Evaluation of the protective effect of bicycle helmets (A GIDAS-analysis 2000-2007)

J Tschernitschek, L Hannawald, R Koch and H Zwipp

Department of Trauma and Reconstructive Surgery, University Hospital "Carl Gustav Carus", Fetscherstr. 74, 01307 Dresden, Germany

Abstract:
Objective: Aim of the study was to evaluate the protective effect of bicycle helmets particularly considering injuries to the head and to the face.
Material: Accidents with the participation of bicyclists which occurred from 2000 to 2007 were chosen from GIDAS.
Results: We observed that injuries to the head and face were more severe in the group of non-helmeted riders. There seems to be no significant difference in injuries with AIS 3-6. Altogether 26 cyclists were killed. 2 of them wore a helmet (1% of helmeted cyclists), 24 did not (1% of non-helmeted cyclists). Only one killed rider (without helmet) did not suffer from polytrauma (only head injuries recorded).
Conclusion: The findings seem to support the thesis of a preventive effect of the bicycle helmet, however the two groups are different in their characteristics related to riding speed. Necessarily we need a multivariate model to evaluate the effect of helmets.

INTRODUCTION

Aim of the study was to evaluate the protective effect of bicycle helmets particularly considering injuries to the head and to the face. We tried to get results to provide advice regarding mandatory helmet legislation in Germany. There is still much discussion in literature about the preventive effect and consequently the mandatory use of bicycle helmets always comparing the situation to other countries and their experiences in bicycle traffic regulations. Nowadays we find rising rates of helmet usage in Germany. In 2008 10% of all bicyclists in Germany were wearing a helmet (2007: 9%, 2006: 7%) [1,2] The latest Systematic Review of the Cochrane Database concluded that the bicycle helmet legislation is effective in increasing helmet use and decreasing head injury rates. [3]

EQUIPMENT

Basis of data

For this paper we used data from GIDAS (German in-depth accident study), which was established in 1999 by the cooperation between FAT (Forschungsvereinigung Automobiltechnik) and BASt (Bundesanstalt für Straßenwesen) and nowadays has a leading role in Europe.
The data is collected by two scientific teams working in Hannover and Dresden. In every year about 2000 accidents are evaluated with each approximately 3000 features.
The surveillance area around Hannover includes the city itself and its surroundings with a total area of about 2289 km^2, 10% is municipal area. This distribution is probably comparable to Germany. About 1 million inhabitants live in and around Hannover.
On 1st July 1999 a second scientific team was established in Dresden. With the help of latest technologies medical student and students of automotive engineering collect data and keep records. This team covers the city of Dresden, the county Sächsische Schweiz-Osterzgebirge as well as parts of the counties of Meißen and Bautzen. About 1 million people live here on ca. 2575 km^2. The choice of this region was made considering its topography which is approximately close to the topography of Germany.
In cooperation between the Medical School of Hannover and the University of Technology of Dresden the teams work in inverted rhythms as well as on weekends and on holidays. In order to record data

there is a team of two technicians, one medicine and a coordinator on every shift. The coordinator keeps in touch with rescue coordination centers and police directions. He is in charge to instruct by sample design.
Of course every collected data of an accident is made anonymous.
Between 2000 and 2007 a total of 2691 accidents with involvement of bicyclists were recorded including the information whether a helmet was worn or not.

Statistics

Chisquaretest of Independence

The Chisquaretest of Independence tests the univariate relation between 2 categorical variables. The following hypotheses are put: Null (H_0): There is no association between the two variables. Alternate (H_1): There is an association between the two variables. We agree upon the level of significance of $\alpha=0.05$. If our test- α^* is lower than 0.05, we drop H_0 and accept H_1.

Cramer's V

Cramer's V is used as a test to determine strengths of association after Chisquare has already determined significance between the two variables. The following limits are set: $V<0,2$ slight correlation, $0,2\leq V<0,5$ distinct correlation, $V\geq 0,5$ strong correlation.

Mann-Whitney-U-test

The test is appropriate to the case of two independent samples of observations that are measured at least at an ordinal level. The test assesses whether the degree of overlap between the two observed distributions is less than it would be expected by chance putting the null hypothesis (H_0) that the two samples are drawn from a single population. We agree upon the level of significance of $\alpha=0.05$. If our test- α^* is lower than 0.05, we drop H_0 and accept the alternate hypothesis (H_1) that the samples are independent.

Logistic Regression

Logistic regression is useful for situations in which you want to be able to predict the presence or absence of a characteristic or outcome based on values of a set of predictor variables. It is similar to a linear regression model but is suited to models where the dependent variable is dichotomous. Logistic regression coefficients can be used to estimate odds ratios for each of the independent variables in the model. Logistic regression is applicable to a broader range of research situations than discriminant analysis.

EXPERIMENTAL PROCEDURE

Personal characteristics

First part of the study was a descriptive analysis of the characteristics of the two groups "Cyclists with helmet" and "Cyclists without a helmet". It is absolutely necessary to remind that we only consider cyclists who had an accident and have been registrated by scientific teams in Hannover and Dresden. We used following variables:
- Age {Children up to 13 years; teenagers 14-17 years; adolescents 18-20 years; 21-60 years; >60 years}
- Gender {male; female}
- Body-Mass-Index {<18.5 kg/m^2; 18.5-25 kg/m^2; 25-30 kg/m^2; >30 kg/m^2}
- Cycling speed
- Type of bicycle {Mountainbike; BMX; road bike; touring bicycle; others}

- Collision speed of opponent
- Type of opponent {Car; van up to 7.5t; truck; motorbike; tram; others}

Injuries

The second part dealt with analyzing and describing the injuries itself without consideration of the possible inhomogenity of the two groups of bicycle riders who had accidents. We particularly concentrate on describing head and facial injuries. When describing the injury severity we used AIS. The Abbreviated injury scale which describes the severity of injury to different body regions: 1=Minor, 2=Moderate, 3=Serious, 4=Severe, 5=Critical, 6=Unsurvivable. However, the AIS is no injury scale in which the difference between AIS1 and AIS2 is the same as that between AIS4 and AIS5.
The location of injuries to the face was arranged into {forehead; nose; eyes; mouth, jaw, teeth; chin; others} and additionally {osseous; soft part}. The type of injuries to the face was arranged into {contused laceration; bruise; abrasion; tooth defect; fracture; others}. The location of injuries to the head was arranged into {brain; scalp; other soft parts; osseous skull; others}.

THEORY

A bicycle helmet as a protective device should downsize injury severity. However, only when having two comparable groups of cyclists, we can make a case whether the bicycle helmet is a protective device that should compulsorily be worn or not.

RESULTS

Personal characteristics

Age

Among all casualties who had worn a helmet the rate of children (up to 13 years) is much higher (26.8%, 57 of 213) than in the group of non-helmeted casualties (10%, 247 of 2472).

Gender

Much more men did wear a helmet. 10.6% of male casualties did wear a helmet (164 of 1550). Only 4.2% of female bicycle-riders who had an accident did wear a helmet (47 of 1130).

Body-Mass-Index

Among those casualties who did not wear a helmet about a third (33.3%, 715 of 2086) had a BMI higher than 25 kg/m^2 which is more compared to 27.3% (51 of 187) in the group of cyclists wearing a helmet.

Cycling speed

Casualties wearing a helmet were in average at significantly higher speed (mean=16.8 km/h, SEM=0.6) than cyclists wearing no helmet (14.3 km/h, SEM=0.1).

Type of bike

Both groups (with and without helmet) are not comparable. Particularly riders of mountainbikes and road bikes more often wore helmets and in addition were at higher speed.

Collision speed of opponent

The two groups of casualties wearing and not wearing a helmet are comparable regarding the collision speed of the opponent. Mean collision speed of the opponent in the group of helmeted cyclists was 17.4 km/h (SEM=1.1) and 19.2 km/h (SEM=0.4) in the group of non-helmeted cyclists.

Type of opponent

Both groups are comparable. In the group of helmeted casualties cars were in 73.4% the main opponent, compared to 75.5% in the group of non-helmeted cyclists, followed by 16.2% bikes in the group of helmeted cyclists compared to 14.1% in the group of non-helmeted riders.

Injuries

In fact 7560 injuries including the information whether a helmet was worn or not were recorded. We observed that casualties not wearing a helmet have had more injuries to the head (13%, 901 of 6950) compared to other body regions. Casualties wearing a helmet less often suffered from head injuries. (6%, 37 of 610). There seems to be no significant difference between the frequency of affection of the face in the group of non-helmeted riders (11%, 791 of 6950) compared to the group of helmeted riders (11%, 68 of 610). Nevertheless when arranging a simple crosstable between AIS (abbreviated injury score) and body region, we find differences in injury severity distribution for facial injuries in our data. Head injury severity seems to be homogenously distributed for both groups, helmeted and non-helmeted bicycle riders. Indeed we found no injury with an AIS more than 4 in the group of helmeted riders who had an accident (n=214). We observed that 1% (49 of 6950) of all injuries to cyclists without a helmet was recorded with AIS 5 or 6. But however, there seems to be no difference in the frequency of death: 1% (2 of 222) of helmeted riders and 1% (24 of 2597) of non-helmeted riders died. Among all killed cyclists the head was 14 times the most grievous injured body region and the chest 13 times. Only 1 killed cyclist did not suffer from polytrauma (only injuries to the head). This person did not wear a helmet.

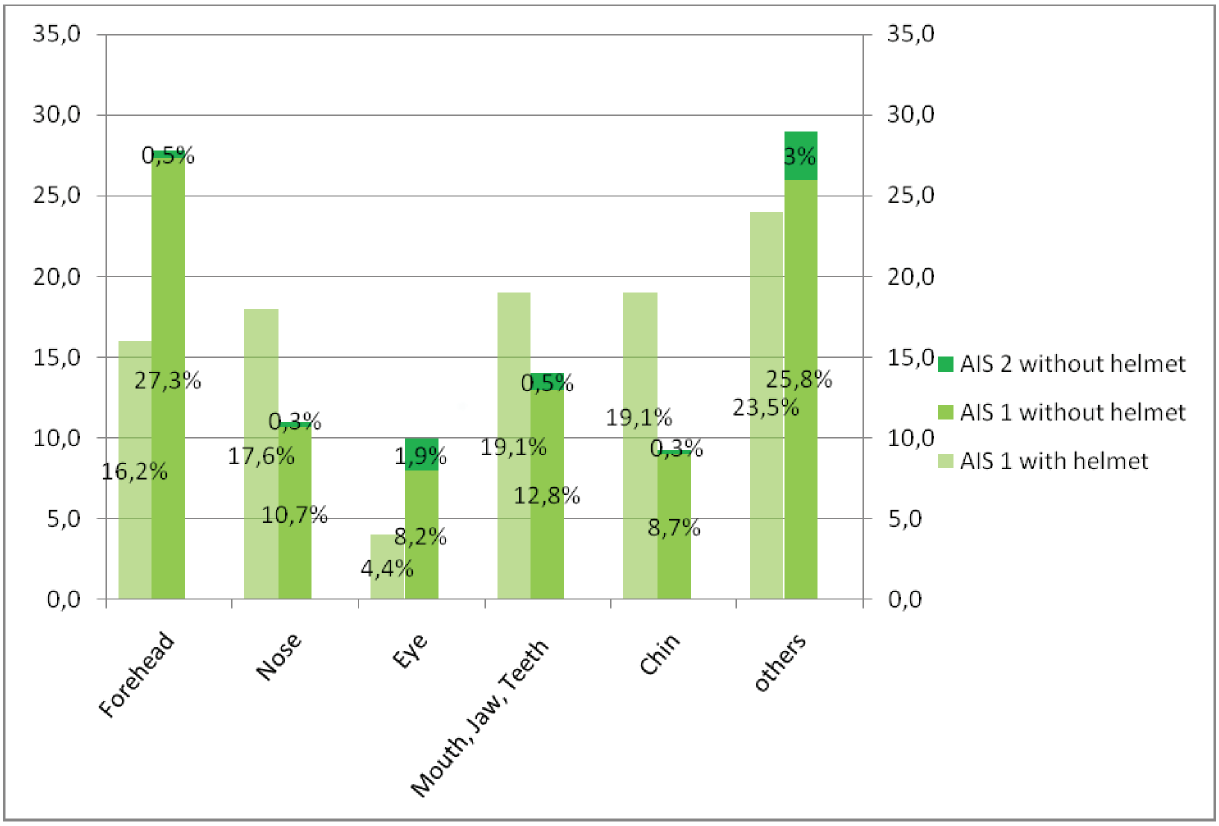

Figure 1: Injuries to the face by region and severity; without helmet: n=791; with helmet: n=68

Figure 1 shows that 791 injuries were recorded to the face of non-helmeted riders, 68 to the face of helmeted casualties. We found that cyclists with a helmet have more often suffered from mild injuries to the chin (19.1% compared to 8.7%), whilst cyclists without a helmet had a higher number of injuries to the forehead (19% compared to 9%). According to our data helmeted cyclists only suffered from mild injuries to the face. 6.5% (51 of 791) of the injuries to the face of non-helmeted cyclists were found severe. The others were mild as well. We observed that the type of injury to the face of cyclists without a helmet was much more often a contused laceration (33%, 258 of 791 compared to 24%, 16 of 68 in the group of cyclists with helmet). We found that cyclists who had worn a helmet had more mild injuries like bruises and abrasions: 24%, 16 of 68 and 32%, 22 of 68 compared to 16% bruises (129 of 791) and 25% abrasions (193 of 791) in the group of cyclists who did not wear a helmet. We observed that cyclists who have worn a helmet seem to have more often suffered of damages to their teeth: 6% (4 of 68) compared to only 2% (16 of 791) in the group of non-helmeted riders.

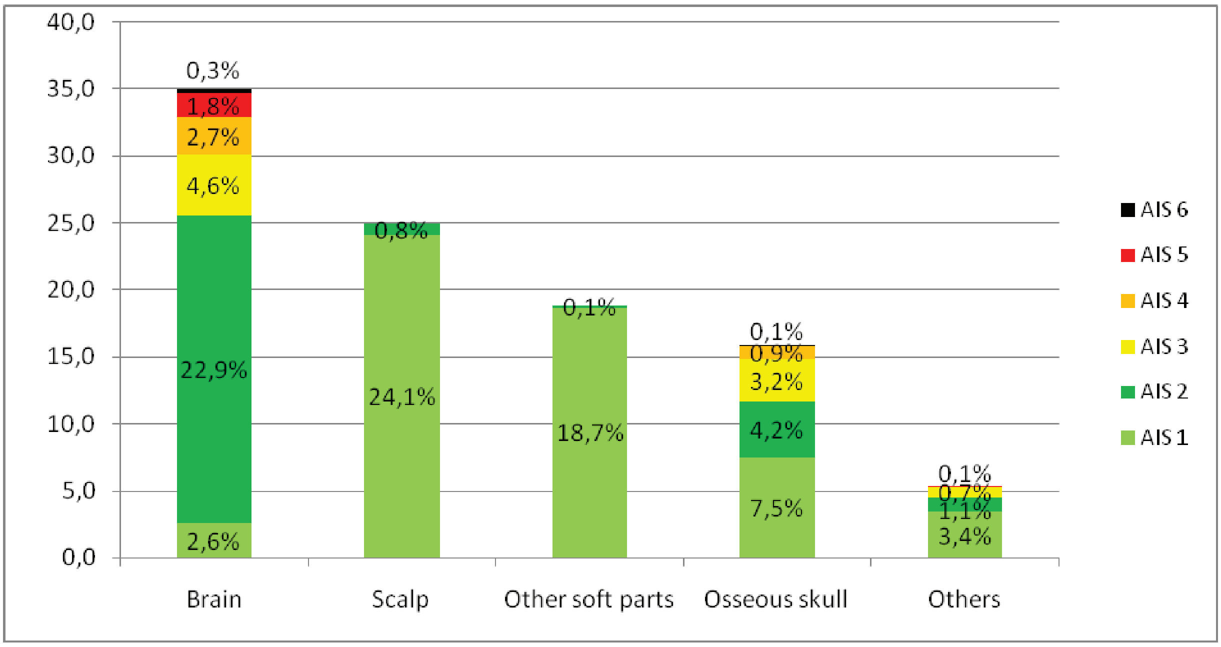

Figure 2: Without helmet (n=882), Injuries to the head by region and severity

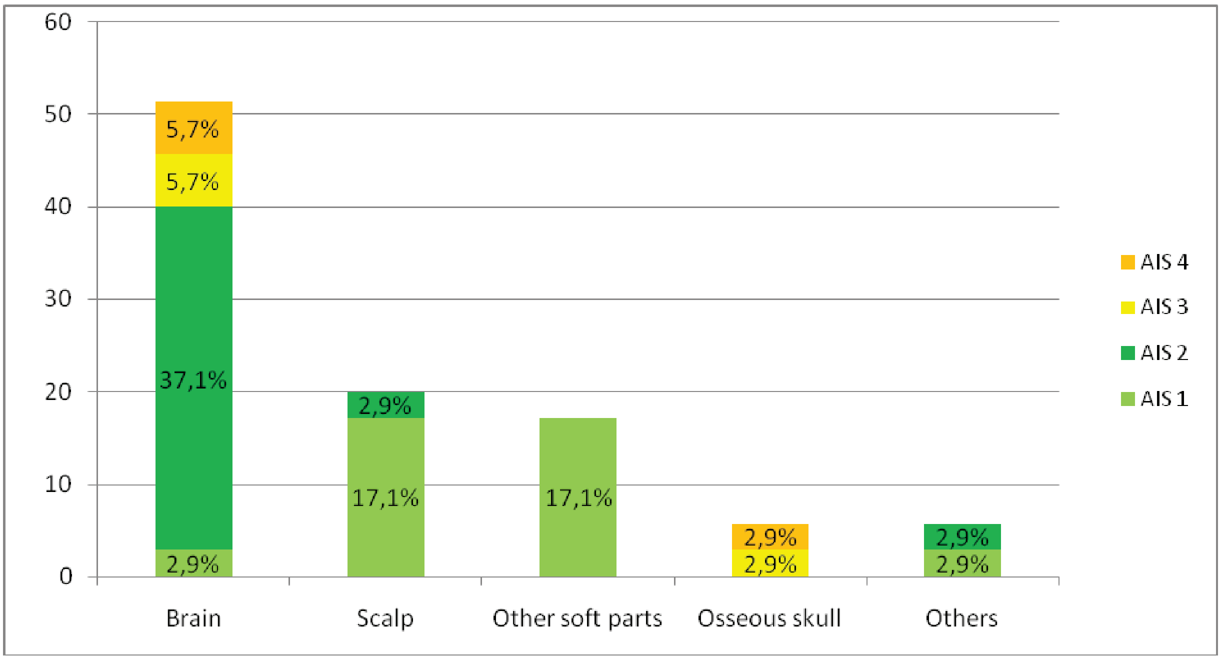

Figure 3: With helmet (n=35), Injuries to the head by region and severity

Figures 2 and 3 show that casualties having worn a helmet did not suffer from critical (AIS 5) or unsurvivable (AIS 6) injuries to the brain or the osseous skull like the group of non-helmeted riders did. Moreover we observed that cyclists who did not wear a helmet had more injuries to the scalp and the osseous skull. Only casualties not wearing a helmet did suffer from compound fractures (7 of 883, 1%).
Please notice that the temporal area as a suggested protected area was injured 13 times (1.4%) in the group of non-helmeted riders and never in the group of helmeted riders. (not shown)

Another aspect might be the appearance of polytrauma among all casualties within this study. A polytrauma is an injury of more than one body region or organ system, where at least one injury or the combination of several injuries could lead to death. The Injury Severity Score (ISS) is higher than 15 points. [6]

Altogether there were 70 cases of polytrauma. 57 of 59 (97%) cyclists in this group did not wear a helmet, 2 of 59 (3%) did wear a helmet. In 11 cases it was not recorded whether a helmet was worn or not. Every polytrauma patient did suffer from injuries to the head or the face. If we take a closer look on the appearance of severe injuries to the head or the face (AIS≥3), there is no significant correlation between helmet use and appearance of severe injuries (chisquare, $\alpha>0.05$) in the group of casualties.

Dependencies

Univariate

correlations	Injury severity of head	Injury severity of face
Helmet usage	**None**	**None**
Age	Slight	None
BMI	None	None
Gender	None	None
Collision speed	None	Slight
Collision speed of opponent	**Slight**	**Slight**
Type of vehicle	Slight	None
Type of bicycle	Slight	None

Figure 4: Table of univariate correlations

Figure 4 shows that the helmet, designed as a protective device, does not correlate neither with the injury severity of the head nor with the injury severity of the face. The age of the cyclist, the type of the vehicle of the opponent and the type of the bicycle correlate at least with the injury severity of the head what probably is reasonable when reconstructing the accident. The collision speed of the cyclist correlates only to the injury severity of the face. There is no evidence why the collision speed of the cyclist does not correlate as well as the collision speed of the opponent, although it may be higher, to the injury severity of the head and face as well. (Tested with Chisquare test, strength with Cramer's V, all results significant) Multivariate analysis is necessary to detect hidden confounders.

Multivariate

The protective effect of the bicycle helmet addresses primarily to injuries with AIS 3 to 6. This way we tried to develop a multivariate model to estimate the risk of suffering from injuries to the head or the face or to head and face together with AIS 3 and higher {yes; no}. Unfortunately this failed till now, as well as attempts to develop a multivariate model by using target variables AIS 1 and higher {yes; no}, AIS 2 and higher {yes; no} and AIS 4 and higher {yes; no}.

The only model that worked was regarding to the target variable Death {yes; no}. The only variable that did have significant influence is the collision speed of the opponent. 2329 Cases that include the information of collision speed contribute to this model. 21 Riders within this group were killed, 2301 stayed alive. The usage of a bicycle helmet did not have a significant influence in this model like the other variables also did not have. Unfortunately only 2 casualties that died did wear a helmet and so a definite conclusion could not be made whether the helmet has a multivariate effect on death as long as the number of recordings is so low.

DISCUSSION

When considering the extent of injuries to the head or the face, one might attribute a protective effect to the bicycle helmet. As long as this is based on observations and descriptive analysis, we did not find AIS 5 or AIS 6 or severe facial injuries in the group of helmeted cyclists. This is why we support the thesis of a protective effect of the bicycle helmet. Nevertheless until now we have no final multivariate model that helps us to give clear evidence of how effective the bicycle helmet is.
Beside the ongoing discussion concerning mandatory helmet use we probably also have to concentrate on improving safety measures as the most frequently recorded accidents occurred in the area of crossings (35.5%) and junctions (25.6%) as figure 5 shows.

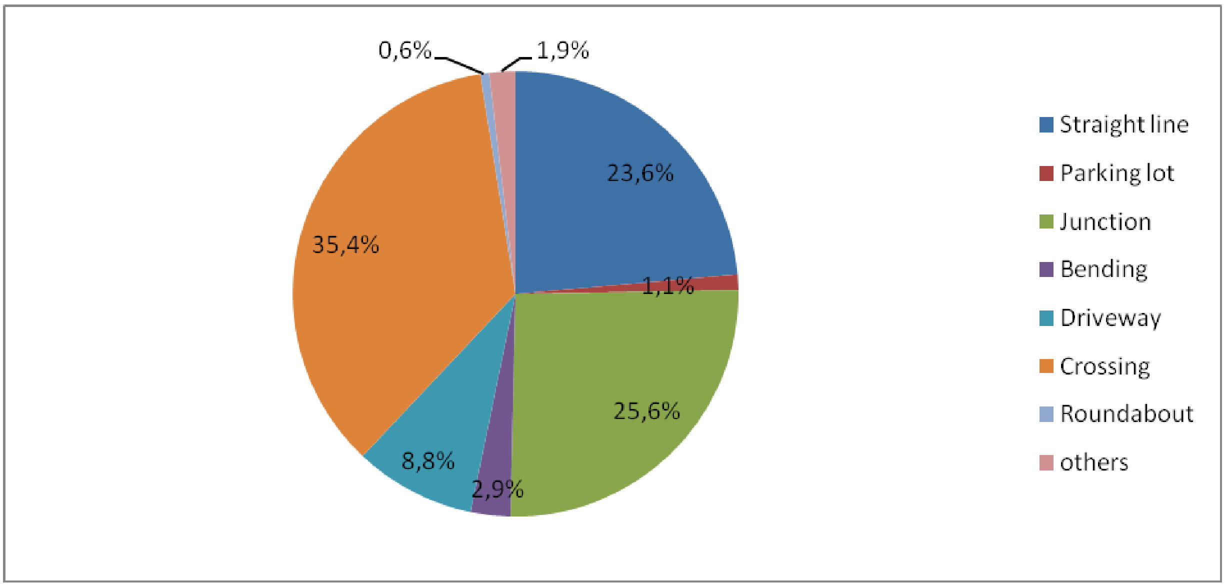

Figure 5: Location of accident with cyclists (n=3276)

Furthermore helmets are tested and certified by the EN 1078. EN 1078 specifies requirements and test methods for bicycle helmets, skateboard and roller skate helmets. It covers helmet construction including field of vision, shock absorbing properties, retention system properties including chin strap and fastening devices, as well as marking and information. The standard's key features are: Test anvils: Flat and kerbstone; Drop apparatus: Guided free fall; Impact velocity, Energy or drop height flat anvil: 5.42–5.52 m/s; Impact energy criteria: <250g; Roll-off test: Yes; Retention system strength: Force applied dynamically, Helmet supported on headform. One has to agree that in high speed impacts a helmet will not prevent death, especially concerning the low criteria of impact energy. [4]

Additionally you will find the expression of risk compensation in international literature. [5] Drivers wearing a helmet thus feel kind of invulnerable and adapt their driving habits. As formerly described even in our research we found that riders with helmet were in average at higher speed. By the way this may be due to gender differences and difference of type of bicycles (both correlate to helmet use, men were faster than women and did more often wear a helmet)
Figure 6 shows the main cause of accidents surveyed by the estimation of the scientific team. This variable is encoded basing on the official accident cause index. We observed that casualties with

helmet more often had accidents because of speeding (8.8% compared to 3.1%) and right-of-way mistakes (40.7% compared to 26.9%), whereas consequently casualties who did not wear a helmet had more often accidents because of using the wrong lane (33.1% compared to 23.0%) and because of inadequate roadworthiness (5.2% compared to 0.9%)

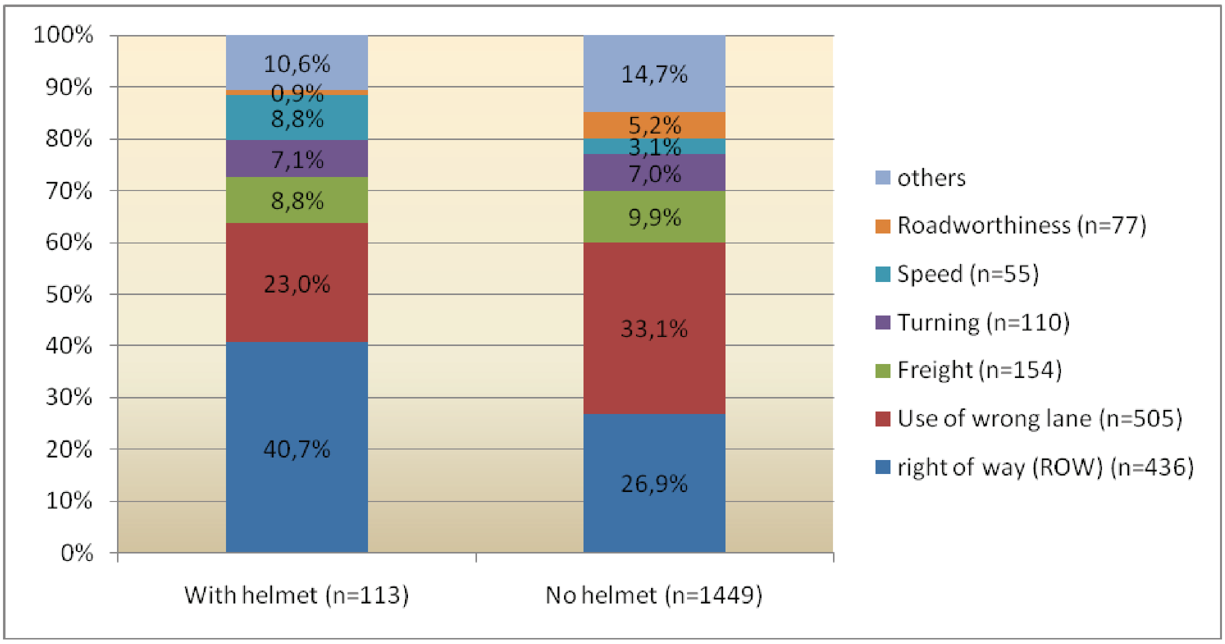

Figure 6: Estimation of main cause of accident

However the theory of risk compensation is not proven yet [7]. It is also assumable, that riders that wear helmets are more aware of safety and security and therefore ride more alertly and defensively.

Unfortunately we are only able to test the helmets function against impacts of different directions if we analyze every single accident and having a closer look on photographies taken on the place of the accident. GIDAS contains the variable KWINK which is a reconstruction of the collision speed vectors of both participants and thus is not properly helpful. Nevertheless there is no difference between the both groups of casualties wearing a helmet and not wearing one in KWINK.

All discussion about cycling safety probably leads to the wrong assumption that cycling is dangerous at all. In fact it should not detain from cycling and its benefits.

CONCLUSION

Unless we have got no multivariate model, we can only compare the injuries of the two groups. The helmet seems to have a protective effect, but it is at the moment not possible to estimate any risk reduction concerning injury severity for example by using the bicycle helmet as a protective device. A further multivariate analysis is in progress.

REFERENCES

1 http://www.bast.de/cln_015/nn_40694/DE/Publikationen/Infos/2009-2008/05-2009.html
2 http://www.bast.de/cln_015/nn_40694/DE/Publikationen/Infos/2009-2008/02-2008.html
3 Macpherson A, Spinks A. Bicycle helmet legislation for the uptake of helmet use and prevention of head injuries. Cochrane Database of Systematic Reviews 2008, Issue 3. Art. No.: CD005401. DOI: 10.1002/14651858.CD005401.pub3.
4 Dr. W Lucas, Toronto Coroner, September 1998
5 J Adams,M Hillman **,**The risk compensation theory and bicycle helmets, Injury Prevention 2001;**7**:89–91
6 W.S. Copes, H.R. Champion, W.J. Sacco, M.M. Lawnick, S.L. Keast, L.W. Bain: The Injury Severity Score revisited. The Journal of Trauma. 28, 1988, 69-77.
7 Lardelli-Claret P, de Dios Luna-del-Castillo J, Jiménez-Moleón JJ, García-Martín M, Bueno-Cavanillas A, Gálvez-Vargas R., Risk compensation theory and voluntary helmet use by cyclists in Spain, Inj Prev. 2003 Jun;9(2):128-32