scanner. This data allows an exactly scaled reconstruction of the crash site for later technical analysis of the crash. Slide and skid marks of bicycles, objects, and victims and any kind of deformation of involved vehicles or objects are also measured, and these data are included in the crash analysis. Data from a database containing technical features of involved bicycles are included in the analysis. The inclusion of the described data in a software-based calculation allows an exact estimation of parameters as delta-v or collision speed.
In total, the monitoring of the crash research unit includes demographic data, type of road user, delta-v (km/h) for motorized vehicle users; vehicle collision speed for bicyclists, Abbreviated Injury Scale (AIS) score, Maximum AIS (MAIS) score, Injury Severity Score (ISS), incidence of serious injuries (MAIS 2-4) or severe injuries (MAIS 5 of 6), and mortality.
For this study, traffic crash reports from 1999-2008 from the local traffic research unit were analyzed for the involvement of injured bicyclists as well as for the following parameters: demographic data, AIS score, MAIS score, ISS, incidence of multiple injuries, incidence of serious and severe injuries, incidence of death, collision speed and collision type.
For statistical analysis of the correlation between crash circumstances with injury severity (AIS/MAIS/ISS) a t-test or linear-trend test was performed.

## Results

The total number of crashes we analyzed was 289. The number of injured bicyclists was 578.

### Demographic Data

Sixty-one percent of all bicyclist were male, 39 % were female.
Of all bicyclists, 1% were of preschool age (1-5 years of age), 8,5% were between 6 and twelve years of age, 12% were between 13 and 17, 66,5% between 18 and 64 and 12% older than 64 years of age.

### Crash Circumstances

The crashes took place in urban areas in 92% of all cases, 8% of the observed accidents took place in rural areas. Ten percent of all crashes happened during night or darkness, 83% took place during daylight and seven percent during dawn or dusk. The road conditions at the time of the crash were dry and solid in 97% of all cases, three percent happened during rain on wet road conditions. Frequent helmet use at crash was observed at only 7,5% (n=43/578) bicyclists, 87% crashed without head protection by helmet (n=503/578), unknown was the use of a helmet protection in 5,5% (n=32/578) of all bicyclists. There were only 32 out of 350 male bicyclists wearing a helmet protection and only 11 out of 228 female bicyclists with a head protection.
Regarding the different groups of age we used for this study there were 2 out of 6 children at preschool age wearing a helmet protection. Only eight out of 49 of the children aged between six and twelve years wore a protection helmet with one unknown, two out of 68 in the group of adolescents with six unknown, 29 of 384 in the group aged between 18 and 64 years of age with 23 unknown, and two bicyclist out of 71 in the group aged 65 years or older with two unknown.
Table 1 indicates the different crash locations and environmental circumstances.
Table 2 indicates the frequency of protective helmet use in correlation to gender without any significant difference.

**Table 1** Crash location and environmental circumstances

| Crash location | Percent of cases |
|---|---|
| Urban | 92 |
| Rural | 8 |
| | |
| **Environmental Circumstances** | |
| Night | 10 |
| Day | 83 |
| Dawn/Dusk | 7 |
| | |
| **Weather conditions** | |
| Dry and solid | 97 |
| Wet | 3 |

**Table 2** Frequency of helmet use in correlation to gender

| | | Helmet Use | | | Total |
|---|---|---|---|---|---|
| | | yes | no | unknown | |
| Gender | male | 32 | 295 | 23 | 350 |
| | female | 11 | 208 | 9 | 228 |
| Total | | 43 | 503 | 32 | 578 |

**Injuries**

Table 3 indicates the MAIS score and AIS score of the different body regions. 82,1 percent of bicyclists sustained only injuries with minor severity (MAIS = 1), and 2,6 percent at least one severe injury (MAIS ≥ 3).. The lesions at the head in not helmet-protected bicyclists were located above the ear level in more than 60 percent of the time, i.e. in the typical helmet protection area.

**Injury Analysis**

Table 3 shows a correlation between use of helmet protection and sustained injuries to the head of major AIS. There were at least 165 of total 498 bicyclists without helmet protection that sustained injuries to the head ranging from AIS 1->3 (30%).

**Table 3** AIS and MAIS of different body regions total and in correlation to helmet use

| | Total | No Helmet | Helmet | MAIS |
|---|---|---|---|---|
| Head | n | n | n | |
| Not injured | 395 | 333 | 30 | |
| AIS 1 | 128 | 118 | 8 | |
| AIS 2 | 48 | 42 | 4 | |
| AIS 3+ | 7 | 5 | 1 | 4 |
| | | | | |
| Thorax | | | | |
| Not injured | 500 | 438 | 30 | |
| AIS 1 | 56 | 44 | 10 | |
| AIS 2 | 20 | 17 | 3 | |
| AIS 3+ | 2 | 1 | 0 | 3 |
| | | | | |
| Abdomen | | | | |
| Not injured | 564 | 488 | 41 | |
| AIS 1 | 13 | 11 | 2 | |
| AIS 2 | 0 | 0 | 0 | |
| AIS 3+ | 1 | 1 | 0 | 3 |
| | | | | |
| Pelvis | | | | |
| Not injured | 545 | 475 | 37 | |
| AIS 1 | 32 | 25 | 6 | |
| AIS 2 | 1 | 1 | 0 | |
| AIS 3+ | 0 | 0 | 0 | 1 |
| | | | | |
| Upper Extremity | | | | |
| Not injured | 361 | 311 | 20 | |
| AIS 1 | 190 | 168 | 17 | |
| AIS 2 | 25 | 19 | 6 | |
| AIS 3+ | 2 | 2 | 0 | 3 |
| | | | | |
| Lower Extremity | | | | |
| Not injured | 390 | 343 | 22 | |
| AIS 1 | 177 | 146 | 21 | |
| AIS 2 | 8 | 8 | 0 | |
| AIS 3+ | 3 | 3 | 0 | 3 |

Table 4-9 indicate the correlation between age of the injured bicyclists and the AIS of different body regions. It shows that there are only injuries of minor severity in the group of preschool children. In the group of children ranged between 6-12 years of age there is also no incidence for injuries of major severity in any of the observed body regions of interest.
Regarding the group of observed adolescents there is a mild progress of injuries of major severity with an AIS $\geq 3$ in two cases. The largest group of observed bicyclists in the group between 18-64 years of age shows more severe injuries and a higher frequency of sustained injuries. The group of elderly bicyclists aged above 65 years sustained frequent injuries to head and upper and lower extremities than other observed groups.

**Table 4-9** Correlation between Age and AIS of different body regions

| | | Age | | | | | |
|---|---|---|---|---|---|---|---|
| | | Preschool | Between 6-12 years of age | Adolescent | Between 18-64 years of age | older than 65 years of age | Total |
| AIS Head | AIS 0 | 3 | 38 | 55 | 258 | 35 | 389 |
| | AIS 1 | 3 | 9 | 8 | 79 | 30 | 129 |
| | AIS 2 | 0 | 1 | 4 | 36 | 6 | 47 |
| | AIS 3 | 0 | 0 | 0 | 4 | 0 | 4 |
| | AIS 4 | 0 | 0 | 1 | 2 | 0 | 3 |
| | unknown | 0 | 1 | 0 | 5 | 0 | 6 |
| Total | | 6 | 49 | 68 | 384 | 71 | 578 |

| | | Age | | | | | |
|---|---|---|---|---|---|---|---|
| | | Preschool | Between 6-12 years of age | Adolescent | Between 18-64 years of age | older than 65 years of age | Total |
| AIS Thorax | AIS 0 | 5 | 48 | 63 | 321 | 59 | 496 |
| | AIS 1 | 1 | 0 | 4 | 40 | 11 | 56 |
| | AIS 2 | 0 | 0 | 1 | 18 | 1 | 20 |
| | AIS 3 | 0 | 0 | 0 | 2 | 0 | 2 |
| | unknown | 0 | 1 | 0 | 3 | 0 | 4 |
| Total | | 6 | 49 | 68 | 384 | 71 | 578 |

| | | Age | | | | | |
|---|---|---|---|---|---|---|---|
| | | Preschool | Between 6-12 years of age | Adolescent | Between 18-64 years of age | older than 65 years of age | Total |
| AIS Upper Extremity | AIS 0 | 5 | 26 | 49 | 235 | 42 | 357 |
| | AIS 1 | 1 | 20 | 18 | 127 | 24 | 190 |
| | AIS 2 | 0 | 2 | 0 | 19 | 4 | 25 |
| | AIS 3 | 0 | 0 | 1 | 0 | 1 | 2 |
| | unknown | 0 | 1 | 0 | 3 | 0 | 4 |
| Total | | 6 | 49 | 68 | 384 | 71 | 578 |

| | | Age | | | | | |
|---|---|---|---|---|---|---|---|
| | | Preschool | Between 6-12 years of age | Adolescent | Between 18-64 years of age | older than 65 years of age | Total |
| AIS Abdomen | AIS 0 | 6 | 45 | 67 | 373 | 69 | 560 |
| | AIS 1 | 0 | 3 | 1 | 7 | 2 | 13 |
| | AIS 3 | 0 | 0 | 0 | 1 | 0 | 1 |
| | unknown | 0 | 1 | 0 | 3 | 0 | 4 |
| Total | | 6 | 49 | 68 | 384 | 71 | 578 |

| | | Age | | | | | Total |
|---|---|---|---|---|---|---|---|
| | | Preschool | Between 6-12 years of age | Adolescent | Between 18-64 years of age | older than 65 years of age | |
| AIS Pelvis | AIS 0 | 6 | 47 | 66 | 354 | 68 | 541 |
| | AIS 1 | 0 | 1 | 2 | 26 | 3 | 32 |
| | AIS 2 | 0 | 0 | 0 | 1 | 0 | 1 |
| | unknown | 0 | 1 | 0 | 3 | 0 | 4 |
| Total | | 6 | 49 | 68 | 384 | 71 | 578 |

| | | Age | | | | | Total |
|---|---|---|---|---|---|---|---|
| | | Preschool | Between 6-12 years of age | Adolescent | Between 18-64 years of age | older than 65 years of age | |
| AIS Lower Extremity | AIS 0 | 5 | 28 | 54 | 255 | 44 | 386 |
| | AIS 1 | 1 | 17 | 13 | 120 | 26 | 177 |
| | AIS 2 | 0 | 3 | 1 | 4 | 0 | 8 |
| | AIS 3 | 0 | 0 | 0 | 2 | 1 | 3 |
| | unknown | 0 | 1 | 0 | 3 | 0 | 4 |
| Total | | 6 | 49 | 68 | 384 | 71 | 578 |

**Table 10-15** Correlation between daytime of accident and AIS of different body regions

| | | AIS Head | | | | | | Total |
|---|---|---|---|---|---|---|---|---|
| | | AIS 0 | AIS 1 | AIS 2 | AIS 3 | AIS 4 | unbekannt | |
| Time | Daytime | 331 | 108 | 31 | 3 | 2 | 5 | 480 |
| | Nighttime | 28 | 14 | 15 | 1 | 1 | 1 | 60 |
| | Dawn | 30 | 7 | 1 | 0 | 0 | 0 | 38 |
| Total | | 389 | 129 | 47 | 4 | 3 | 6 | 578 |

| | | AIS Thorax | | | | | Total |
|---|---|---|---|---|---|---|---|
| | | AIS 0 | AIS 1 | AIS 2 | AIS 3 | unbekannt | |
| Time | Daytime | 411 | 49 | 16 | 1 | 3 | 480 |
| | Nighttime | 52 | 3 | 4 | 0 | 1 | 60 |
| | Dawn | 33 | 4 | 0 | 1 | 0 | 38 |
| Total | | 496 | 56 | 20 | 2 | 4 | 578 |

| | | AIS Upper Extremity | | | | | Total |
|---|---|---|---|---|---|---|---|
| | | AIS 0 | AIS 1 | AIS 2 | AIS 3 | unbekannt | |
| Time | Daytime | 293 | 163 | 19 | 2 | 3 | 480 |
| | Nighttime | 42 | 12 | 5 | 0 | 1 | 60 |
| | Dawn | 22 | 15 | 1 | 0 | 0 | 38 |
| Total | | 357 | 190 | 25 | 2 | 4 | 578 |

| | | AIS Abdomen | | | | Total |
|---|---|---|---|---|---|---|
| | | AIS 0 | AIS 1 | AIS 3 | unbekannt | |
| Time | Daytime | 464 | 12 | 1 | 3 | 480 |
| | Nighttime | 58 | 1 | 0 | 1 | 60 |
| | Dawn | 38 | 0 | 0 | 0 | 38 |
| Total | | 560 | 13 | 1 | 4 | 578 |

| | | AIS Pelvis | | | | Total |
|---|---|---|---|---|---|---|
| | | AIS 0 | AIS 1 | AIS 2 | unbekannt | |
| Time | Daytime | 455 | 21 | 1 | 3 | 480 |
| | Nighttime | 50 | 9 | 0 | 1 | 60 |
| | Dawn | 36 | 2 | 0 | 0 | 38 |
| Total | | 541 | 32 | 1 | 4 | 578 |

| | | AIS Lower Extremity | | | | | Total |
|---|---|---|---|---|---|---|---|
| | | AIS 0 | AIS 1 | AIS 2 | AIS 3 | unbekannt | |
| Time | Daytime | 324 | 142 | 8 | 3 | 3 | 480 |
| | Nighttime | 39 | 20 | 0 | 0 | 1 | 60 |
| | Dawn | 23 | 15 | 0 | 0 | 0 | 38 |
| Total | | 386 | 177 | 8 | 3 | 4 | 578 |

Table 10-15 indicates the correlation between daytime at accident and AIS of different body regions. It shows that there is no significant difference regarding the daytime of accident.

The correlation between age and use of helmet protection indicates table 16.

| | | Helmet | | | Total |
|---|---|---|---|---|---|
| | | yes | no | unknown | |
| Age | Preschool | 2 | 4 | 0 | 6 |
| | Between 6-12 years of age | 8 | 40 | 1 | 49 |
| | Adolescent | 2 | 60 | 6 | 68 |
| | Between 18-64 years of age | 29 | 332 | 23 | 384 |
| | older than 65 years of age | 2 | 67 | 2 | 71 |
| Total | | 43 | 503 | 32 | 578 |

The use of helmet protection was more frequent in the group of preschool children and the group aged between 6-12 years of age than in the other observed groups as table 16 indicates.

**Discussion**

In this study, a technical and medical in-depth investigation of more than 280 bicycle to bicycle crashes with consequent injuries to bicyclists was performed. This study was focused on crash circumstances and epidemiologic data. Injury mechanisms were analysed in further detail including the use of protective bicycle helmets. The purpose of this study was to analyse the actual injury situation of bicyclists far beyond those mentioned in the numerous previous epidemiologic studies regarding accidents involving more than one bicyclist.

**Special Injury Situation of bicyclists**

In bicyclist, the head and extremities are at a high risk for injuries. Almost one third of the injured bicyclists sustained injuries to head and/or upper extremity and/or lower extremities. These body regions are more endangered than for other crash occupants in motorized vehicles.
The impact of head injuries is still underlined by the high percentage of inpatient treatment among the group who sustained head injuries. A bicycle helmet has been shown to significantly decrease the risk of, and suffer protection against, head injuries.
Only 7.5 percent of the injured bicyclists in our study were helmet protected. This percentage was observed for the entire sample.
The helmet protection rate was higher in the groups of the younger children, but already starts to decrease in the adolescent group.
Regulations requiring bicycle helmet use could be a tool to increase the number of protected bicyclists.
We did not observe any significant difference regarding the correlation between daytime circumstances and severity of the accidents.
There was a non-significant correlation between accidents with major injuries and age of years of the bicyclist. Especially the group of young adults, maybe influenced by the use of alcohol, and travelling at higher speed is in danger of bicycle injuries with major injuries.
Also, the group of elderly people is maybe because of their lower ability of fast reaction is in more danger to accidents with major injuries. These groups are also the groups with the lowest percentage of frequent helmet use. A professional teaching compared to driving license test could here prevent the bicyclists from sustaining major injuries.
At least, in conclusion, head and extremities of bicyclists are still at high risk of injuries.
Most of the injuries to the head could have been prevented by the frequent use of fitting helmet protection. The helmet use rate is still unsatisfactorily low. Maybe a mandatory regulation could help to raise the number of bicyclists with frequent helmet use rate.

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