TYPICAL INJURIES TO THE SOFT BODY PARTS AND FRACTURES OF THE MOTORIZED TWO-WHEELERS

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Purpose of the study

The number of traffic participants killed or injured in road-accidents in West-Germany should be seen in relation to the current number of registered vehicles. In defining this relation as a grade of safety, a pronounced danger to the motorized two-wheeler is evident (trucks 98.6/car: 80.9/ motorized two-wheeler: 28.2).

One out of every 28 of the motorized two-wheelers existing in the Federal Republic of Germany is injured in traffic accidents. This relation - interpreted as safety grade - is, however, different for the various types of motorized two-wheelers. It shows for the motorcycle with one accident victim to every 15 vehicles the lowest, and for the mofa with one injured person for every 47 vehicles the highest accident rate (for moped/mokick 30).

30% of all people injured in traffic accidents are users of motorized two-wheelers. Of these motorcycles, mofas and mopeds/mokicks take an almost equal share. The greater part (approx. 65%) of the injured two-wheel riders receive - according to the official injury severity grade classification (1, 2) - slight, about 33% severe, and 2% fatal injuries. This calls for measures to reduce accidents, especially those from slight to medium injuries according to AIS $\leq$ 3 (3).

	Grade of injury		
Type of two-wheeler	slight	severe	fatal
mofa	65.6%	32.7%	1.7%
moped/mokick	66.5%	32.0%	1.4%
motorcycle	61.1%	36%	2.9%

STBA figures for 1979

The high risk to users of motorized two-wheelers has already been established in several studies (Knoflacher (4),

Feldkamp (5), Aldman (6), Thomas (7), Mackay (8), Langwieder (9), as well as our own studies (10, 11)).

2. Project description

224 accidents of motorized two-wheelers, involving 272 users, documented, reconstructed and analyzed within the framework of a research project by the Federal Highway Department (BAST, Cologne, West-Germany) are the basis of this survey. The project, carried out on the basis of field studies, exists since 1973 at the Department of Trauma Surgery, Medical School Hannover. It is carried out in co-operation with the Institute of Automotive Engineering, Technical University Berlin. A team of accident surgeons, engineers, and psychologists collect data of traffic accidents. This comprehensive data is collected by direct approach of the accident scene and hospital, immediately after the event of accident. For this purpose special cars, equipped with blue light, radio and sirens, are at the disposal of the team. This data is not available by other means, such as files of the Statistical Federal Office and insurance companies. The methodical advantage is especially noticeable in two-wheeler accidents. They are rarely comprehensively documented by the police.

3. Analysis of accidents of motorized two-wheelers

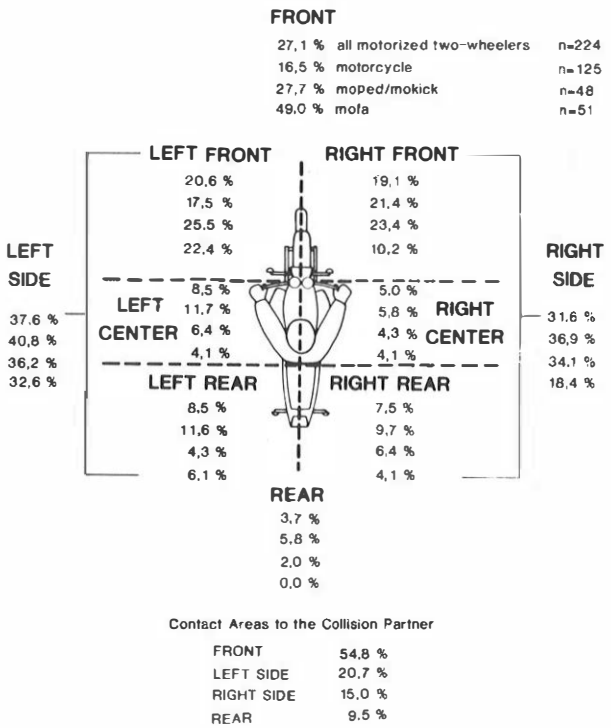
3.1 Accident risk

In our study motorcycles are involved in 40.6% of all motorized two-wheeler accidents (46% according to the Federal Statistic). The accidents with motorcycles and light motorcycles were compiled into one group (55.8%) for the analysis and compared with the group moped/mokick (21.4%, 23% according to the Federal Statistik) and the mofas (22.8%, 23% in the Federal Statistic).

Earlier studies showed varying group-specific but characteristic accident and driving behaviour (11, 12). 57.6% of the two-wheelers belong to the capacity class up to 50 ccm, 63% of the motor-cycles to capacity class $\leq$ 500 ccm. An increased injury severity can be observed with greater capacities. A tendency to increased driving speed seems, however, to be responsible for a higher pre-crash speed (from capacity 250 ccm upwards).

The motorized two-wheelers collided mainly with the vehicle front of the collision partner (54.8%), rarely (9.5%) with the rear of the vehicle (diagram 1). Crashes with the left or right side of the collision partner were almost equal (right 15%, left 20.7%). Lateral crash points are predominately seen on the two-wheeler (right 31.6%, left 37.6%, front 22.1%, back 3.7%).

A study of 900 motorcycle accidents of the NHTSA (13) which also bases on local accident research shows almost the same procentual rate of collision impact points.



Diag. 1:

Contact Areas of the motorcycle (each kind of cycle = 100%;

all contacts to the partner = 100%).

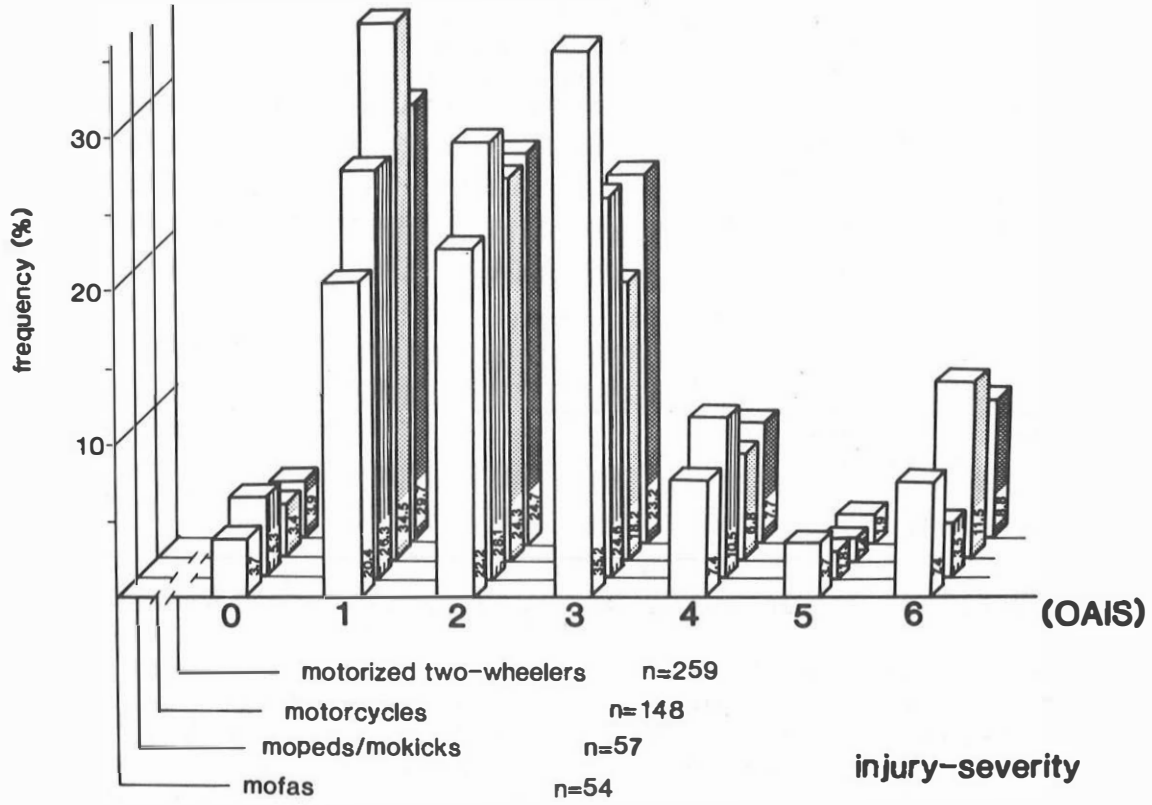
The distribution of crash points is marked by different driving- and accident behaviour of the varying two-wheel types. Owing to this, different collision constellations result for the different groups.

3.2 Injuries

3.2.1 Injury severity

A comprehensive photographic documentation and description of injuries are at the disposal of the medical accident analysis. In addition, there was access to complete single-case hospital files, X-rays, and section protocols. To standardize the injury severity, a classification basing on the Abbreviated Injury Scale (3) was compiled. The revised edition 80 (14) is at the present time not in use. It can, however, be used as a guideline by way of transformation procedure. Besides other methods, the arithmetic means of several injury severity grades by the Abbreviated Injury Scale was established for the descriptive evaluation of the injury severity. This is not exact in the statistic sense, it provides, however, a good possibility of comparing evaluations.

3.9% of the 272 motorized two-wheel users remained uninjured. Injuries of severity grade OAIS 1 to 3 (77 to 79%) were mainly found. 8.9% (diagram 2) suffered primarily fatal injuries.



Diag. 2: Frequency of injury severities of 259 motorized two-wheelers (driver and pillon-rider) - each group of cycle = 100%.

Most of the fatal injuries (11.5%) were observed in accidents with motorcycles, fewest (3.5%) with mopeds/mokicks; 7.4% of the mofa-users were fatally injured. In the moped/mokick group severe injuries OAIS 4 were more frequent (10.5%), while they are almost equal for mofa and motorcycle group (7.4 respectively 6.8%). On the whole, a different picture emerges in regard to the distribution of the injury severity grade for the users of various two-wheeler types. The users of motorcycles evidently receive more often slight injuries OAIS 1 (34.5%) than moped/mokick or mofa users. Moped/mokick users receive more often slight injuries (OAIS 2 (28.1%) than users of motorcycles or mofas, and the latter receive more often medium injuries OAIS 3 (35.2%). Next to the motorcyclists, users of mofas race a special risk.

3.2.2 Injury pattern

48% of all injuries to soft body parts of two-wheel users are bruises, abrasions or hematoms, 49% simple open soft-part injuries

2% extensive soft-part injuries, and 1% complex soft-part injuries to the sinews, nerves, and vasculars. On average one person received 4.2 injuries. 47% of all injuries were combinations of bruises and simple open soft-part lesions, 23% isolated bruises, and 7% a combination of bruises, simple open soft-part or extensive soft-part injuries. Other combinations were found in 23% of the injuries.

Soft-part injuries represent 55% of all thorax injuries, 49% abdomen/pelvis injuries, and 80% of all injuries to the extremities:

	thorax (n = 51)	abdomen/ pelvis (n = 73)	upper extremities (n = 231	lower extremities (n = 401)
closed soft-part inj.(n=510)	51%	44%	70%	73%
open " " " (n=49)	4%	5%	10%	5%
fractures (n=154)	20%	10%	20%	22%
organ-injuries (n=43)	25%	41%	-	-

total (n = 756) all injuries on one body region = 100%

Fractures are evident with 20% of all injuries to the body region, with the exception of 10% for the abdomen/pelvis region. 52% of these occur to the drivers of motorcycles, 22% to moped/mokick, and 26% to mofa users. Fractures of the extremities are often oblique or torsion fractures, or fractures with bending-wedge (35%) as well as slanting fractures (33%). Impacted fractures of the tibial head, fractures with lucation of the ankle joint, and cumminuted fractures respectively fractures with multiple fragments were noted with 10%. The localizing of these fractures was done to:

9.8% proximal joint
14.4% prox. 1/3
38.6% diaphysis
27.4% distal 1/3
12.4% distal joint

To procure objective protective measures, it is absolutely inevitable to know the type of injuries and the cause. In an interdisciplinary detailed analysis the injury-causing objects were seen in each case in correlation with the injuries. For the group as a whole, the bumper at the vehicle front, and the windscreen region as well as the vehicle side, further the side pillars and the roof edge must be described as injury causing (11).

Motorcyclists suffered on average 3.4 times more isolated injuries than users of mopeds/mokicks, and 1.8 times more than users of mofas. The vehicle front is for motorcyclists the least injury-causing part. The bumper caused 18.2% of all injuries to mofa-users, 12.7% to moped and mokick users, and only up to 5% of all motorcycle riders. The facts are reversed for the vehicle sides. Users of mofas suffer less injuries from the side of the collision

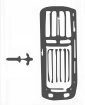
partner. Injuries caused by the own motorcycle occurred with all types to an almost equal amount (3.5 to 5.6%). Injuries to users of motorcycles by the road surface are the most frequent, with 35% (mofas = 20%; mopeds/mokicks 30.6%).

3.2.3 Kinematic observation

From our own studies (9, 10) it is evident that the severity and extent on injury to an involved motorcyclist depend on the speed of the two-wheeler as well as that of the collision partner. They depend further on the impact point on the collision partner, the collision angle, the impact point on the two-wheeler during the flying phase (from impact of the two-wheeler to the contact with the road surface). The combination of all influencing factors to a clear form, describing the two-wheeler accident could prove to be very useful, as

- it simplifies the kinematic observation
- makes a comparison of accident reality and experimental test technique feasible
- defines the cause and grade of risk.

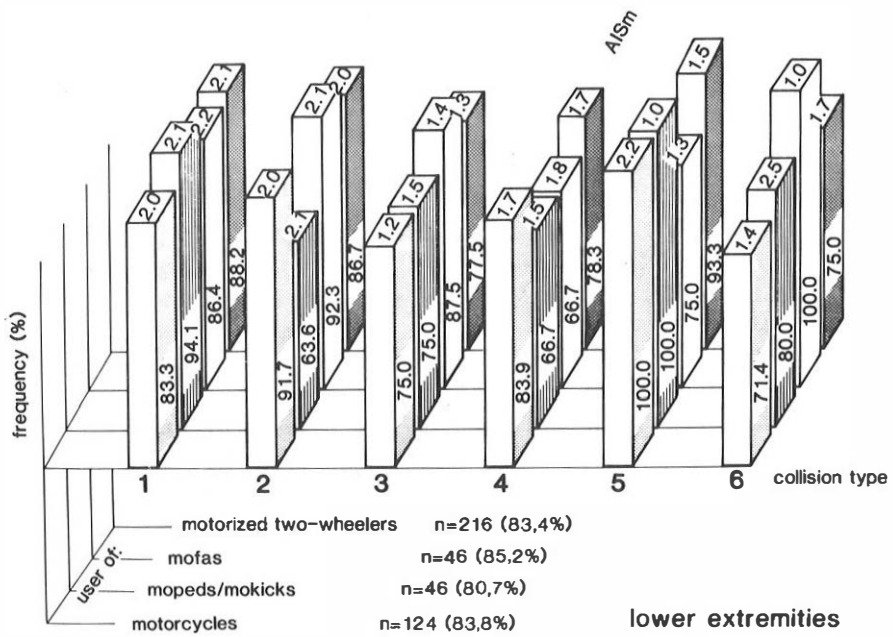
The division into collision types, kinematic and projection groups simplifies the task of accident observation. This way, the different collision constellations between the accident partners are marked by 8 collision types (diagram 3), which show the position of the vehicles at the time of collision, with angle and impact point. The most frequent collision type is type 2, with 22.4%, i.e. the two-wheeler colliding in an oblique angle with the front of the car/trucks. It is evident that especially type 1, i.e. a motorcycle colliding almost rightangularly with the front

		characteristic collision type							
									
	type	1	2	3	4	5	6	7	8
definitions	impact point on collision partner (clockwise)	11 12 01		08 09 10	02 03 04	11 12 01	05 06 07	cycle 01–12	
	classification of collision-angles (Grad)	90 ± 20 270	180 ± 69	90 ± 20 270	180 ± 69 0	0 ± 69	0± 89	0–380	
frequency	all motorized two-wheelers	20,4	22,4	15,1	17,6	5,9	7,7	2,9	4,8
	motorcycle	8,9	23,4	15,8	20,9	3,8	9,5	5,1	7,8
	moped/moklck	33,3	18,3	13,3	15,0	10,0	8,3	-	1,7
	mofa	40,7	24,1	14,8	11,1	7,4	1,9	-	-

Diag.3: Definition and frequency of characteristic collision types (each kind of cycle = 100%)

of a vehicle occurs quite frequently for mokick or mofa (33.3% respectively 40.7%), compared with motorcycles (8.9% only). Single accidents, however, are more frequent with motorcycles (12.7%), compared with 1.7% for mopeds/mokicks and none for mofas.

For the two-wheeler groups different collision constellations cause different injury concentrations to the body regions. Almost all two-wheeler users in all collision types suffered injuries to the lower extremities with the same frequency. 83.4% of all motorized two-wheel users received injuries, 80.7% of the mokick users, 83.8% of the motorcyclists, and 85.2% of the mofa riders (diag. 4). Except for the mofa user with 75%, these are most frequently found in collision type 5 (93.3%).



Diag. 4: Frequency and average severity of injuries to the lower extremities in collision types (all persons in each group of cycle and collision type = 100%)

Fewest injuries to the lower extremities are found for the whole group of motorized two-wheelers with types 3 and 4, i.e. collision of a two-wheeler with the vehicle side (78%), and type 6, i.e. a two-wheeler driving up the rear of a car (75%). A lesser injury danger for the lower extremities is found in collision types 2 and 4 for the group moped/mokick (63.6%, respectively 66.7%) of all users of this two-wheel group. For the mofa user this refers to types 3 and 6.

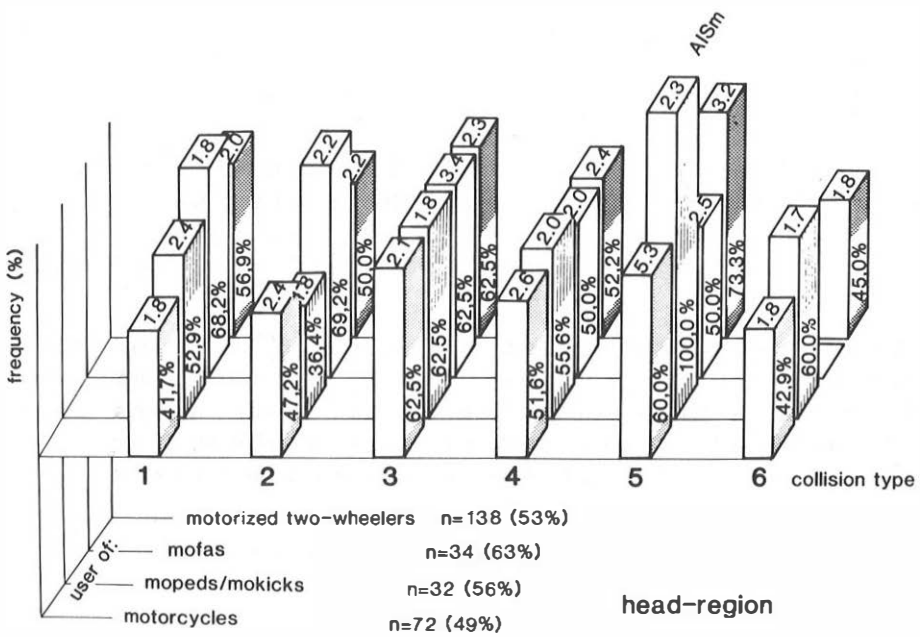
The greatest average injury severity (AIS_m of the legs) is inflicted on users of motorized two-wheelers in collision with the front of the car (collision types 1 and 2), resulting in AIS_m = 1.3 to 1.7 in the lateral impact with the car. 56.8% of all

two-wheel riders receive injuries to the upper extremities. These injuries are on average slighter than those to the lower extremities (AIS_m = 1.2 to 1.7). Collision type 1 inflicts almost identical injury frequency with all two-wheel types (motorcycle = 58.3%, moped/mokick = 52.9%, mofa = 59.1%) as well as injury severity (AIS_m = 1.31). The other collision types represent a different risk for each two-wheel type:-

- type 2: mofa highest frequency (69.2%), moped/mokick lowest danger (36.4%),
- type 3: moped/mokick highest frequency (75%), lowest danger (50%) for mofa,
- type 4: motorcycle highest frequency (61.3%), other groups equally low (33.3%),
- type 5: mofa most frequently (75%), motorcycle lowest risk (60%),
- type 6: moped/mokick greatest danger (60%), less danger for other groups.

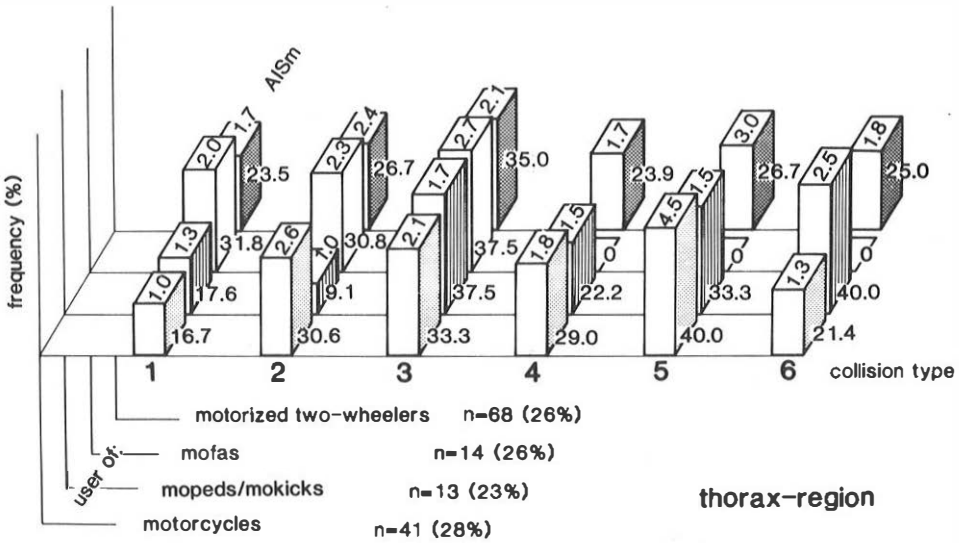
Almost 50% of all riders of two-wheelers suffer head injuries (53% of all riders of motorized cycles, 49% motorcycles, 32% moped/mokick, and 63% mofa users).

From diagram 5 it is evident that head injuries in collision type 3 are equally frequent with every two-wheel type (62.5%). The injury severity, however, is for every two-wheeler type different (motorcycle: AIS_m = 2.1, moped/mokick: AIS_m = 1.8, mofa: AIS_m = 3.4). Collision type 3 causes for the motorcyclist the most



Diag. 5: Frequency and average severity of injuries to the head-region in collision types (all persons in each group of cycle and collision type = 100%)

frequent and severe head injuries (62.5%). Type 5 causes for the moped/mokick group with 100%, and types 1 and 2 with 68.2% respectively 69.2% the most head injuries. The most serious head-injuries were caused to users of motorcycles in collision types 1 and 5, and for mofa users in type 3. There were no substantial differences regarding the use of helmets, for the various collision types. Injuries to the thorax-region were less frequent. They can be defined with 26% for all motorized two-wheeler users, 23% of the moped/mokick riders, 26% of mofa users, and 28% of the motorcyclists (diagram 6).



Diag. 6: Frequency and average severity of injuries to the thorax-region in collision types (all persons in each group of cycle and collision type = 100%)

Collision type 3 is for all two-wheeler types almost equally frequent (33.3 to 37.5%). No injuries to the thorax were registered in types 4, 5 and 6. Regarding the injury severity, type 3 proved to be very dangerous for the users of moped/mokick, types 1 to 3 for mofa users.

Injuries to the pelvis/abdomen-region are fewer (21.6% of all 272 motorized two-wheeler riders), but especially serious (AIS_m =2.3)-27% of all moped/mokick users, and 18.5% of all mofa users receive such injuries. The average injury severity is highest for the motorcyclists (AIS_m = 2.4), lowest for the moped/mokick user (AIS_m = 1.7).

4.6% of all motorized two-wheelers received injuries to the cervical vertebra, with an average injury severity of AIS_m = 3.8. This injury which is mostly found with motorcyclists (6.1% of all motorcyclists) can be seen in every collision type, except for types 6 and 8. They are most frequent in collision type 5 (20%), and type 7 (28.6%). 1.9% of all mofa users (without exception in type 1) received injuries to the cervical vertebra.

It is quite evident from these results that the collision constellation has a marked influence on kinematic and injury pattern, as well as on the injury severity of the two-wheeler riders (10). Additional influental factors are the speed spectrum (transformed energy), safety precautions like helmet and leather clothing as well as the impact spot on the two-wheeler.

7 kinematic groups were established for further analytic reflection in order to describe the flying phase of the body during the crash and post-crash phase (diagram 7).

Kinematic groups for the trajectory in accidents with two-wheel riders (n=272)

	flight without impact A	thrown upon the collision partner B	direct impact and seated C	impact on the collision partner with change in direction D	impact on the collision partner without change in direction E	slipped off the collision partner F	indirect collision G
picture							
frequency (%) -all motorized two-wheelers-	11,8	15,1	2,9	36,4	7,7	6,3	15,1
-motorcycle-	13,3	7,6	3,8	33,5	7,0	7,0	20,9
-mofa-	1,9	37,0	1,9	40,7	7,4	5,6	5,6

Diag. 7: Characteristic kinematic groups for trajectory with frequencies (all accidents in each group of cycle = 100%)

The most frequent kinematic performance occurs in the post-crash phase. 36.4% of all injured motorized two-wheeler users suffered an impact with the collision partner, with change of direction, 15.1% were thrown up or had an indirect collision, 11.8% had a flight over the collision partner, without touching the vehicle. Of the mofa riders only 1.9% had such a 'free flight'. Only 7.6% of the motorcyclists were thrown up, and only 5.6% of the mofa users collided indirectly. An almost equal distribution can be established for the kinematic groups with the respective two-wheel groups.

In a collision of the two-wheeler with the front of the collision partner the user of the two-wheeler suffers in 42.9% (collision type 1), up to 47.5% (collision type 2) an impact with change of direction, and in 26.8% respectively 24.6% a throw-up by the collision partner (diagram 8).

collision types	kinematik groups A (n=32)	B (n=41)	C (n=8)	D (n=99)	E (n=21)	F (n=17)	G (n=41)
1 (n=55)	18,8	36,6	12,5	24,2	28,6	—	2,4
2 (n=60)	18,8	36,6	—	29,3	23,8	—	12,2
3 (n=40)	21,8	12,2	—	15,2	14,3	23,5	7,3
4 (n=47)	25,1	4,9	37,5	19,2	4,7	29,4	19,5
5 (n=16)	3,1	9,7	—	7,1	—	—	7,3
6 (n=20)	3,1	—	—	2,0	—	47,1	19,5
7 (n=8)	6,3	—	12,5	—	28,6	—	12,2
8 (n=13)	—	—	25,0	3,0	—	—	4,9

persons (n=259)

unknown trajectories are separate (n=13)

(encluded = 100%)

Diag. 8: Distribution of kinematic groups in all collision types (all persons in each kinematic group = 100%)

In a collision with the vehicle side, the impact with change of direction lessens (36.8%, respectively 39.6%). The throwing-up is also reduced, while a free flight (17.1%, respectively 16.7%) as well as an indirect collision (7.3%)respectively 16.7% increase. The driving up of a two-wheeler results in most cases in a throw-up (25%), an impact with change of direction (43.8%), or an in-direct collision (18.1%). The driving up of a two-wheeler on to a car causes besides an indirect collision a sliding-off of the collision partner (38.1%). Besides the described danger for the involved two-wheeler during the crash phase, as illustrated in collision type and kinematic group, an additional danger exists in the type of the running-out phase.

The rider of the two-wheeler may, for instance, slip on the road (73.2% of all motorized two-wheelers), turn over (1.8%), get run over (1.5%). He may also hit a small (12.9%) or a large (5.5%) object (diagram 9). While motorcyclists mainly slip in the run-out phase (68.4%), the mofa rider (21.6%) could also have an impact with small objects (22.9%) and be run over (25%).

A slipping run-out phase exists in two thirds of all cases among the collision types. An impact with small or large objects was established in 19 to 23%. In collision type 3, however, such an impact rarely occurs (12.2%). All established overturnings of the body happened in collision type 2. After the two-wheeler collision the body was subjected to a so-called 'free flight' (kinematic group A), or to an impact with the collision partner, without change of direction (kinematic group E). The users of two-wheelers

experienced a secondary impact of the body to a small, respectivdy large object, after a free flight over the collision partner (21.9%) and with group D (29.3%). No impact with such objects could be found in groups C and F.

Kind of outrun after the flying-phase of a two-wheeler						
	-groups-					
	slipped away	roll over	small impact point	large impact point	run over	other (unknown)
frequency (%)	-all motorized two-wheels-					
	73,2	1,8	12,9	5,5	1,5	5,1
	-motorcycle-					
	68,4	3,2	13,3	7,6	1,3	6,3
	-mofa-					
	21,6	-	22,9	-	25,0	14,3

Diag. 9: Groups of different kind of outrun after the flying phase (post-crash phase) - all persons in each group of cycle = 100%)

4. Effectivity of crash helmets

The high positive protective quality of the crash helmet was already described in (10). This fact can be confirmed as far as this study is concerned. Of the persons whose head remained uninjured (AIS 0) 62% wore helmets (without losing these during the crash phase). 38% were not wearing helmets (diagram 10). 32% of the injured with severity grade 3 or 4 wore helmets, while 68% respectively 83% were not wearing helmets. The figure reveals that the helmet does not generally prevent fatal injuries. 2.2% of the helmet wearers and 0.9% of the non-helmet wearers for instance suffered an injury severity grade OAIS 6. When including those helmet wearers who lost their helmets during the crash phase, the proportion of OAIS 6 amounts to 5.3%. These will, however, not be considered during the further observations.

injury severity to the head: AIS-head	frequency (%) with helmet (n=150)	use of helmet: without lost their helmet (n=91)		use of helmet: without helmet (n=110)	
1 17,7 (n=46)	13,3	44	13,2	32	23,6 68 56
2 17,7 (n=46)	14,0	46	13,2	32	22,7 68 54
3 9,2 (n=24)	6,0	38	3,3	17	13,6 83 62
4 2,7 (n=7)	1,3	29	1,1	17	4,5 83 71
5 2,7 (n=7)	2,7	57	—	—	2,8 100 43
6 3,5 (n=9)	5,3	89	2,2	67	0,9 33 11
0 46,5 (n=121)	57,4	71	67,0	62	31,9 38 29
	100%	100%	100%		100%

100%

224 accidents with 260 persons involved

Diag. 10: Frequencies of injury severities of the head (percentage horizontale: 100% = all persons with and without helmet - (100%) = all helmet wearers who did not lose their helmets and all persons without helmet)

Of the non-helmet wearers suffered 93%, of the helmet wearers only 7% abresions, bruises, lacerations and cuts (diagram 11).

frequency of head-injuries	all two-wheelers	use of helmet: all persons	use of helmet: without lost helmets	use of helmet: without helmet	
persons involved (n)	260	150	91	110	
persons injured (n)	144	35	34	75	
kind of injuries: soft body part (n=299) (%)	54,6	21,4	6,8 7	78,6 93	100%
kind of injuries: fracture (n=88) (%)	16,1	34,9	6,0 9	65,1 91	
kind of injuries: commotio (n=104) (%)	19,0	28,3	13,0 19	71,7 81	
kind of injuries: contusio (n=49) (%)	8,9	30,4	6,5 9	69,6 91	
kind of injuries: compressio (n=4) (%)	0,7	33,3	33,3 33	66,7 67	
kind of injuries: other (n=4) (%)	0,7	—	—	100,0	
	100%				260 persons in 224 accidents

Diag. 11: Frequencies of different kind of head-injuries (percentage horizontal: 100% = all persons with and without helmet - 100% - all helmet wearers who did not lose their helmet and all persons without helmet)

A reduction of injuries by the helmet is, therefore, established in all injury types inclusive the total amount of head injuries. Injuries of severity grades AIS 1 to AIS 3 inclusive cannot totally be eliminated for helmet wearers, but a reduction can be expected.

In diagram 12 the injury frequency to the head - with and without helmet - in various collision constellations (collision types) are illustrated.

		collision-type							
		1	2	3	4	5	6	7	8
persons used helmets	(n)	56	61	41	48	16	21	8	13
head impact	(%)	83,9	91,8	90,2	81,6	81,3	81,0	100	84.6
all injuries *	(n)	83	74	65	58	31	21	14	13
with helmet	(%)	22,9	55,4	40,0	39,7	48,4	71,4	100	92,3
without helmet	(%)	77,1	44,6	60,0	60,3	51,6	28,6	-	7,7
soft body parts	(n)	43	37	27	26	15	14		
with helmet	(%)	9,3	45,9	40,7	32,3	48,4	64.3		
without helmet	(%)	90,7	54,1	59,3	67,7	51,6	35,7		
closed fractures	(n)	4	7	11	11	2	-		
with helmet	(%)	25,0	42,9	20,0	36,4	-	-		
without helmet	(%)	75,0	57,1	80,0	63,6	100	-		
opened fractures	(n)	1	2	2	-	-	-		
with helmet	(%)	-	50	-	-	-	-		
without helmet	(%)	100	50	100	-	-	-		
commotio	(n)	11	13	15	9	5	3		
with helmet	(%)	18,2	53,8	40,0	66,7	20,0	66,7		
without helmet	(%)	81,8	46,2	60,0	33,3	80,0	33,3		
contusio	(n)	7	6	5	5	2	2		
with helmet	(%)	14,3	66,7	20,0	20,0	100	100		
without helmet	(%)	85,7	33,3	80,0	80,0	-	-		
compressio	(n)	-	-	-	-	1	-		
persons injured cervical spine	(n)	2	1	2	2	2	-		

* unknown injuries are enclosed

Diag. 12:

Frequencies of kind of head injuries in collision types by persons with and without using helmets

With two-wheelers colliding almost rightangularly with the vehicle front (type 1), 83.9% of the involved persons suffered a head impact. A high protection effect is especially recognise-able with this type, as only 9.3% of the helmet wearers, but 90.7% of the non-helmet wearers suffered soft-part injuries to the head. Closed skull fractures were evident in 75% of the non-helmet users, and in 25" of the helmet wearers. Open fractures were suffered exclusively by non-helmet wearers, a Commotio with 81.8% of the non-helmet wearers, and 18.2% of the helmet wearers. A Contusio was evident in 85.7% of non-helmet wearers, and 14.3% of the helmet wearers. Of 83 injuries to the skull in this collision type, 77.1% were suffered by non-helmet wearers, and only 22.9% by persons with helmet protection. Differences between the various types regarding the protection effectiveness can be recognized, although on average 0,7 head injuries per involved

persons could be established in all collision types. The frequency of the head impact is almost equal (80% of the involved persons in various collision types).

Of all head injuries almost 50% (41.5 to 66.7% per collision type) are soft-part injuries (diagram 13). Closed fractures fo the head did not occur in collision type 6, but most frequently in a collision with the side of car/trucks or in the two-wheeler-only accident (maximal 28.6%). Open fractures of the skull are rare (max. 7.1%). They could only be observed in collision types 1 to 3 and 7. Commotio represents 7.1 to 23.1% (depending on collision type) and Contusio 6.5% to 15.4% of head injuries to motorized two-wheelers.

	collision type							
	1	2	3	4	5	6	7	8
head-injuries (n)	83	74	65	58	31	21	14	13
of them: (%)								
soft body parts	51,8	50,0	41,5	44,8	48,4	66,7	51,0	53,8
closed fracture	4,8	9,5	16,9	19,0	6,5	-	26,6	15,4
open fracture	1,2	2,7	3,1	-	-	-	7,1	-
commotio 2	13,3	17,6	23,1	15,5	16,1	14,3	7,1	15,4
contusio 3-4	8,4	8,1	7,7	8,6	6,5	9,5	7,1	15,4
compressio	-	-	-	-	3,2	-	-	-
AIS-head 1-3	>65,1	>67,6	>64,6	>60,3	>64,5	>61,0	>58,1	>69,2

Diag. 13: Frequencies of kind of head injuries in collision types (all injuries in each collision type = 100%) and percentage of injury severity grades 1 to 3

Type and intensity of energy transformation have an essential influence on the possible safety effect of helmets. 57.3% of soft-part injuries and 46.2% of the contusio occured for non-helmet wearers with forces applied to the two-wheeler by the transformed energy during the collision phase < 50.000 joule, 20% respectively 24.6% up to 100.000 joule, and 10.9% respectively 13.8% with forces of more than 200.000 joule (diagram 14). Severe injuries to the skull (contusions) are in low forces less frequent, but they are more often observed with higher forces. A compression could be observed with forces > 200.000 joule. The proportion of uninjured people decreases with receeding forces. Injury severity grade AIS 1 (up to and incl. 3) decreases from 87% (force <50.000 joule) up to 53% (forces >200.000 joule). A protective effect is, however, seen with persons wearing helmets, although an increase in injuries of severity grade AIS 1 up to and incl. 3 can be established.

kind of head-injuries	force of energy impressed upon the cycle (joule)							
	< 50.000		50.000-100.000		100.001-200.000		> 200.000	
frequency 100%	(n=180)		(n=72)		(n=60)		(n=61)	
soft body part (n=220)	57,3	70	20,0	61	11,8	43	10,9	39
fracture (n=54)	29,6	9	14,8	11	25,9	23	29,7	26
commotio (n=65)	46,2	17	24,6	22	15,4	17	13,8	15
contusio (n=32)	25,0	4	12,5	6	31,0	17	32,0	16
compressio (n=2)	—	—	—	—	—	—	100,0	4
uninjured (n=68)	70,6		17,6		8,8		3,0	

kind of injury=100% and region of energy=100% persons (n=109) without helmets

Diag. 14: Frequency of kind of head injuries by force of energy impressed upon the cycle.

At the same time, there is a reduction of severe injuries (i.e. skull-basis fracture, contusio) noticed, with a tendency to the slighter ones.

Despite the protective helmet, the oblique impact of the two-wheeler as well as the drive-up accident (collision types 2, 4, 5 and 6) present a special danger for the involved two-wheeler. The same can be claimed for the isolated accident of a two-wheeler during which he could - with a helmet-protected head - reduce force on impact with objects.

It is noticeable that injuries of the cervical vertebra happened to 3.6% of all non-helmet wearers, and to 8.7% of all helmet wearers, a factor which was observed in all collision types. This could be interpreted as a possible disadvantage of helmet wearing.

Final conclusion

With the above analysis of motorized two-wheeler accidents the accident events of this group of traffic participants can be illustrated in detail. Essential differences are apparent in the respective two-wheel groups (motorcycle/small motorcycle/moped/mokick, and mofa) as a result of different influental parameters:

- speed spectrum
- population (age, profession, purpose of journey)

- safety conscience (helmet wearing quota, type of helmet, leather clothing, vehicle adaptions)
- accident causes and accident fault
- injuries (type, extension, body region), injury-causing parts, injury severity, risk.

It was evident that by forming of collision types, kinematic groups and run-out types, the various influental parameters with the two-wheeler accidents could be analyzed in regard to accident sequences and kinematic observation:-

- kinematic group/type of energy transformation during the crash and flying phase of the user (amount, speed, type of impact object)
- run-out type: type of energy transformation during the run-out phase, type of impact object.

Injuries of severity grades AIS 1 to and including 3 represent the greater proportion of all injuries, depending on collision constellation (collision type, kinematic group, run-out type, are different in their frequency. A reduction of these injuries by safety measures like helmet or leather clothing (13) could generally be established. A shifting from severe to slight injuries is evident with users of helmets, although there is a possibility that the absolute frequency for the latter can increase.

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