Injury prevention in motorcycle accidents: Italian evidence from MotorcycleAccidents in-Depth Study (MAIDS)

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Abstract
The purpose of this work is to investigate the association between the injuries in motorcycle accident and the main accident configurations. The data were provided by a multicentric case-control study MAIDS regarding the risk of crash and injuries of motorcyclists. Chi-square test was used to evaluate the relationship between the variables and a logistic regression was performed to evaluate the association of injury severity with some variables supposed to be predictive factors. Lesive patterns characterized by internal haemorrhages are mainly associated with fronto-lateral crashes, above all in urban areas. Lacerations or abrasions, mainly reported in torso and lower extremities, are mostly associated with single crashes or accidents in queue also for crashes occurred to low speed (< 50 km/h). The severity of injuries is highly associated with impact speed, regardless of the crash configuration. Fractures and haemorrhages play an important role in determining the severity of injuries. The upper extremities are the most frequently traumatised anatomic areas.

Introduction

In literature several studies deal with injuries on individuals involved in road accidents.
Most surveys try to find a causal link between injuries and determinants. Some of them lack an epidemiologic design, do not arise from ad hoc surveys and do not provide information on the accident dynamics. This is due to the fact that the health data and those on the cinematic reconstruction of the accident come from different unlinked sources. The gradual increase in the number of injured people involved in two-wheel accidents regarding both passengers and/or run-over pedestrians and above all riders, strongly calls for a thorough and up-to-date knowledge of injury patterns. The detailed analysis of "road injury"provides interesting evidence to improve people's active and passive safety (to adopt specific preventive measures and/or achieve better standards of the currently used protective systems). Accordingly, the analysis provides good and useful epidemiologic background information on the proper reconstruction of the accident traumatologic dynamics and it corretly ascribes accident responsabilities [1].
The study aims at pointing out the etiopathogenetic relationship between the injury pattern on involved people and crash configuration. Therefore, the analysis of scientific evidence has been based on:

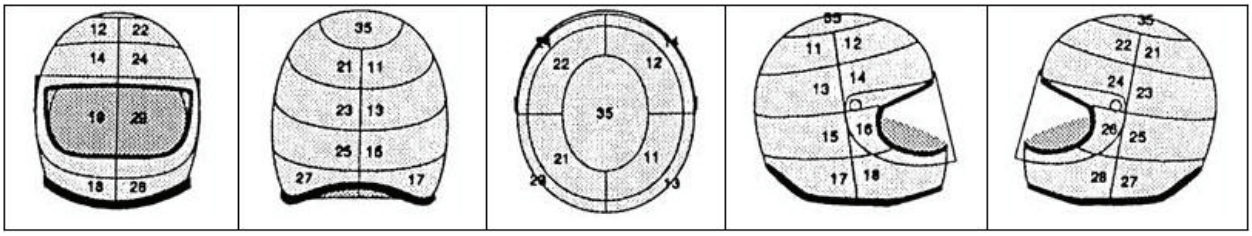
- the dynamic-cinematic reconstruction of the traumatic event identifying the lesive pattern of injured people registered by medical practitioners;
- clinical- anatomopathological in-depth study of lesions;
- analysis of injuries related to crash configuration.

Methods

The current study develops an ad hoc research methodology that hinges on existing data sources provided by the international database MAIDS (Motorcycle Accidents in-Depth Survey) [2-5]. MAIDS study is a multicentric case–control research conducted in Italy, Spain, Germany, Holland and France from 1999 to 2001, with the specific aim of identifying risk factors of motorcycle crashes and risk factors to discriminate between serious and minor injuries. The target population is formed of all two wheeled vehicles circulating through definite areas. Cases consist of motorcycles and their riders that were involved in accidents with injuries; to be enrolled in the study either the rider and/or passenger had to be injured and transported to an emergency ward. Controls consist of riders and vehicles that were not involved in an accident; trained research workers at sampled petrol stations contacted them. Variables grouped into three major subjects, mechanical, environmental and human, were collected. They concern the place where accidents happened, crash dynamics, mechanical characteristics of vehicles, damage produced by the crash, the personal, social and behavioural characteristics of riders, drivers and passengers, and a detailed set of information regarding injuries.

In Italy the MAIDS study was carried out by CIRSS, Centre of Studies and Research on Road Safety of the University of Pavia, including about 900 road accidents involving two-wheels. The present study considers the 200 two-wheel crashes occurred in Italy in the Province of Pavia between 1999 and 2001. For the Italian cases a revision of the injured people's interviews and their clinical records has been made. All the accidents of the survey have been examined considering the traumatic lesion abscribed to the accident to assess a direct causal link between the accident dynamics and the injury pattern. From the MAIDS study the following variables have been considered and analized:
accident configuration;
injury pattern;
body region traumatized (head: face and neck; trunk: thorax, abdomen and pelvis; lower extremities and upper extremities);
injury severity;
impact speed (< 50Km/h; ≥ 50 Km/h).
The most common collision typologies have been grouped into five classes: head-on and side impact collisions (frontal-lateral collision: crash with opposite/perpendicular traffic); side impact accidents (crash with perpendicular traffic); rear-end collisions (crash with a vehicle travelling on the same road in the same direction); single accidents (only one vehicle is involved in the accident); other (special cases: the vehicles in the collision can suffer more than one type of impact).
This distinction has been made to better define the statistical-epidemiological relationship between the lesive pattern and type of accident considering impact speed.
The most frequent types of injuries have also been grouped into three classes: contusions-abrasions (including luxations and sub-luxations, sprains, blunt injuries, abrasions, ecchymosis); fractures-haemorrhages (including the injuries that together with fractures are associated with mono and polidistrectual haemorrhages); internal bleeding (including all injuries involving the fracture of internal organs, not necessarily related to bone fractures).
Injury severity has been coded using the AIS98 (Abbreviated Injury Scale) system. The Abbreviated Injury Scale, decided by consensus, is an anatomically-based system that classifies each injury according to the body region on a 6-point ordinal severity scale ranging from AIS 1 (minor) to AIS 2 (moderate) to AIS 3 (serious) to AIS 4 (severe) to AIS 5 (critical) to AIS 6 (currently untreatable).
The helmet has been given particular attention. It has been analyzed according to the reported damage, classified on the basis of typology and region. A further analysis has been focused on the existing relationship between cranium-brain injury severity and the damage reported on the helmet. Thus, the helmet has been divided into different parts marked by a number shown in the figure below. Each part corrisponds to topographical and anatomical regions. Such regions have beeen grouped into five areas: top; front left; back left; front right; back right. The numbers corrisponding to the above-mentioned regions are the following:
top region: 35, 11, 12, 21, 22
front left: 24, 26, 28, 29
back left: 23, 25, 27
front right: 14,16, 18, 19
back right: 13, 15, 17
Then, for the following analyses, in order to make them more consistent, the helmet regions have been grouped into three sections: top region, left region (front left and back left), right region (front right and back right) and they have been compared to the related injury severity coded in "minor" (AIS1) and "serious" (AIS2-AIS-6).

Figure 1:Region of the helmet



A multiple logistic regression analysis has also been performed to assess the relationship between injury severity and some variables considered to be predictive included in the model: impact speed, crash typology, injured body region and type of injury.

Results

Table 1 provides an overview of the 200 motorcycle riders trauma status according to the six different levels of the AIS coding system. A total of 471 injuries were recorded for 200 riders involved in road crashes. Most riders were slightly injured and only 1.5% of them were seriously injured. This low frequency is explained by the fact that most Italian accidents were registered in an urban area.
The following relevant results have been found out by analyzing the main injury pattern registered according to accident configurations. As regards the accident configurations examined for the 200 Italian cases, head-on and side impact collisions show the highest percentages followed by rear-ends (56% and 16.5% respectively), while the rider' s injuries are mainly localized in lower extremities and cranium (21% and 11% respectively). The most injured anatomical parts turn to be lower extremities and trunk (29.3% and 27.8% respectively), followed by the cranium and upper extremities (22.1% and 20.8% respectively). As for the frequency of the different accident configurations considered jointly with the injury region, lower extremities and trunk are the most injured, followed by the cranium and upper extremities. If single and/or side crashes are considered, trunk and lower extremity injuries show the highest percentages, mainly contusions and abrasions. Fractures and haemorrhages are lower in this accident typology and they are mainly localized in the cranium and upper extremities. As to frontal-lateral accidents, contusions and abrasions result to be more frequent, followed by fractures and haemorrhages localized in lower extremities and trunk and, to a lower extent but with approximately overlapping percentages, in the cranium and upper extremities. As to single accidents, the injury pattern is quite the same as the one above mentioned. In particular, if no fractures are reported, thorax-abdominal injuries have the highest percentages. In case of fractures, injuries are mainly localized in the pelvis region. As to rear-end collisions, contusions and abrasions show the highest percentages in the trunk and lower extremities, followed by the cranium and upper extremities. In rear-end, single and other crashes, haemorrhagic lesions caused by the damage of internal organs are not significantly reported. Anyway, haemorrhagic lesions are almost exclusively reported in head-on and side impact collisions (Tabb.2-3).
If impact speed is considered, the most frequent crash typology is the frontal-lateral followed by rear-ends which, for speed $\geq$ 50Km/h, show the same percentage as side crashes. If speed is < 50Km/h, side crashes and single crashes have approximately the same frequencies (Tab.4).
If the injury region and impact speed are jointly considered, for speed above and below 50Km/h, the most injured anatomical regions are lower extremities and trunk respectively, followed by the cranium and upper extremities (Tab.5).
Besides, as regards the frequency of injury pattern by impact speed, both above and below 50Km/h, contusions and abrasions turn to be higher, proportionally followed by fractures and haemorrhages which, if speed is $\geq$ 50Km/h, are slightly less than half of all injury patterns (Tab.6).
Finally, the analysis of the relationship between the helmet damaged sections and severity of brain lesions has pointed out that there is no statistical significant relation ($p>0.05$) between the two variables considered (Tab. 7). Moreover, it is important to say that 89% of riders wore the helmet.

The logistic analysis (Tab.8) highlights that injury severity is highly associated with impact speed, regardless of the accident configuration (OR = 3.6; $p < 0.01$). If the injury pattern is taken into account, fractures and haemorrhages play a considerable role in determining injury severity, while as regards injured body regions, upper extremities turn to be the most traumatized anatomical regions (OR = 11.41; $p< 0.001$).

Discussion

The analysis of the relationship between injuries and two-wheel crashes has allowed to link the various injury patterns to the different accident configurations.
Regarding the injury pattern, there is a clear high percentage of contusions and abrasions immediately followed by fractures and haemorrhages. The most frequent crash configuration, considered that most accidents occurred in an urban area, is the frontal-lateral collision, followed by rear-ends, side crashes and single crashes.
If the injury region and injury pattern are jointly analyzed, the cranium and lower extremities turn to be more traumatized with fractures and haemorrhages, while the trunk and upper extremities suffer more from contusions and abrasions. If, on the contrary, the injury region is seen in relation to the accident, the trunk and lower extremities are the most frerquently traumatized anatomical regions,
followed by cranium and upper extremities, with no significant differences among the various accident configurations.
The relationship between the injury pattern and accident configuration shows a high percentage of contusions and abrasions followed by fractures and haemorrhages, respectively in frontal-lateral crashes, rear-ends and single accidents. Internal bleeding has been reported almost exclusively in frontal-lateral collisions, often together with concealed lesions caused by lacerations. On the basis of such evidence, it seem reasonable to say that frontal-lateral crashes are potentially the most dangerous collisions. Thus, it is advisable to plan, in such cases, clinical exams for an early diagnosis of possible internal lesions.
Speed does not significantly affect the elective distribution of the lesive pattern and turns to be almost independent of the different accident configurations.

Conclusions

The analysis carried out owes much of its importance to the unique availability of data sets coming from a database of an ad hoc study. It throughly investigated all the accident features related both to the driver's health consequences and to the collision dynamics.
Some relevant conclusions can be drawn from the results.

- Injury severity is highly associated with impact speed, regardless of the accident configuration.
- Injury patterns characterized by internal bleeding are mainly linked to frontal-lateral collisions, above all in urban areas. Therefore, considering the high frequency of such injury pattern, frontal-lateral collisions, even if speed is less than 50 Km/h, are likely to cause concealed lesions which may be fatal.
- Contusions and abrasions, localized mainly in the trunk and lower extremities, are primarily associated with single crashes or rear-ends. If the trunk is the most traumatized anatomic region, both for contusions-abrasions and fractures-haemorrhages, single and side collisions are the most frequent accident configurations, even if speed is less than 50 Km/h.
- In case of contusions-abrasions associated with fractures-haemorrhages localized not only in the trunk but also in the cranium and lower extremities, frontal-lateral accidents are the most frequent accident configurations, even if speed is less than 50 Km/h.
- In case of lesions involving different anatomic regions, the pattern may be ascribed to single and other types of accidents, above all if the cranium and upper extremities are injured.

Such evidence may be useful to plan adequate actions on road safety education, train health operators dealing with road emergencies and train police forces in charge of road safety.

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Table 1 – Distribution of injuries based on the AIS98 code.
No of injured people and No of injuries

		Injury severity (AIS)						
		1	**2**	**3**	**4**	**5**	**6**	Total
Injured people	n	136	36	13	3	9	3	200
	%	68.0	18.0	6.5	1.5	4.5	1.5	100.0
Injuries	n	367	58	30	3	10	3	471
	%	77.92	12.31	6.37	0.64	2.12	0.64	100.0

Table 2 – Frequencies of accident configuration by injury region

Injury region	**Accident configuration**					Total
	Head-on and side impact	Side	Rear-end	Single	Other	
Cranium	57	13	18	12	4	104
	21.2%	24.1%	22.2%	23.1%	26.7%	22.1%
Trunk	71	16	25	14	5	131
	26.4%	29.6%	30.9%	26.9%	33.3%	27.8%
Upper extremities	56	11	16	12	3	98
	20.8%	20.4%	19.8%	23.1%	20.0%	20.8%
Lower extremities	85	14	22	14	3	138
	31.6%	25.9%	27.2%	26.9%	20.0%	29.3%
Total	269	54	81	52	15	471
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table 3 - Frequencies of accident configuration by injury pattern

Injury pattern	Accident configuration					Total
	Head-on and side impact	Side	Rear-end	Single	Other	
Contusions-abrasions	178	37	67	38	11	331
	66.2%	68.5%	82.7%	73.1%	73.3%	70.3%
Fractures- haemorrhages	79	16	14	14	4	127
	29.4%	29.6%	17.3%	26.9%	26.7%	27.0%
Internal bleeding	12	1	/	/	/	13
	4.5%	1.9%	/	/	/	2.8%
Total	269	54	81	52	15	471
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table 4 - Frequencies of accident configuration by impact speed

Accident configuration	Impact speed		Total
	< 50 km/h	≥ 50 km/h	
Head-on and side impact	95	12	107
	54.3%	70.6%	55.7%
Side	22	2	24
	12.6%	11.8%	12.5%
Rear-end	31	2	33
	17.7%	11.8%	17.2%
Single	24	/	24
	13,7%	/	12,5%
Other	3	1	4
	1.7%	5.9%	2.1%
Total	175	17	192
	100.0%	100.0%	100.0%

Table 5 – Frequencies of injury region by impact speed

Injury region	Impact speed		Total
	<50 km/h	≥ 50 km/h	
Cranium	89 22.6%	10 18.5%	99 22.1%
Trunk	106 26.9%	18 33.3%	124 27.7%
Upper extremities	82 20.8%	11 20.4%	93 20.8%
Lower extremities	117 29.7%	15 27.8%	132 29.5%
Total	394 100.0%	54 100.0%	448 100.0%

Table 6 – Frequencies of injury pattern by speed impact

Injury pattern	**Speed impact**		Total
	< 50 km/h	≥ 50 km/h	
Contusions- abrasions	287 72.8%	30 55.6%	317 70.8%
Fractures-haemorrhages	100 25.4%	20 37.0%	120 26.8%
Internal bleeding	7 1.8%	4 7.4%	11 2.5%
Total	394 100.0%	54 100.0%	448 100.0%

Table 7 – Frequencies of cranium injuries in rerlation to the damage registered in the region of helmet

	Region of helmet		
	Top	**Left**	**Right**
AIS1	81.3	90.9	71.9
AIS2-AIS6	18.8	9.1	28.1
n	16	11	32

Table 8 – Relationship between injury severity, impact speed, accident configuration, injury pattern and body region: logistic regression model (n = 448)

		OR	IC 95%	P-value
Impact speed	< 50 km/h	1		
	≥ 50 km/h	3.62	1.39-9.41	0.008
Accident configuration	Head-on and side impact	1		
	Side	1.75	0.63-4.52	0.279
	Rear-end	0.85	0.31-2.32	0.751
	Single	0.71	0.23-2.25	0.566
	Other	2.08	0.37-11.72	0.408
Injury pattern	Contusions- abrasions	1		
	Fractures-haemorrhages	92.35	40.08-212.08	<0.001
Body region	Cranium	1		
	Trunk	6.00	2.17-16.57	<0.001
	Upper extremities	11.41	3.82-34.09	<0.001
	Lower extremities	5.93	2.38-14.75	<0.001