Accident and injury causation of motorcycle accidents

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Abstract

Motorcycle riders are one of the most vulnerable road users. Annually, on estimate 3000 people are killed in motorcycle accidents in the former 15 EU countries. The objective of this research was to investigate and analyze the main aspects and causes of this vulnerability and the accidents in general. For this aim around 70 accidents in The Netherlands were investigated in the framework of an international research program (MAIDS). Also a control group of motorcycles with riders was investigated so that exposure could be taken into account. An important result is that human failure is in 82% of the cases the main cause of the accident, in 52% this is due the other vehicle driver. Perception and decision failures are the most common failures. The most injuries are caused by the environment but they are typically only less severe (AIS1). Injuries caused by the car (front and side) are typically severe injuries (AIS4+). Previous convictions of the MC rider seem to be related to the chance to get involved in an accident. It was shown that the Dutch and the total MAIDS accident sample are comparable.

NOTATION

ACEM	European Motorcycle Manufactures Association
AIS	Abbreviated Injury Scale
ar	adjusted residuals
DART	Dutch Accident Research Team from TNO
IMMA	International Motorcycle Manufactures Association
MAIDS	Motorcycle Accident In-Depth Study
MC	Motorcycle
n	number
OV	Other Vehicle
OECD	Organization for Economic Cooperation and Development
PTW	Powered Two Wheeler (motorcycle, moped or mofa)
SD	Standard Deviation

INTRODUCTION

More and more people are choosing the motorcycle as a way of their transportation. Its small size gives the advantage of easy maneuverability in the cities, moving through the jammed traffic and spending no effort for parking. The effect of that is the increased number of motorcyclists every year. Despite the many advantages that the motorcycle has as a vehicle, it has also disadvantages that have to be taken into consideration. The safety that it provides to the occupant is limited, in comparison to the safety that the 4-wheeled vehicles provide during an impact. The reason to that can be found in the motorcycle itself as a construction. The motorcycle has no cage and it can be seen as a bench on which the rider is sitting. The occupant separates most of the times from the PTW during an accident and he is exposed to any impact with environmental objects. High injury severity and high rate of mortality are the results. Approximately 3000 are killed annually in the former 15 EU countries (EU15). Also the risk riding a motorcycle is the highest per kilometer ridden when compared with other road traffic means (16 fatalities per 100 million kilometer as compared to 1.1 for all road vehicles).

Motorcycle accidents have been a major concern and the need for detailed information on the accident causes and the effect on the human lives increased during the last decades. In 1994, IMMA published a report concerning motorcycle safety. The report pointed out the need for an internationally harmonized in depth method for the analysis of motorcycle accidents. In 1999, ACEM proposed the MAIDS study in order to fill the gap for detailed information of accidents of modern PTW's. Five different countries participated in the MAIDS study, which lasted two years. For The Netherlands, the

DART of TNO Automotive was one of the five research partners. The study allowed the investigation of several parameters: the accident environment, the vehicles involved, the human factors, the accident causation and the injuries sustained. The analysis of these parameters could lead to the development of countermeasures for the prevention of motorcycle accidents and the reduction of their severity. In July 2004, ACEM published a reported of the analysis of the MAIDS data and presented the first results [4].

In the next sections, the analysis of the Dutch MAIDS data can be found. The first sections describe the data collection method and the statistical analysis method that were applied by the DART. The sections there after describe the results and as last, discussion of the findings and conclusions will be given.

INVESTIGATION METHOD

Accident collection

From mid 1999 till the end of 2001, almost 1000 motorcycle accidents were collected in 5 European countries (France, Germany, Italy, Spain and The Netherlands) in the framework of the MAIDS project. A harmonized method of accident collection, accident reconstruction and parameter's codification was used in all 5 countries. The methodology was developed by OECD, particularly by a group of experts from the industry and major research institutes worldwide. The methodology was structured so that a basic module had to be used by all teams, but some additional modules were also developed, allowing a more detailed analysis of topics such as helmets and mopeds. The sampling plan required the investigation of every *n-th* accident, where *n* was kept constant for 24 hours, in an area representative to the national accident distribution. The inclusion criterion was that at least one PTW occupant had to sustain an injury. The research team visited the accident scene within 24 hours from the accident occurrence. Besides to the collection of accidents, an equal amount of case control data (comparison data from riders and motorcycles that were not involved in accidents) had to be collected. This method is known as "concurrent exposure". The data from the control group would be used to measure the occurrence of a given risk factor in the accident and in the exposure population.

The DART team operated in the police area of Rotterdam-Rijnmond and Haaglanden during the period September 1999 until October 2001. The sampling area was well representative to the national profile, considering that only the percentage of accidents on secondary roads was about 10% lower than the national figures and the percentage of passenger car accidents was slightly lower too. 200 accidents were investigated, from which 113 moped, 66 motorcycle and 21 mofa accidents. The data were obtained by visiting the accident scene, inspecting the involved vehicles, interviewing the victims, receiving police accident registration forms and technical accident reports, reconstructing the accident and calculating parameters such as vehicles velocity and vehicle motion and collecting medical data from the victims hospital dossier. For this reason, special contacts had to be established with 16 hospitals and the police force of the sampling area.

Parallel to the collection of accidents, the DART collected the concurrent exposure data too. 200 PTW were inspected and their occupants were interviewed. Petrol stations were selected randomly as the location where the concurrent exposure would take place. Before the start of the exposure, the DART contacted the petrol station owners and the head offices of the oil companies for their cooperation. From the 200 PTW controls, 151 are moped/mofa and 49 motorcycle controls.

Data analysis

The data analysis was done by means of the SPSS computer program. Frequency counts and cross tabulation routines were used. The chi-square test was used for detecting significant differences. The inspection of the adjusted residuals (ar) allowed the identification of significant under or over representation of a certain factor with respect to the other tabulated factors. When the adjusted residuals are below –2 or above 2, the cell value deviates significantly from the model of independence. It may then be concluded that the deviation is not due to pure chance. Besides cross-tabulations, regression techniques (in particular the General Linear Model (GLM)) and Box-plots were used. Figure 1describes the symbols of a box-plot [3].

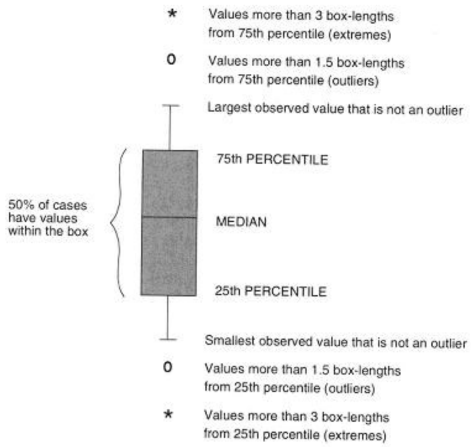


Figure 1 Description of a box-plot

RESULTS

The sample consists of 66 motorcycle accidents. 9 of these are single ones and in the remaining 57, another party was involved. In the analysis section, these two groups were often treated separately. Some of the results were compared with the outcome of the MAIDS common analysis. The MAIDS analysis often refers to the PTW in general and not specifically by category (motorcycle, moped and mofa). Therefore it was not always possible to compare the results of the Dutch analysis with those from the whole MAIDS study.

The results are divided into four sections: the accident type, the human factors, the causation factors and the injury analysis. It is worth of mentioning that not all the results are based on objective accident data. Parameters such as causation factors and contact codes were determined by the judgement of the accident investigator. In order to minimize the factor of subjectivity, two or three investigators took part during the accident reconstruction and the determination of such parameters.

Accident type

From the 66 accidents almost 14% were single accidents (n=9). A single accident is an accident without any other vehicle involvement. In 78% of the single accidents (n=7), the motorcycle was involved in a collision with a fixed object. The remaining 2 are accidents where there was a slide-out on the roadway (impact with pavement). In the MAIDS report, single accidents account for 15,5% of the whole sample (for all PTW types), which is approximately the same. The other 86% (n=57) of the Dutch sample concerns collisions with another road traffic party (e.g.: passenger car, pedestrian). In Table 1, the involved collision partners are shown. The most frequent collision partners are passenger cars, followed by (heavy) trucks.

Table 1: Other parties involved in the accident

	Frequency	Percent
Passenger car with a maximum mass less than 800 kg (M1)	11	19,3
Passenger car with a max. between 800 kg and 2 t (M1)	28	49,1
Bicycles	3	5,2
Pedestrians	1	1,7
Minibuses, buses and vans with a max. mass less than 5 t	2	3,5
Moped, mofas	3	5,3
Light trucks with a mass between 1.5 t and 3.5 t	2	3,5
Trucks and heavy goods veh. With a max. mass > 3.5 t	7	12,3
Total	57	100

Figure 2 shows the accident configurations of the sample (single and non-single accidents). Almost 70% (n= 46) of the impacts are against an opposing vehicle, either a direct impact or a slide-out followed by an impact. Impacts with an object or slide-out on the road (impact with pavement) account for 29% (n=19) of the accident configurations. A cross-tabulation between *accident configuration* and *vehicle type* was made to identify over or under representation of certain vehicle types. Some of the results of this cross-tabulation are described below.

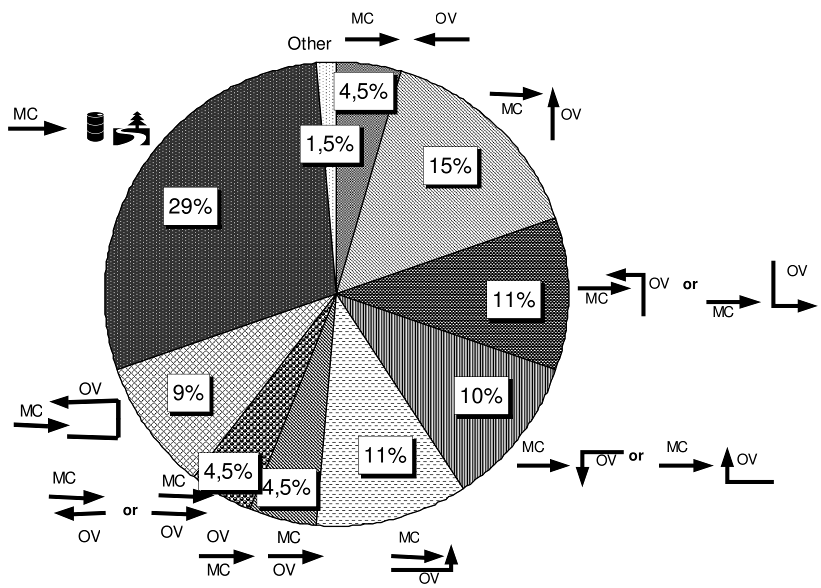
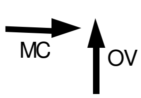
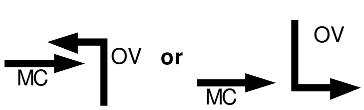


Figure 2 Motorcycle accident configurations

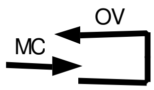


Looking at the type "MC into OV impact at intersection; paths perpendicular" (15%), it is found that 57% of the OV's are passenger cars with a mass between 800 kg and 2 tons, but the group in not over represented with respect to the other accident configurations. This large group is equally present in other accident configurations, and mere a product of exposure.



In the configurations "OV turning left in front of MC, MC perpendicular to OV path" (11%), two types of OV are frequently represented: passenger cars with a mass between 800 kg and 2 tons

(43%) and trucks and heavy goods vehicles with a maximum mass over 3.5 tons (43%). The last one was over represented (ar = 2.9, n = 3); so more presented than expected based on pure chance.



In the configuration "OV making U-turn or Y-turn ahead of MC" (9%), 83% of the OV are passenger cars with a mass between 800 kg and 2t and they are over represented (ar = 2.1, n = 5); so more present than expected.

The configuration "MC falling on roadway in collision avoidance with OV" is part of the 29% impacts with the roadway or an object. The most frequent involved party is the passenger car with a maximum mass less than 800 kg (63%), which is over represented (ar = 3.7, n = 5) and therefore more present than expected based on pure chance.

Human factors

For the analysis of the human factors, both the accident and the exposure group were used. The analysis is focused on some of the general parameters, such as age, kilometers ridden, previous violations/accidents and alcohol/drugs use.

Age

To identify any differences in age distribution between the accident case population and the control group population an independent-sample t-test was performed, which shows whether two samples deviate from each other. A criterion for this test is that the sample is normally distributed, which is the case here. It should be stated that the t-test is even quite robust for small deviations from normal distributions. The t-test showed that the average age of the accident population is significantly younger (approximately 5 years) than the average age of the control population (see table 2 and Figure 3).

Table 2: Independent sample t-test for age.

			Rider age
			Equal variances not assumed
t-test for Equality of Means	t		-2.451
	df		84.917
	Sig. (2-tailed)		.016
	Mean Difference		-5.064
	Std. Error Difference		2.066
	95% Confidence Interval of the Difference	Lower	-9.173
		Upper	-.955

The difference in distribution is however not caused by the youngest riders (less than 25 years old), but more in the range of 25 to approximately 30 years. The analysis of the whole MAIDS data shows that for the accident population, the majority of the riders are between the age of 26 and 40 years old (50%).

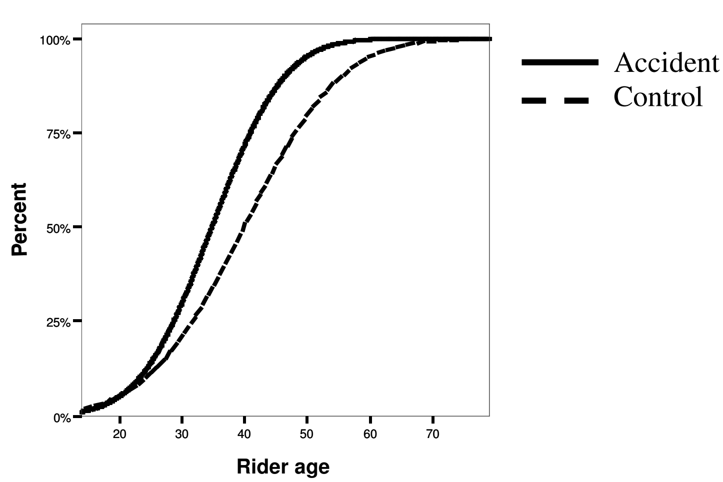


Figure 3 Cumulative distribution of MC rider age

Driving experience

For the kilometers ridden per year, the same strategy was applied as for the analysis of age. No significant difference was shown. It has to be mentioned that data were available only for 38 riders of the accident group.

For the number of days driven per year, there was a significant difference. The accident population drove approximately 60 days more per year, than the control group (see Figure 4, and Table 3).

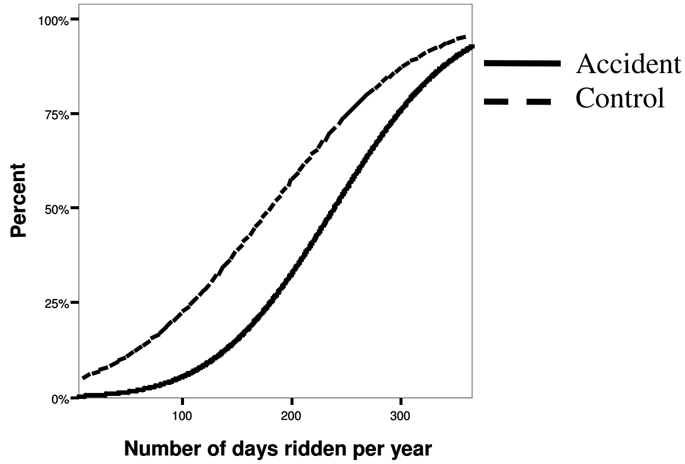


Figure 4 Cumulative distribution of number of days ridden per year.

Table 3: Independent sample t-test for days ridden per year.

			Number of days ridden per year
			Equal variances not assumed
t-test for Equality of Means	t		2.906
	df		89.564
	Sig. (2-tailed)		.005
	Mean Difference		58.558
	Std. Error Difference		20.153
	95% Confidence Interval of the Difference	Lower	18.517
		Upper	98.599

The difference found here seems to be quite large, and therefore the data was investigated more thoroughly and conditions under which the data was acquired were inspected. This is further explored in the discussion section.

Previous violations/accidents

Looking at the previous violations of the last five years, it was found that in the accident group riders with two or more convictions are slightly over represented (ar = 1.9, n = 22) with respect to the control group (seeFigure 5). Consequently, slightly less riders in the accident population had less than one conviction. Data were available for 48 riders of the accident group. This factor was inserted in the GLM model together with the already known influential factors age and number of days driven per year (and kilometers driven per year). It was found that the factor previous violations on record increased the significance of the model (p<0.01) for the prediction of an accident. Two or more previous violations on record gave a significantly higher probability to be in the accident population.

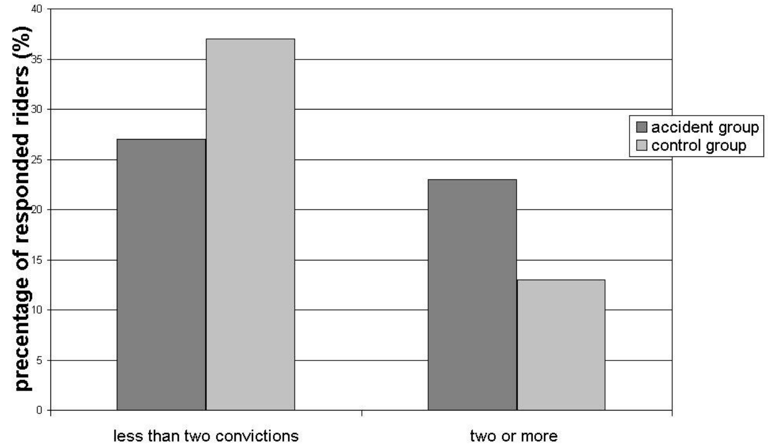


Figure 5 Comparison of the number of convictions of the last five years between accident and control group

No such significant difference was found for the riders with previous accident involvement (less or more than two) in the last five years in the accident and exposure group. 49 riders of the accident group responded to this question.

Also the relation between “unsafe act” during the accident and the previous convictions/accidents was investigated (Figure 6). No relation was found between “unsafe act” and previous convictions. Also no difference in the number of previous accidents was found based on the presence of an ‘unsafe act’ or lack thereof. This is not in agreement with the study into mopeds and mofas [1], in which such a difference was found.

Alcohol consumption was not significantly different and rather low (3-4%) for the accident and control group. This seems to differ from the whole MAIDS population (all PTW’s) in which 4% of the accident riders used alcohol and only 1.5% of the control group. Drugs use was only found in the control group for the Dutch MC riders (2%). This differs from all MAIDS data in which 0.5 % of the accident and 0.2% of the control group riders was found to have used drugs. It has to be mention that the alcohol/drugs MAIDS analysis refers to the whole PTW group (motorcycle and moped riders).

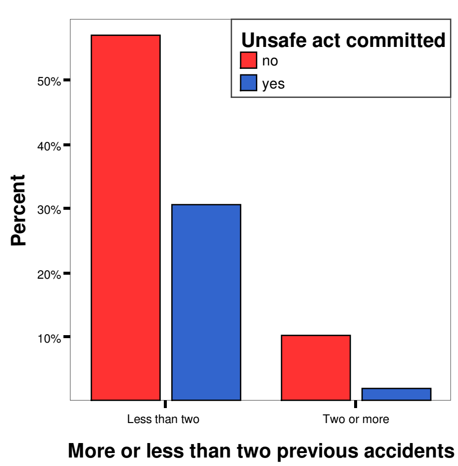


Figure 6 Comparison of the number of accidents for MC riders who committed (or not) an unsafe act

Causation factors

The accident cause or causes are coded by the investigator and are based upon expert opinion. The cause(s) are coded in the contributing factors section of the methodology. Three levels of certainty can be distinguished for the contributing factors: 95%, 80% and less than 80% confidence. In the analysis, only the primary contributing factor and the 95% certainty-level factors are taken into account. They are analyzed together.

The accident sample is split up into single accidents and accidents with two or more parties involved. The analysis is described bellow.

Single accidents

Table 4 shows the different primary factors for the 9 single accidents. Motorcycle rider comprehension and decision failure are the most frequent.

Table 4. Primary factors of single MC accident

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	motorcycle rider comprehension failure	3	33.3	33.3	33.3
	motorcycle rider decision failure	3	33.3	33.3	66.7
	roadway design defect	1	11.1	11.1	77.8
	roadway maintenance defect	1	11.1	11.1	88.9
	other	1	11.1	11.1	100.0
	Total	9	100.0	100.0	

In almost all cases (n=7) a MC rider's unsafe act or risk taking behavior also were a main contributing factor. The possible relation between "unsafe act/risk" and violation of the traffic controls or the road speed limit was investigated and no relation was found. Analysis of the MC rider's action just before the accident showed that in 45% (n=4) no action was taken and in 45%, the action failed due to loss of control or poor execution.

Accidents with other involved vehicles

In Figure 7 the primary accident factors are depicted for accidents with an OV involved. It can be seen that the failure of the OV driver to observe the MC is the most frequent primary factor (34%). The second most frequent code is the MC rider decision failure (13%) and other MC rider and OV driver related factors (reaction/perception failure etc.) which are both 13%. OV driver decision failure (9%) and view obstruction (9%) follow as next.

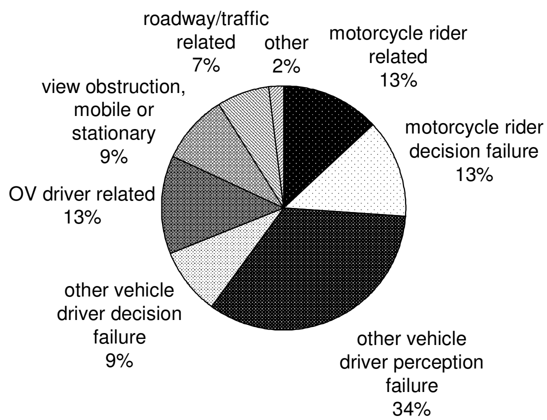


Figure 7 Primary accident factors in non-single motorcycle accidents

The most frequent other contributing factors (i.e. besides the primary cause) are the MC rider's unsafe act or risk taking behavior (40%), the OV driver's unsafe act or risk taking behavior (23%) and the OV driver perception failure (9%). The factor "MC rider's unsafe act/risk" was mostly combined with the primary factors "OV driver perception failure" (33%) and "MC rider decision failure" (24%). The factor "OV driver's unsafe act/ risk" was combined more frequent with the primary factors "OV driver perception failure" (25%) and "OV driver decision failure" (25%) and the other contributing factor "OV driver perception failure" with the "motorcycle rider decision failure" (40%) and "view obstruction" (40%).

The possible over representation of MC rider's/OV driver's unsafe act with respect to the violation of the traffic control/road speed limit was investigated in this case too. No over representation was found for both MC rider's and OV driver's unsafe act, either with the violation of the traffic control or with the violation of the road speed limit. These aspects were equally present in accidents with and without an unsafe act as contributing factor.

Looking at the action taken by the motorcyclist to avoid the accident, the available time was not enough to complete his action in 40% of the cases, in 35% of the cases the MC rider lost control during his action and in 16% no action was taken. On the other hand, the OV driver did not react in 66% of the cases (70% in the MAIDS report), he had not enough time for his action in 18% (21% in the MAIDS report) and he made the wrong choice for an evasive action in 7% of the accidents (3% in the MAIDS report).

Loss of control

Because of the high frequency of the MC loss of control in single and non-single accidents, the parameter was analyzed more in detail. It was found that 43% of loss of control is related to braking slide-out, which means that one of the wheels (or both) blocked during the brake actuation, resulting to a motorcycle/rider fall. From the accident group, only 2% of the motorcycles was equipped with an Anti-block Brake System. In the control group, the percentage was 6%. In the final MAIDS report, ABS is reported in 0,6% of the accident and in 2,9% of the exposure population (the whole PTW population).

In the group of single accidents, two of the three cases with loss of control, had an insufficient front tyre inflation pressure, while in other situations this under inflation is not predominantly present. The number of cases is very small, but the same findings were found in a study into motorcycle accidents on motorways[5]. In accidents with other vehicle presence, front tyre under inflation is not found.

Injury analysis

The medical information, which was reported in the paramedics file or the hospital dossier, was collected by a DART member after having the written consent of the victim. The injuries were coded according to the AIS scale, version 1998.

Almost 11% of the cases were fatal accidents. In 71% of these cases, an OV was involved. The percentage of fatalities coincides with this of the whole MAIDS population in the final report. From the 921 MC riders, 100 died due to the accident (10.9%). Another aspect that was investigated is the relation between loss of control before the impact and number of deaths. It appeared that 23% of the riders who lost control (n=22), died due to the accident. This group was over represented (ar = 2.2, n = 5) compared to riders that did not lose control.

In table 5, the distribution of the injuries of different severity across the body regions is shown. Note that no AIS5 were found in the Dutch accidents, which is due to pure chance. The comparison with the final MAIDS report shows that the results match for the regions "head (face)" and "upper and lower extremities". The injuries for the thorax, spine and abdomen appear to be of a higher severity in the Dutch analysis. It has to be mentioned that the final MAIDS report refers to the entire PTW population. The injuries, which were significantly over represented in the Dutch analysis with respect to the total injury group, are shown in red in table 5. Under represented injuries are shown in green.

Table 5. Injury severity vs. body region

			AIS Level					
			1.00	2.00	3.00	4.00	6.00	Total
Body Region	Head	Count	1	19	9	3	0	32
		a.r.	-5.1	2.7	3.0	2.1	-.8	
	Face	Count	17	6	0	0	0	23
		a.r.	2.9	-1.2	-1.8	-.9	-.6	
	Neck	Count	1	1	0	0	0	2
		a.r.	.1	.4	-.5	-.3	-.2	
	Thorax	Count	10	8	6	4	1	29
		a.r.	-1.3	-1.2	1.6	3.5	.9	
	Abdomen	Count	3	4	3	1	0	11
		a.r.	-1.2	-.1	1.6	1.1	-.4	
	Spine	Count	4	8	0	0	3	15
		a.r.	-1.5	1.3	-1.5	-.7	5.9	
	Upper Extremity	Count	30	29	2	0	0	61
		a.r.	.7	1.8	-2.4	-1.6	-1.1	
	Lower Extremity	Count	49	21	10	0	0	80
		a.r.	3.4	-2.6	.2	-2.0	-1.4	
Total		Count	115	96	30	8	4	253

It was further looked at the body region/injury severity versus the contact partner (e.g.: car, pavement). 48% of the injuries were caused by an impact with the environment or an object (mainly the pavement), 19% by the side and 13% by the front of a vehicle. The environment/object was also the cause of the most injuries on head (47%), thorax (33%), spine (44%), lower (54%) and upper extremities (59%). The side of a vehicle caused the most abdominal injuries (16%).

The severity is depicted in table 6. Over represented factors are shown in read, and under represented factors in green.

Table 6. Injury severity vs. contact code

Contact code		AIS Level 1.00	2.00	3.00	4.00	6.00	Total
	Count	1	0	0	0	0	1
	a.r.	1.1	-.8	-.4	-.2	-.1	
Indirect	Count	0	1	0	0	0	1
	a.r.	-.9	1.3	-.4	-.2	-.1	
Unknown	Count	3	4	0	0	0	7
	a.r.	-.1	1.1	-1.0	-.5	-.3	
Environment	Count	72	35	13	1	1	122
	a.r.	4.2	-2.9	-.6	-2.1	-.9	
OV front	Count	10	15	6	1	2	34
	a.r.	-2.0	.8	1.1	-.1	2.2	
Own motor	Count	11	7	2	0	0	20
	a.r.	.9	-.3	-.3	-.8	-.6	
OV rear	Count	0	4	0	0	0	4
	a.r.	-1.8	2.6	-.7	-.4	-.3	
OV side	Count	10	24	8	6	1	49
	a.r.	-3.9	1.8	1.1	4.0	.3	
OV top	Count	5	3	1	0	0	9
	a.r.	.6	-.3	-.1	-.6	-.4	
OV bottom	Count	3	3	0	0	0	6
	a.r.	.2	.6	-.9	-.4	-.3	
Total	Count	115	96	30	8	4	253

The relation between MC impact speed and injury severity was investigated too. The MC impact speed is defined as the speed of the MC just before the impact. The OV speed was not taken into account yet in this study. Figure 8 shows the speed versus AIS level. The impact speed is relatively high and no clear relation can be found between the speed versus AIS level. There seems to be an increase of the median speed for increasing AIS level, but this is not a significant effect. The number of AIS 4+ injuries is probably too limited to find a trend.

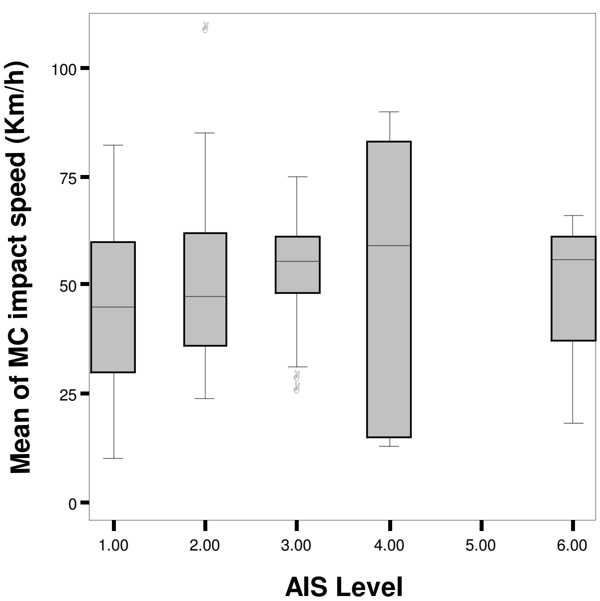


Figure 8 AIS score vs. the mean of the MC impact speed

Accident and exposure groups were compared in order to identify differences in the representation of the use of motorcycle garment. The garment was split up into four categories: upper torso and upper extremities, lower torso and lower extremities, footwear and hand protection. The accident group was over represented with respect to the control group (ar = 2.0, n = 51) for use of motorcycle oriented equipment of the upper torso. For the other three categories, no significant differences were identified.

The effect of the MC oriented garment on the severity of the injuries produced to the area covered by the garment, was investigated too. The analysis showed no significant over or under representation of any of the four cloth categories with respect to the severity of the injuries.

Passengers were not frequently involved in accidents and therefore no injury analysis was performed. From the 66 cases, only three riders were accompanied by a passenger. In all three cases, no interaction took place between them during the crash events.

DISCUSSION

Due to the limited amount of cases the results are not always statistically significant. However, trends and important aspects can be clearly indicated.

Accident type

The majority of the Dutch motorcycle accidents were accidents in which another vehicle was involved (86%). The accident percentage of OV-accidents almost coincides with this of the whole MAIDS study. The vast majority of impact partners was a passenger car (all masses: 68.4%), which is most likely caused due to exposure. The configuration "OV performing some sort of turn in front of MC" (in general) is the most common accident type with another vehicle involved (41%). Another important configuration is driving perpendicular to the motorcycle direction by the OV (15%). Small cars (mass < 800kg) are significantly over-represented in accidents where the MC rider fell trying to avoid an impact with the car. The reason for this is unclear at the moment. Heavy traffic vehicles were over represented in accidents where the OV turned in front of the MC, and their paths were perpendicular to each other.

Human factors

It was found that the average age of the accident rider population is significantly lower than the control group age (95% confidence). This means that younger riders have a significantly higher change to be involved in an accident. Also the number of days driven per year differed significantly. These differences were so pronounced that further investigation into this area were required. A major difference was found in the months in which the accident and control data was collected. As can be seen in Figure 9 the accidents were collected in different months than the control cases. This is significantly different, and should be taken into account. For this purpose it was investigated whether the control group riders are mainly seasonal riders, and the accident cases are not. It was found that in the accident case population the daily use of the particular road is over represented (a.r. = 2.1, n=31) with respect to the control group, and in the control group more weekly use of the particular road is found (a.r = 2.0, n=18). So this factor seems to confirm this hypothesis. Also the type of use (recreational vs. work) has a tendency in this direction. The case population seems to use the motorcycle somewhat more for work, and the control group more for recreation. This difference is however not significant.

When the number of days driven and the collection month were inserted into a logistic regression model for the prediction of case or control group (see Figure 9), it was found that the number of days driven per year was not anymore a significant factor. This was also the same for the age difference between the accident population and the control group. It is therefore concluded that the difference in the number of days driven per year and the age between the accident and control group population is an artefact of the time of collection of the cases and the controls. Another explanatory factor may be that the control group sampling caused a bias towards recreational use, simply because recreational riders might have a tendency to co-operate better with a control study (that took 20 minutes of their time at the petrol station).

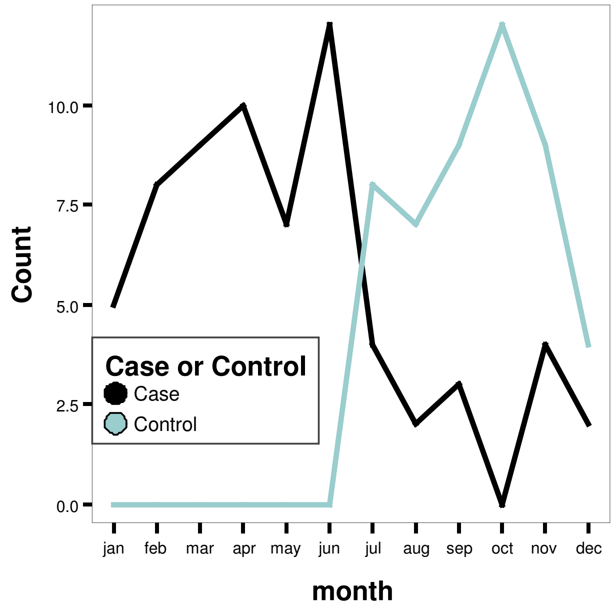


Figure 9 Number of accidents and controls collected per month.

The investigation of previous violations on record shows a significantly higher accident involvement of riders with two or more convictions the last five years, when the effects of age and number of days driven per year were taken into account. This indicates that the number of convictions could predict the chance to be involved in an accident. These conclusions can only be drawn with more certainty if further research into this specific topic confirms this. The numbers for alcohol consumption and drug use are too low to attach any conclusions to.

Causation factors

Rider's comprehension and decision failure are the dominating primary factors in single MC accidents (67%). An OV driver failure (perception, decision or another failure) is by far the most common primary causation factor in accidents with OV involvement (52%). The OV perception failure is the most prominent of this failure (accounting for 34% of all accidents, i.e. 65% of all failures). Motorcycle rider related factors (e.g.: decision, reaction failure) are also very frequent (26%). In total, in 82% of the accidents any human failure was the primary cause of the accident.

Other contributing factor besides the primary cause, which appears to a high percentage in both single and non-single accidents, is the MC rider's unsafe act/risk taking behavior in the first place (40%) and the OV driver's unsafe act/risk in the second place (23%). Violation of the traffic controls and violation of the road speed limit were not related to the unsafe act of both MC rider and OV driver. The MC riders seem to be more alert in general than the OV drivers before the impact, because they attempted an evasive action in 75% of the cases, as opposed to the OV driver, who reacted in only 25% of the cases. In 66%, the OV drivers did not attempt an evasive maneuver as opposed to 16% of the MC riders. Despite the fact that the motorcyclists relatively often tried to avoid the accident, their action was apparently not successful due to loss of the motorcycle control in 43% of those cases where an evasive maneuver was attempted. In particular, they locked a wheel of their vehicle and slid on the pavement. In 45% of the cases where an evasive maneuver was attempted the action was not successful simply because there was not enough time left.

Although the frequency of ABS in the accident case group (2%, only one case) was lower than in the control group (6%, 3 cases) this is not a significant difference (a.r. is only 1.3 and the number of cases is too small as well). Although the tendency is in the direction of a conclusion that ABS increases MC safety this should be checked for a larger group accidents (e.g. in the MAIDS study).

Injury analysis

The percentage of fatalities is almost the same with the percentage in the whole MAIDS study (11%). An OV was present in 71% of the fatal cases, whereas in 86% of all cases an OV was involved. This seems to indicate that single MC accidents are more severe than accidents in which an OV was involved. This can however not statistically be proven; however, there is a slight tendency towards this direction. The slightly higher level of injuries in single accidents can be supported by the higher number of riders that lost control of the motorcycle in the avoidance maneuver. It was also found that motorcyclists, who lost control have a higher probability to die in an accident.

Injuries on the lower (32%) and upper extremities (24%) and the head and face (22%) were the most frequent. The extremity and facial injuries tend to be less severe: AIS1 and AIS2 only. Head injuries seem to be more severe: AIS 2 to 4 injuries to the head are significantly over-represented. Also more severe injuries were observed to be higher for the spine and thorax (AIS4 to AIS6). The environment or an object (e.g.: pavement, poles) was the most common injury causation on head, thorax, spine, lower and upper extremities. The injuries caused by the environment and objects are typically low severity injuries: AIS1 was significantly over represented, a.r. of 4.2 whereas the more severe injuries are under represented. The side and front of an OV showed a tendency to produce more severe injuries: the AIS1 injuries are under represented whereas the heavier injuries (AIS4+) are over represented.

Concerning the speed of the motorcycle and its influence on the severity of the injuries, no significant relation could be found, although a slight increase of the median of the impact speed can be observed with higher injury severities. This might indicate that the injuries are more related to the accident configuration. This could be explained by the vulnerability of the MC rider.

CONCLUSIONS

1. In 86% of the accidents, another party is involved in MC accidents. In almost 70% of these cases the OV is a passenger car.
2. “OV turning in front of MC” (in general) is the most common accident type with another vehicle involved (41%). This might be combined with OV driver perception failure which is the most frequent primary accident factor in MC-OV accidents (34%).
3. An important result is that human failure is in 82% of the cases the main cause of the accident, in 50% this failure is due to the OV driver.
4. MC riders with two or more convictions tend to be more often involved in accidents
5. Motorcycle riders attempted an evasive action in 75% of the cases, opposed to other vehicle drivers, who reacted in only 25% of the cases.
6. Mechanical factors hardly play any role in MC accident causation. The only factor that could play a role is front tyre underinflation.
7. Fatal MC accidents due to loss of control are significantly over represented.
8. Less severe injuries to lower and upper extremities are the most present for MC accidents. Head injuries are the most dangerous for MC riders, because the still appear quite often and they are typically rather severe.
9. The most injuries are caused by the environment but they are typically less severe (AIS1). Injuries caused by the car (front and side) are typically severe injuries (AIS4+).

The most important possibility for preventing MC accidents is to reduce the number of human errors, especially at the OV driver. With respect to injury prevention it is especially worthwhile improving rider protection in motorcycle to passenger car accidents, because the contact with the car as other vehicle accounts for many and relatively severe injuries (as opposed to the environment).

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