Injuries in motorbike accidents in correlation with protective clothes and mechanism of the accident

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Abstract – This study deals with a possible connection between safety clothing / accident mechanism and injury severity in a state-wide traffic accident investigation with focus on light and small motorbike-involvement for accidents in the area of the Saarland in which the persons riding the bike have been injured or killed. An interdisciplinary team of medical scientists and engineers collected the medical and technical data as well as all the relevant traces of the accident on scene and in time. During twenty months of data collection a total of 401 cases could be gathered. Grave injuries were more common for the group of heavier motorcycles (>125 ccm). Motorcyclists had been polytraumatized only in the group where the accident was connected with a collision. Significant correlation between protective clothes and injury severity could only be found for protective gloves and protective trousers. The knowledge about mechanism of the accident, protective clothes and severity of injuries can be helpful for the improvement of road and motorcyclists' safety.

NOTATION

ccm cubic centimetre
kW kilowatt

INTRODUCTION

2010 there were 374.818 persons involved in traffic accidents with motorized vehicles in the federal republic of Germany. Powered two-wheelers (PTWs) are included with 44,216 persons. 745 of them were lethally injured. 2011 the total number of injured people rose to 395,934 with 49,332 PTWs included (an increase of 11.6 %). 806 people didn't survive the accident (an increase of 8.2 %), whereas the number of passenger cars involved in accidents only rose by 1.7 %. [1]
The region of the Saarland (a German federal state) with its 1 million residents registered 5,328 of accidents in the same period 2010; 621 of them where PTWs; 10 of them were fatally injured. 2011 the total number of traffic accidents rose up 5,607, including 671 PTWs, an increase of 8 % in relation to the preceding year, which equals 6 lethally injured people. [2]
Although the worldwide number of traffic accidents is declining over the past decades, the group of powered two-wheelers doesn't seem to be affected by this downward momentum. [3] It seems as if the group of PTWs is the least affected one in the face of achievements in passive as well as active road safety.
The goal of this study is to determine whether protective clothes have an influence on drivers' injury severity or not and – with the help of technical reconstructions – to investigate the potential relationship between accident mechanisms and typical injury patterns.

METHODS

Study design

The study design is a prospective on scene and in time traffic accident investigation and data collection for the whole region of the Saarland.
From June 2010 till December 2011 all traffic accidents with powered two-wheelers, in which the persons riding the bike have been injured or killed, were collected and analysed. The elicitation of small and light motorcycles accidents (≤ 125 ccm) had been initiated by the GDV e.V. (Unfallforschung der Versicherer).
In order to gather all the relevant details of the accident an interdisciplinary team of medics from the University Hospital of the Saarland and technical engineers from Priester's engineering office investigated the site of the accident.
Due to the nationwide planning and situation centre resp. the individual police duty stations all accidents were submitted to the technical engineer in charge in sync with all the other rescue forces through a centralized phone number.
Operational reasons and time restrictions made it impossible to form an around the clock stand-by with a complete team of scientist. A main stand-by time and an auxiliary stand-by time were defined.
During main stand-by time (24.06.2010 to 10.10.2010, Thursday through Sunday, from noon till 8.00 p.m. each and from 01.04.2011 to 30.09.2011, Friday through Sunday, from noon till 8.00 p.m. each) a complete research team of medics and technicians was on hold and able to reach any given accident right after they were alarmed, using a joint emergency vehicle. Attached emergency lights (after §38 StVO, German law) made them able to use way leave and arrive at the accident-site within a narrow time frame. An exception permit for the time of the project was given by the Saarland's department of environment, energy and traffic.
In the auxiliary stand-by time (01.06.2010 to 31.12.2011, around the clock, as far as not covered by the main stand-by time) the technician was in charge of the emergency vehicle. If possible, the medic joint the technician at the accident site in his private car after he had been alarmed. That is assuming that the medic was able to reach the site of the accident on short notice.

Data collection

After arriving at the scene the researchers approached the policemen already at the accident-site. The police informed the team about the presumable circumstances of the accident.
After that the medic tried to contact the ambulance personnel and the persons involved in the accident. Each patient, if still available at the location and able to give his consent, was briefly informed about the content of this project. A first verbal consent was taken. If possible, a first impression of the worn protection clothes and their damages was taken and the patient was questioned about the circumstances of the accident and his injury pattern to collect the data mentioned above. This happened with the greatest caution to not endanger or hinder the medical treatment.
While this happened the technician gathered the non-medical parameters, starting with a detailed photographical documentation followed by a measurement of the site.

At the site of the accident the researchers collected especially the following technical parameters:

- Basic parameters, e.g. type and passenger count of the PTW and its opponent in the accident, technical deficiencies or manipulations of the PTW and its lighting system before the collision

- Potentially protective parameters, e.g. the kind of worn protective clothing and available security systems on the motorcycle

- Surrounding parameters, e.g. road category, route and condition, as well as predominant light and weather conditions on site

- Collision and post-collision parameters of the involved vehicles, characteristics of the skid marks, collision type, vehicle deformations due to the accident, motorcyclist's path of motion (in order to reconstruct pre-crash speed / collision speed) and damages to the protective clothes

The following medical characteristics were gathered:

- General information about the cyclist, e.g. age, sex, height and weight, evidence for a possible impairment of its fitness to drive

- Perception of the events of the accident, especially course of events that led to the accident and guilty party from the cyclist's viewing point or if there's any evidence for amnesia

- Perception of the patient's own injuries, pain and sensibility disorders

- Injury patterns with their exact location and manifestation, state of consciousness and initially measured vital parameters

- Parameters of medical care, e.g. arrival-time of the ambulance, first aid measures, the rescue forces' judgment about the injury pattern and severity, the target clinic

In order to simplify the analysis of the gathered information, a database (Oracle OpenOffice.org 3.3.0) has been created, in which the technical as well as the medical data could be categorized. The final evaluation of the data has been conducted in IBM SPSS 17.0. To document the injury pattern and its severity the individual injuries were coded after the Abbreviated Injury Scale (AIS 1990 Revision Update 98 [4]). The (M)AIS score (Maximum Abbreviated Injury Scale [4]), pointing out the body region with the highest AIS score, could be documented and - for the body in whole - the Injury Severity Score (ISS [5]) has been calculated.

Because of the fact that only a small percentage of all accidents could be documented on-site, a thorough post-processing was necessary. Each patient had to be personally contacted; access to their medical data was needed.
A positive vote of the ethical review committee of the medical association of the Saarland was given. The Saarland's Commissioner for Data Protection and Freedom of Information defined guidelines on how the patients had to be contacted and how their individual-related information had to be handled. With the given specifications the police directorate of the Saarland was able to hand over the data that was needed to get in contact with the persons involved in the accident. Only the medical researchers had access to this kind of data.
Upon receipt of the data mentioned above all cyclists have been contacted by mail; giving them information about the goal of the project and the possibility to participate in the study. The letter included an answer card to make the patients able to express their interest in participating in the study. He also had the possibility to define a certain time frame in which a medic should contact him by phone. Of course, all patients also had the chance to deny their willingness to be part of the study.
If the mail stayed unanswered a reminder mail has been sent out to the patients in an interval of 3 resp. 12 months.
Given that the study captures medical data as well as data that is / could be used in preliminary proceedings the patients had to be informed very thorough about data protection aspects by phone.
In the next step a in-depth project information and a consent form were sent to the patients by mail. This mail included a questionnaire in which the patients were asked about the clothes they were wearing during the time of the accident, whether or not they had pain and where they were injured, furthermore a form to unbind the doctors that treated the patient after the accident from their professional discretion towards the medics of this study.
This form allowed the medical researchers to get in contact with the doctors and hospitals where the patients were treated and made them able to get access to the patients' medical data and the protocols of the rescue forces.

The hospitals were informed about the project by mail prior to a phone call by the project's medics to define an individual approach in order to get to the needed information.

The findings of the autopsies performed on the patients that were lethally injured in the accidents were made available by the department of public prosecution.

Analysis

The defined groups in the process of evaluating this study were checked about their connection and their statistical significance with Spearman's rank order correlation. A significance level of $p<0.05$ was defined.

RESULTS

In this study a total of 401 accidents with powered two-wheelers were investigated. 203 of them were accidents with small and light motorcycles (≤125 ccm not exceeding and a power output not exceeding 11 kW); 198 involved a heavier motorcycle (>125 ccm). The final evaluation included merely 267 accidents because of deficiencies in the available data or data protection reasons. 132 of them with a small motorcycle (≤125 ccm); 135 with a heavier motorcycle (>125 ccm).

Epidemiology

88% of all motorcyclists involved in an accident were male (n=210). 25.2 % could be assigned to the age group till 24 years; including the group of cyclists under 18 with 14.8 %. The newly formed group of people between 25 and 50 accounted with 39.5 % thus making them the biggest group. The age group of 51 to 66 formed 26.7 %. Patients over 66 of age were represented with 8.6 %. This classification has been created with the goal to set a focus on risk groups (e.g. < 24).
In the months between July 2011 and June 2011 a total of 251 relevant accidents were collected in which the persons were injured or killed (Figure 1). As expected there were only a few accidents in months between November and February (n=12).

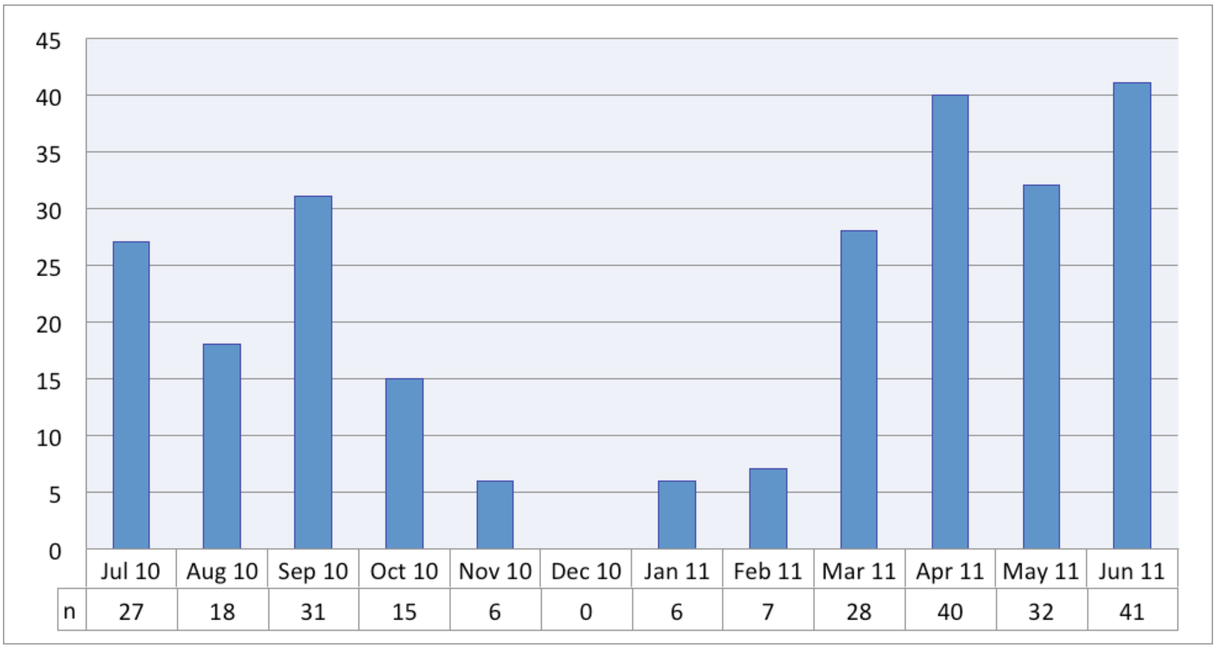


Figure 1: number of accidents per month

Following a upward drift starting in March, June is the month with the highest accident count (n=41). Subsequent to preliminary studies [6, 7] in the Saarland, there's a raise in accident numbers as the week progresses from Thursday to Sunday (67.4 % in total), which is why the main stand-by times were defined to cover that certain timeframe.
Regarding the time of day the authors noticed a peak between 12.01 p.m. and 6.00 p.m. (141 of 240 accidents). The second most amount of accidents were gathered in the time between 6.01 a.m. and noon (Figure 3). In-town accidents made the greatest amount of PTW accidents (n=125).
Considering the type of motorcycle used it could be noticed that in the group of small and light motorcycles there's a peak on weekdays whereas the heavier motorcycles were involved in their accident mainly on the weekends, especially on Sunday (≤125 ccm n=13; >125 ccm n=29).
This could be expected because small and light motorcycles are often used as a primary means of transportation whereas heavier motorcycles are considered to be recreational vehicles.

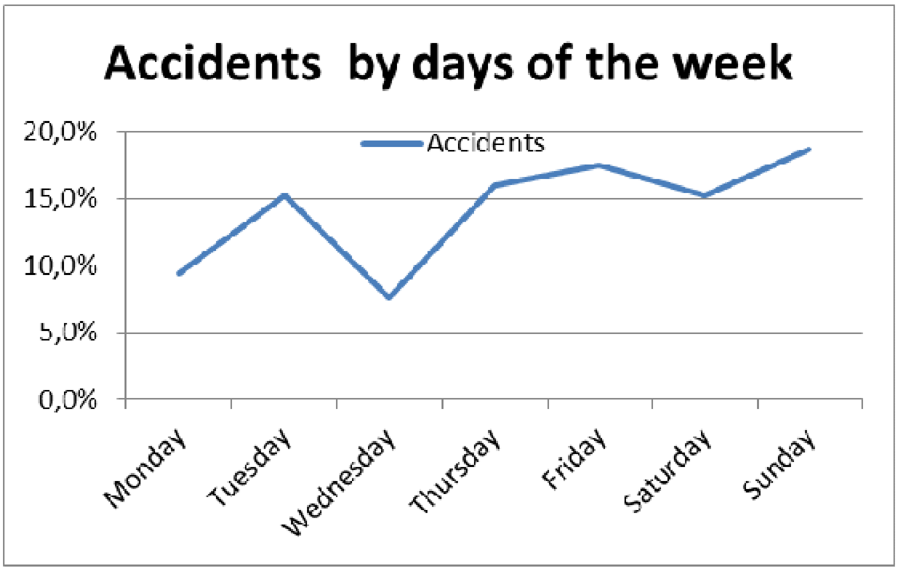


Figure 2: Accidents by days of the week

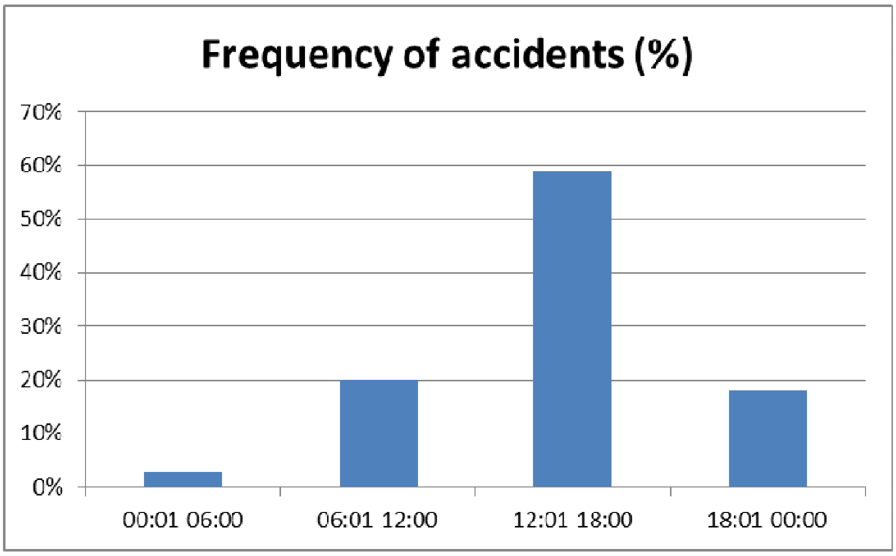
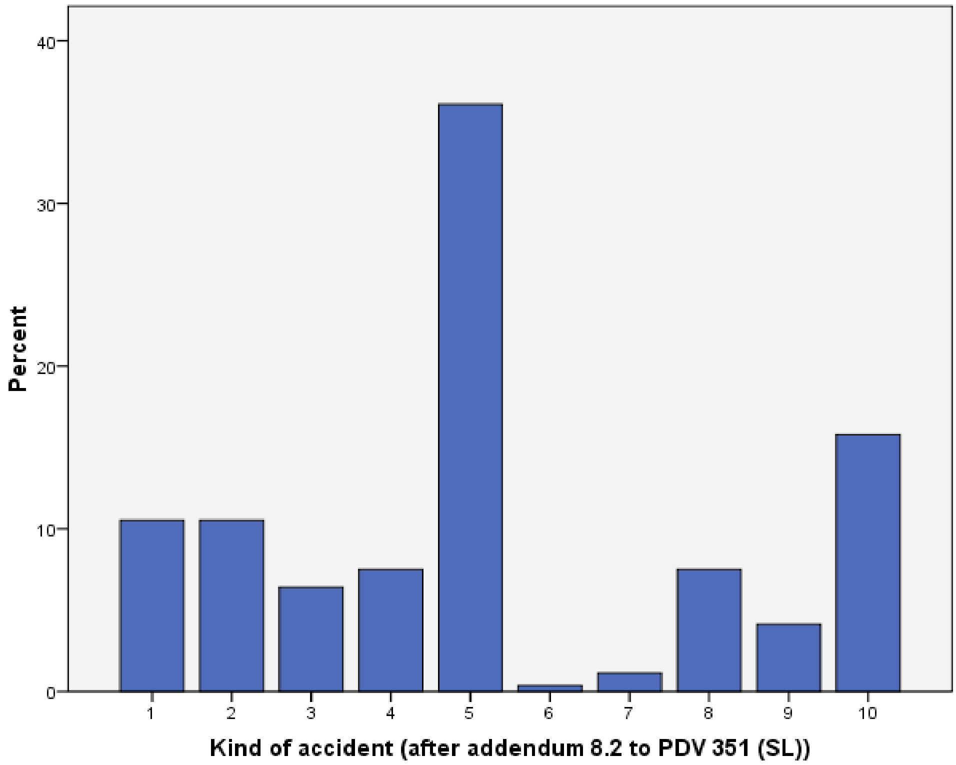


Figure 3: Frequency of accidents assigned to the time of day

Development and mechanism of the accidents

Referring to police duty regulation 351 addendum 8.2 (SL) all cases were assigned to a certain kind of accident from 1 to 10. Kinds of accident 1, 2, 5 and 10 were the most frequent ones (Figure 4).
The biggest amount (n=96 / 36.1 %) of accidents could be assigned to group 5 (collision with another vehicle that turns around, turns into a street or crosses the street) with a corresponding mean MAIS of 1.73±1.



1: collision with another vehicle that starts, stops or stands still in stationary traffic
2: collision with a vehicle that drives ahead or waits
3: side-collision with a vehicle going the same direction
4: collision with an oncoming vehicle
5: collision with another vehicle that turns around, turns into a street or crosses the street
6: collision between vehicle and pedestrian
7: collision with an obstacle on the road
8: swinging off the road to the right side
9: swinging off the road to the left side
10: accident of a different kind

Figure 4

The kind of accident that occurred the second most (n=42 / 14.8 %) was number 10 (accident of a different sort, e.g. a camber from motorcycle without collision) with a mean MAIS of 1.6±1.
Kind of accident 1 (collision with another vehicle that starts, stops or stands still in stationary traffic) with a mean MAIS of 1.5±0.8 occurred 28 times (10.5 %).
Same occurrence for kind of accident 2 (collision with a vehicle that drives ahead or waits) with a mean MAIS of 1.5±1.
All accidents were assigned with a 3 digit identifier to define their type of collision according to ISO 12323 [8]. At first the authors created specific groups after the ISO value 1. Figure 5 shows that the digits 12, 1 and 2 equal a collision in the front of a car whereas the digits 6, 7 and 8 equal a collision in the back of a car. All other digits were assigned to the group of side-collisions, with no discrimination between the directions. The collision angle from the cyclists point of view (after ISO value 3) was of no relevance.

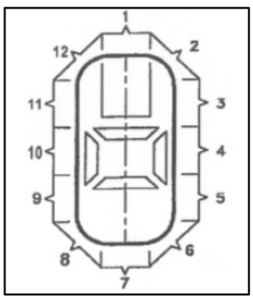


Figure 5

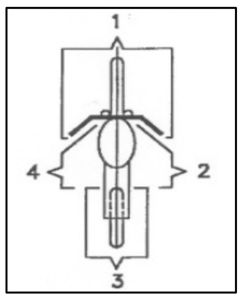


Figure 6

The injury severity in front-collisions could be determined with a mean ISS of 5.63±7.6 (n=41); back-collisions (n=24) with a mean ISS of 4.21±7.7 and side-collisions with a mean ISS of 9.05±16. From the motorcycles point of view (Figure 6) the collision took place in the front (ISO value 2, digit 1) in 80 % of the cases (n=70) with a mean ISS of 3.0±3.27. Digits 2 and 4, meaning side-collision, showed a mean ISS of 5.71±9.7 (n=14). Only in 4 cases the opponent drove into the back of the motorcycle leading to a mean ISS of 3.0±4.0.

Severity and pattern of the injuries

For the injured persons in this study (n=134) an overall injury severity, according to the ISS, of 6.16±11.02, with a mortality of 3.7 %, could be determined. 7 cyclists, in contrast to the report prior to the arrival at the accident site, were unharmed and showed no injuries (MAIS 0).
In 4 of the 6 lethally injured cases it was possible to determine a MAIS-Score between 4 and 6, with injuries to the head, thoracic or abdominal region (1 died after open traumatic brain injury (TBI), 1 died after cerebral oedema while suffering a closed TBI, 2 died because of intrathoracic or intraabdominal vascular injuries). People who suffered from multiple traumas (ISS ≥16) showed a mean ISS of 35.45±21.37. It could be shown that accidents with small or light motorcycles lead to a lower ISS (4.22) than the ones that occurred with a heavy motorcycle (ISS 7.03). (Table 1)

Spreading of motorcycle classes and assigned mean ISS		
Motorcycle	***n***	***ISS (Mean)***
≤ 50ccm, ≤ 25km/h	16	**4,19**
≤ 50 ccm, ≤ 45/50km/h	16	**5,38**
≤ 125 ccm (max. 11kW)	25	**3,08**
> 125 ccm	70	**7,03**

Table 1

Divided in body regions, the MAIS2+ shows a distribution as in Table 2. In both groups (≤125 ccm & >125 ccm) the most injuries are located in the region of the upper and lower extremities, though the severest injuries can be found in the head and thoracic region. This is consistent to the findings of other studies [9]. Injuries to the spinal column, the pelvic area and abdomen are very rare in the group ≤125 ccm, what can be explained with the lower speed and the associated energies in the case of an accident.

Injured region	**Injured > 125 ccm**		**Injured ≤ 125 ccm**	
	n	**MAIS (Mean±SD)**	**n**	**MAIS (Mean±SD)**
Lower extremity	17	2,41±0,5	10	2,40±0,5
Head	6	3,17±1,2	4	2,25±0,5
Upper extremity	22	2,09±0,3	12	2,17±0,4
Thorax	11	3,09±1,2	4	3,0±1,2
Spinal column	4	2,25±0,5	1	2,0±0
Pelvis	2	2,5±0,7	2	2,5±0,7
Abdomen	3	2,33±0,6	1	2,0±0

Table 2

It was possible to show with a statistical significance of p=0.026 and a correlation of 0.224, that severe injuries with an ISS ≥ 16 were only found in the group where a collision has happened (Figure 7).
The values of the ISS were consolidated into 5 different groups whereas there were no accidents with an ISS value between 46 and 60. Included were all accidents with a collision to another motorized vehicle or a solid object, which means that in this group the energy is degraded suddenly while the collision hence the more severe injuries in this group.
With the given data (n=40) it was not possible to show that higher collision speeds are tied to higher values in the ISS. Clearly this circumstance has to be revaluated with a higher number of accidents.

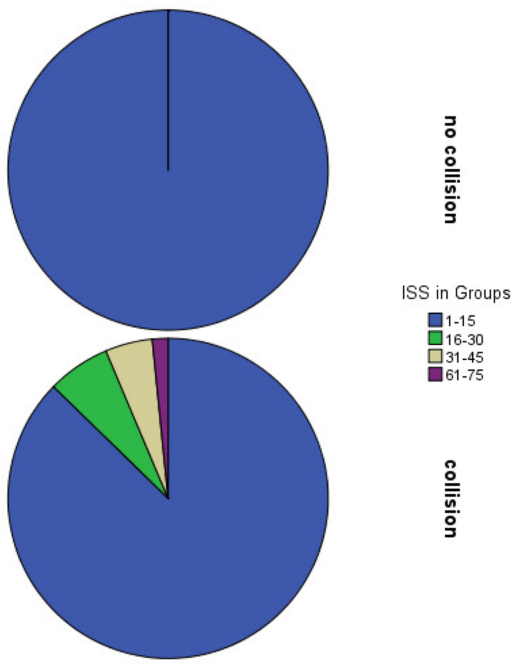


Figure 7

Protective clothing

A protective helmet (n=147) conformable to the law was worn in 99.5 % of the cases in all motor classes, though in one case the patient had been given an exemption of the helmet obligation (0,5 %).
Regarding the other protective clothes there were broad differences: only in 9.5 % the patients were wearing a protective combination.
In the group of ≤125 ccm a protective jacket (n=141) was worn in 16.3 % (versus 50.4 % in the >125 ccm group). As an protective jacket the authors defined a jacket equipped with hard or soft protectors und tailored from a resilient material like leather or a polyamide composite material.
Similar circumstances were observed for protective trousers (n=143): drivers of light motorcycle wore protective pants in 2.1 % of the cases; drivers of heavier motorcycles in 30.8 %. The hands were sheltered by protective gloves were worn in 51.1 % (>125 ccm). Drivers of light motorcycles were riding without such protection in 48.3 % of the cases.
In order to simplify the evaluation the authors created a safety index consisting of the following parameters: helmet, trousers, length of the trousers, shoes, protectors of the upper and lower extremities and the spinal column. Since wearing a helmet is required by the law (§21a StVO) and its protective value is unquestioned [10], a worn helmet add counts twice in the calculation of the safety index. Said index can reach points between 2 and 30. The authors formed groups from 1-3 from the index's manifestations. Points 2-12 (group 1) with the least protection and points 24-30 (group 3) with the highest possible protection. It should be shown whether or not allegedly better protection is associated with lower values in the MAIS (Figure 8).
In the least protection group severe injuries (MAIS 3-6) are more common. In the medium protection group most of the injuries had 1-2 points in the MAIS-Score, which was an anticipated circumstance. Patients that belonged to the very high protection group had more injuries coded with MAIS 3-6.
After that the effects of protection clothing towards the injury severity were investigated. In order to compare there characteristics anatomical groups were formed (head, torso incl. upper extremities, hands, legs and feet) and their MAIS 1+ values transformed into a binary variable, where 0 equals "not injured" and 1 equals "injured", leading to a correlation analysis. In this binary interpretation it wasn't possible to make a statement about the severity of the injury. All injuries were considered.

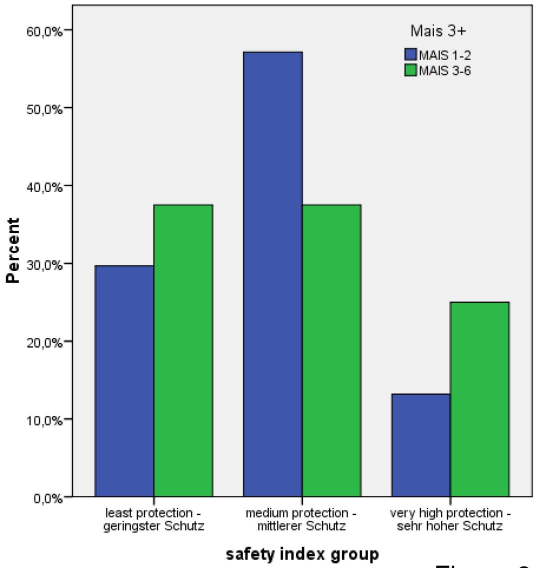


Figure 8

Correlation of head injuries with protective helmets (n=131)

It was investigated whether or not head injuries MAIS 1+ can be avoided by wearing a protective helmet. There were only persons accounted to this that wore the same type of protective helmet resp. helmets with the same type of security concept (chin protection system). Open-face helmets were not included. A very weak correlation, indicating that helmets with better protective features are associated with fewer injuries, was observable (-0.067) with no relevant significance (p=0.445).

Correlation of injuries to the torso with jackets (n=132)

It was investigated whether or not an injury could be correlated with the protective jacket worn by the patient. The groups were divided in "no jacket", "light jacket" e.g. cotton and the like and "protective jacket". There was no significant correlation (0.005) between MAIS 1+ and the jacket observable (p=0.955).

Correlation of foot injuries with shoes (n=130)

It was investigated whether or not an injury to the foot could be correlated with the protective boots worn by the patient. The groups were divided in “no shoes”, “other shoes” and “protective boots”. The weak correlation (-0.166), indicating that shoes with better protective features are associated with fewer injuries, showed no relevant significance (p=0.188).

Correlation of hand injuries with gloves (n=126)

It was investigated whether or not an injury to the hands could be correlated with the protective gloves worn by the patient. The groups were divided in “no gloves”, “other gloves” and “protective gloves”. The test showed a significant correlation between the absence of injuries to the hands and protective gloves. The weak value in Spearman’s rho correlation test showed -0.197 with p=0.027.

Correlation of leg injuries with trousers (n=135)

It was investigated whether or not an injury to the legs could be correlated with the protective trousers worn by the patient. The groups were divided in „light trousers“ and „protective trousers“. The test showed a significant correlation between the absence of injuries to the legs and protective trousers. The weak value in Spearman’s rho correlation test showed -0.202 with p=0.019.

DISCUSSION

A lag of data is a common problem in prospective accident data analysis, making detailed reconstructions impossible. The authors tried to elude this problem with the help of a technician on-site. This wasn’t always possible, because of data protection laws and delayed callings at the beginning of this study. The medical treatment had to be the top priority on scene. Despite of all obstacles in the execution of prospective data collections they are a useful tool for accident data analysis. Especially minor injuries are providing detailed information about the mechanisms of the accident and minor collisions. This kind of information can only be gathered on scene because not all the patients seek treatment or their injuries are poorly documented. Because there aren’t many studies regarding theses aspects, further studies are advised.

Powered two-wheelers were and are still one of the most endangered group of traffic participants. They can be harmed very seriously in general. In the underlying study most of them were not.

The determined correlation herein regarding the correlation of protective clothes and injuries could be false-low because there was no large unharmed comparison group. Especially in the cases with minor injuries and with slower collision speeds the empirical data points towards very strong protective capabilities of the clothes mentioned above. Furthermore patients that belonged to the very high protection group had more injuries coded with MAIS 3-6, which can be explained by the fact that the accidents with high collision speeds (80-100 km/h) are represented in this group. The findings on scene and in time suggest a decrease in the importance of protective clothes with increasing collision velocity. Further active traffic safety measures have to be enhanced systematically. On the other hand the study showed a very low acceptance rate of already provided safety systems, e.g. ABS (anti-lock braking system). Only in 9 of 189 cases such a system was used. Further education regarding this matter as well as how to use these systems is strongly recommended.

On strategic points throughout the Saarland traffic controls were performed with a focus on all kinds of motorcycles with less than 125 ccm in association with the police simultaneously to this study.

In these controls as well as in this study the general willingness to wear safety clothing was very poor. Improved legal regulations could create a foundation to avoid severe injuries, for example through the requirement to wear protective clothes in all classes of motorcycles. Another problem is the willingness and the simple possibility to modify the vehicle illegally. Modifications on the lighting status and the rear view mirrors (smaller reflecting area) were observed; some even heightened their motorcycles. Altogether illegal manipulations were found in 50 % of the cases. Tougher sanctions,

raising the legal driving age and a general hampering of such manipulations through political intervention or the manufacturers should be mentioned.
Side-collisions, leading to a severe injuries, were the most common kind of accident in this study and have to be highlighted separately. The benefit of safety systems such as crush-collapsible zones and road safety systems turns out smaller for two-wheelers than for passenger cars. Considering the fact that some of the severest injuries could be found in the thoracic region the development of safety systems especially for this area should be expedited. The application of airbag system in PTWs on a regular basis and the their possible benefit remains to be seen. The most common kind of accident here is the one happening on intersections (accident type 5). In order of its prevention simple rules of visibility should be kept in mind. Protective clothes in signal colours and striking paintwork on the motorcycles can increase the drivers perceivableness. Traffic circles and driving lane separation could help in order to avoid this kind of accident.

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