CHARACTERISTICS OF OBJECTS STRUCK BY THE HEAD OF MOPED RIDERS OR MOTORCYCLISTS

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ON THE BASIS OF 293 MOPED AND MOTORCYCLE ACCIDENTS involving a head impact, the objects struck by the head have been classified according to their shape and estimated stiffness.

Eight characteristic object parts were classified according to the frequency and severity of the head injuries recorded.

The differences between the type of obstacles hit by moped riders and by motorcyclists were investigated from this standpoint. The distribution of the sites of impact on the head (or helmet) was also given. Cases of multiple impacts were analyzed separately.

These data should help to improve the representative nature of the collision tests to which the two-wheelers' helmets would be submitted. The efficiency of the protection afforded by the helmet is not included in the scope of this study.

METHODOLOGY

The "Two-wheelers" file was opened in 1975 and includes today 365 cases. Initially focused on the study of moped accidents (n = 223) (1)(2)(3), the file has recently been enlarged to include analyses of motorcycle accidents (n = 142). Each case is studied through a collection of accident data: the accident plan drawn up by the police, study of the vehicle and of the struck object, measurements, photographs, analysis, if necessary, of the shell of the helmet, of padding material and restraint system, etc. The obstacles struck by the different parts of the body of the victims and an assessment of the velocity were deduced from analysis of these facts and from collision configurations. A first medical report is provided by the Medical Emergency Unit, and then further details by the hospital record (or the post-mortem examination).

MATERIALS

1. Different kinds of riders - The sample used in this study includes 115 non-helmeted riders and 178 helmeted ones who undergone at least a head impact (Table 1).

	Helmeted	Non-Helmeted
Moped riders	64	103
Motorcyclists	114	12

Table 1 - Types of Riders and Helmet Wearing

2. Severity of injuries - None of the 293 riders involved was uninjured. This resulted partly from a bias in the selection criteria. More than the half of victims had an M. AIS* equal to or greater than 3 (Table 2). 14 % were killed whereas this percentage is only 2 % at the national level (SETRA, 1978).

M. AIS	0	1	2	3	4	5	Killed
Nb. of cases	0	57	78	80	20	16	42 (including 16 non-autopsied people)
Percentage	-	20	27	27	7	5	14

Table 2 - Maximum Abbreviated Injury Scale (M. AIS) of Riders in the Sample

The body segment which is the most severely injured is the head: 47 % of AIS $\geq$ 3 lesions.

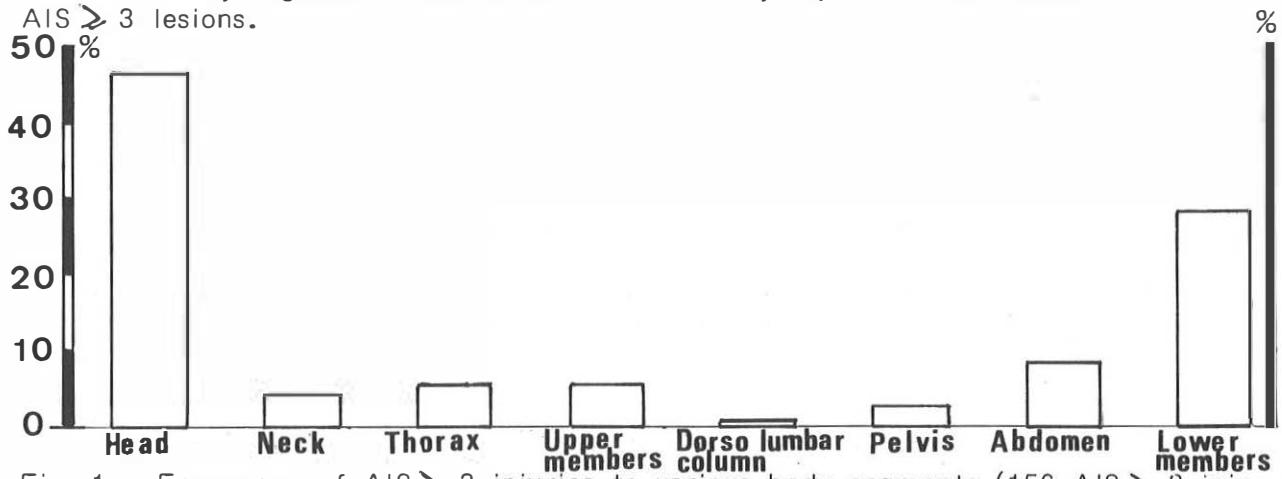


Fig. 1 - Frequency of AIS $\geq$ 3 injuries to various body segments (156 AIS $\geq$ 3 injuries for 142 victims).

RESULTS

1. Obstacles - The moped riders are more frequently involved in collisions with vehicles (77 %) than motorcyclists (63 %). However, the category of vehicle involved in two-wheelers accidents varies from one class to the other (Table 3). In the case of moped riders, 87 % are involved in collisions against a car and 13 % in accidents against a truck or a van. For motorcyclists, the proportions are, respectively, of 65 % and 35 %. The over-representation of motorcyclists in collisions with trucks may be explained by the fact that 17 % of them occurred on motorways where the traffic of trucks is important (Table 4). Motorcyclists are more represented in single accidents than moped riders (respectively 31 % and 16 %).

Table 3 - Obstacles Hit by Two-Wheelers

	Mopeds (167)		Motorcycles (126)	
Cars	111 (67%)		52 (41%)	
Single accident	19 (11%)		16 (13%)	
Fixed and stiff objects	9 (5%)	100%	22 (18%)	100%
Trucks (or vans)	17 (10%)		28 (22%)	
Pedestrians	5 (3%)		4 (3%)	
"2-wheeled" machines	6 (4%)		4 (3%)	

* M. AIS : the AIS of the most severely injured body segment

Table 4 - Accident Location

	Urban area	Rural area
Mopeds	156	11
Motorcycles	95	31*

(*) 22 on motorways

2. Objects struck by the head - Although cars are the obstacles the most frequently hit by motorized two-wheels, they account for only 33 % of objects struck by the head of the riders (40 % and 22 % respectively for moped and motorcycle riders) (Table 5).

Type of Obstacle	Type of Object struck by the Head or Helmet	Moped Riders N	(%)	Motorcyclists N	(%)
Vehicle	. Sheet metal	13	8	4	4
	. Stiff metal element	32	20	12	11
	. Windows and windscreen	17	11	3	3
	. Tyres	3	2	5	4
Others	. Ground	87	54	69	63
	. Fixed, stiff object	7	4	16	14
	. Injuries caused by the two-wheeled machine	2	1	1	1
	Overall	161	100	110	100

Table 5 - Nature and Type of Obstacles Struck by the Head (or Helmet) According to Riders' Category (22 riders who struck their head against an unknown object are not taken into account in this table).

3. Classification of object parts struck by the head (or helmet) of moped riders and motorcyclists - If the stiffness and the shape are taken as criteria for objects struck by the head, eight categories of obstacles can be drawn up (Fig. 2).

The objects of types No. 1,2,3,4 are stiff. A dent or perforation are observed in types No. 5, 6, 7.

The objects of types 4, 5, 6, 7 and 8 are found on vehicles, whereas those of types 1, 2 and 3 are found from ground contacts. There are two kinds of objects: the "Plane": types No. 3, 5 and 6 and the "Corner": types No. 1 and 7.

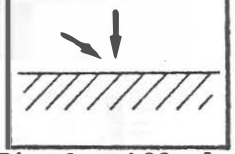
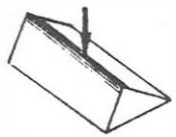
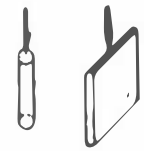
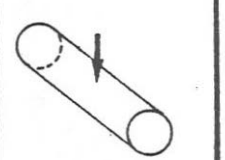
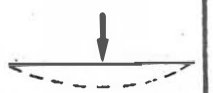
Deformable objects (types No. 5, 6, 7 and 8) are more often struck by moped riders: 36 % (56/155) than by motorcyclists: 14 % (15/108).

"Plane" type objects are struck as often by moped riders: 80 % (125/155) as by motorcyclists: 80 % (86/108).

The proportion of victims striking "Corner" type objects is quite the same for moped riders (13%) and motorcyclists (16%).

4. Frequency and severity of head injuries according to object type - The objects are classified according to the criterion of the sum of the head AIS raised to the cube (*)(fig. 3).

(*) $\sum AIS^3$ takes into account both the frequency and the severity of injuries. Raising the AIS to the cube gives a better idea of the social cost of the injury than does the simple AIS because the increase in this value in function of the severity of the injury is not linear but cubic. The value resulting from the sum makes it easier to compare samples.

	"PLANE"	"CORNER"	OTHERS
STIFF	MP=89 | MC=78 3  Fixed, stiff plane	MP=4 | MC=12 1  Fixed, stiff with a rounded right-angle	MP=3 | MC=1 4  Stiff with area of contact ⟨ 200mm²
			MP=3 | MC=2 2  Fixed, stiff and cylindrical (100 ⟨ Ø ⟨ 200mm)
DEFORMABLE	MP=18 | MC=5 5  Plane surface, deformable, dents noted (sheet metal)	MP=18 | MC=3 6  Windows	MP=19 | MC=5 7  Rounded, deformable metal structure.
			MP=1 | MC=2 8 tyres of the vehicle run over, only

MP=MOPED RIDERS N°=155
MC=MOTORCYCLISTS N°=108

FIGURE 2*: CLASSIFICATION OF OBSTACLES ACCORDING TO THEIR SHAPE AND THEIR STIFFNESS AND ACCORDING TO THE TYPE OF RIDER

* 30 riders are excluded because the obstacle struck is either unknown or unclassifiable. If more than one obstacle is struck, then the one causing the most severe injury is taken into account.

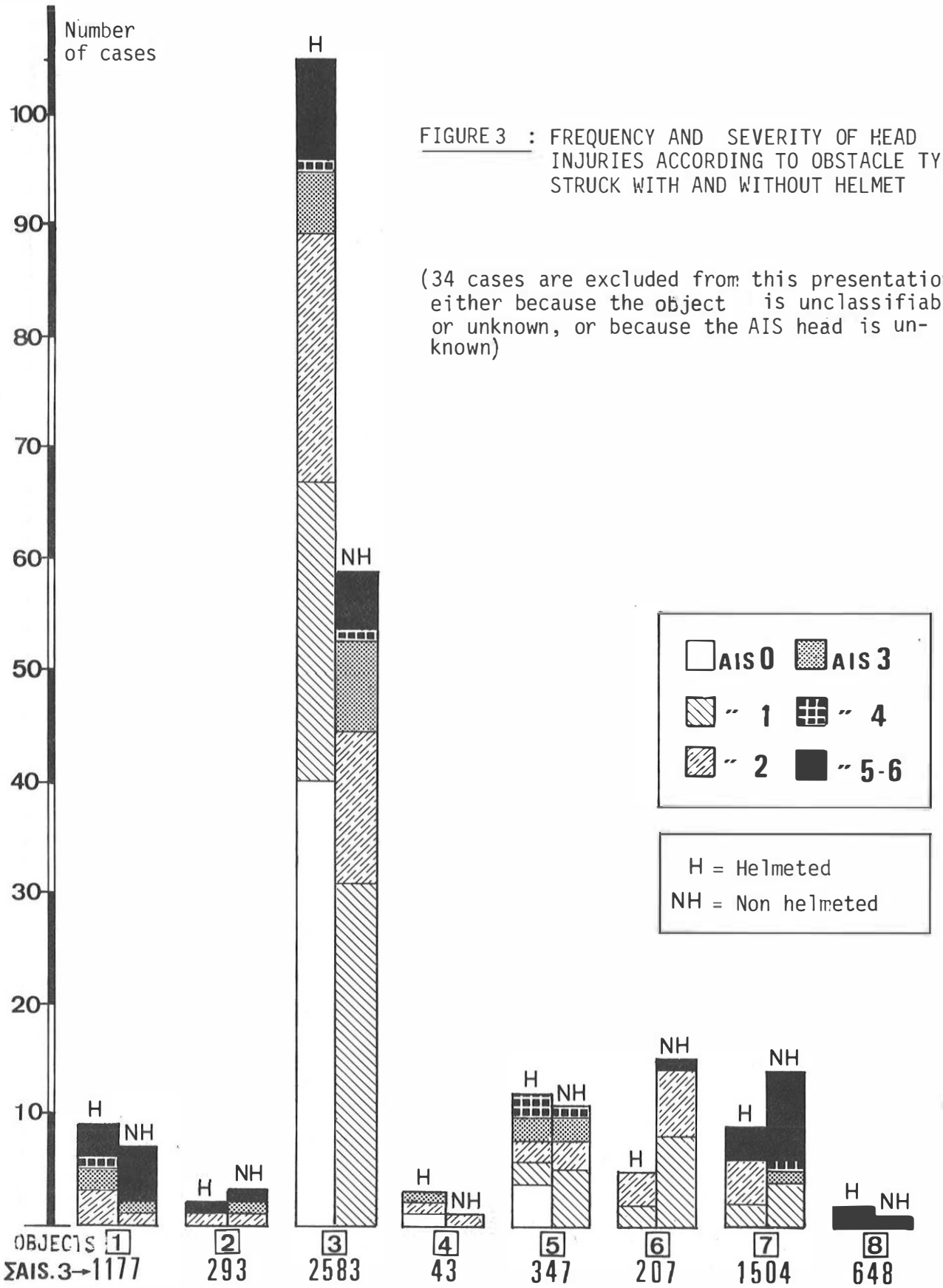


FIGURE 3 : FREQUENCY AND SEVERITY OF HEAD INJURIES ACCORDING TO OBSTACLE TYPE STRUCK WITH AND WITHOUT HELMET

(34 cases are excluded from this presentation either because the object is unclassifiable or unknown, or because the AIS head is unknown)

Out of the 69 head AIS $\geq$ 3 observed, 54 % and 36 % were respectively caused by "Plane" and "Corner" types objects.

- "Plane"-type - fixed and stiff objects (type 3) - give the highest value in terms of Σ AIS^3 (N = 2583). One can notice that the ground is responsible for numerous severe head injuries (29 cases of head AIS $\geq$ 3out of 164 victims, i.e. 18%).

- "Corner"-type is relative to types 7 and 1. The difference between them consists of their stiffnesses and of the radius of their sharp edges. The frequencies of head AIS $\geq$ 3 and the values of Σ AIS^3 for types 7 and 1 are as follows:

	Type No. 7	Type No. 1
. Number of contacts	23	16
. Percentage of head AIS $\geq$ 3	57 %	75 %
. Σ AIS^3	1504	1177

- Run-over of the head (or of the helmet) by vehicle tyres (type 8) are few (3 cases only) but very severe (Σ AIS^3 = 648).

- Objects of type 5 (deformable metal sheet) come in fifth place (ΣAIS^3= 347). 30 % of the 23 cases have a head AIS $\geq$ 3.

- Three out of the five head contacts against a stiff cylindrical object part (type 2) have an AIS $\geq$ 3.

- Head injuries due to window and windscreen impacts (type 6) are generally slight, except one case of head AIS 5. In this case, the head of the non-helmeted moped rider (55 years old) hits the rounded part of the laminated windshield near the windscreen frame.

- Object parts with a surface area less than 200 mm2 (type 4) are very rare. The most serious injury (AIS 3) observed with this type of object concerns a helmeted user who sustained a contact of the head against the pin of a windshield-wiper of a car.

5. Sites of impact to the head (or helmet) for each category of rider - Table 6 shows the distribution of sites of impact for each category of riders according to the four following areas of the head (or helmet):

	Fronto-facial	Lateral	Posterior	Top	Total
Moped riders	90 (56%)	40 (25%)	27 (17%)	4 (2%)	161 (100%)
Motorcyclists	44 (36%)	45 (36%)	30 (24%)	5 (4%)	124 (100%)

Nota: 8 victims are excluded from this table because the impact area is unknown. In the case of multiple impacts to the head (or helmet), only the area of impact which produced the greatest injury is taken into account.

Table 6 - Location of Head (or Helmet) Impacts

The fronto-facial area appears to be the most frequently struck: 56 % in moped riders and 36 % in motocyclists. Impacts to the top of the helmet are very rare, both for moped riders (2 %) and for motorcyclists (4 %).

6./ Multiple Impacts - a) multiple impacts at different sites - We find a higher proportion of multiple impacts among motorcyclists (37 %) than among moped riders (24 %). This difference can be explained partly by the different speeds between mopeds and motorcyclists.

	Single Impact	Multiple Impacts
Moped riders (n = 167)	127	40
Motorcyclists (n = 126)	79	47

Table 7 - Number of Impacts According to the Category of Users

b) Multiple impacts at the same site - Despite exhaustive examination of the helmets, identification of multiple impacts remains difficult. In fact, it is only possible when the types of damages are different. Only 3 out of 293 (1 %) are observed in the sample. All of them are motorcyclists. They suffered important slides on the ground (from 10 to 25 meters long). By way of comparison, SNIVELY (4), in a study including 360 motorcyclists notices 14 cases of multiple impacts to the same site (3,9 %).

DISCUSSION

The importance of a study trying to classify types of objects struck by the head (or helmet) of two-wheelers is to define better what shock absorption tests for the approval of crash helmets should be like to represent, as truly as possible, the risks presently encountered on the road. The main results concern the shape of objects, the frequency of double impacts on the same site and the frequency of impact point on the head (or helmet). About these three points, there are some noticeable differences between what is presently observed and what is laid down in both French regulation (NF 572-302) and the planned European one (Standard ECE 22, amendment 2).

(1) The shape of objects - Regulations consider three types of objects: the plane, the hemisphere and the striker. Our results highlight that the plane is indeed well represented in our sample: 80 % of the objects struck and 54 % of the AIS head $\geqslant$ 3. However, the hemisphere and the striker do not seem very realistic because no object of this type has been noticed in accidents. The existence of such standard tests had consequences on technological choices for designing crash helmets which may not result in safety improvement. The "corner"-type does account for 15 % of objects struck and 36 % of those with an AIS head $\geqslant$ 3. So, it seems to be necessary to test helmets against a "corner"-type object which is in fact dangerous and widespread. Finally, using both the "plane" on one hand and the "corner" on the other hand for shock-testing would be representative of 95 % of the objects struck and 90 % of serious and fatal injuries (AIS head $\geqslant$ 3).

(2) Multiple impacts on the same site - Both French regulation and Std 22 amended require tests on the same site*. We observed only 3 victims out of 293 who undergone such impacts. The consequence of this test, in fact, consists of increasing the stiffness and the thickness of the shell and hence the weight and inertia of the helmet. The usefulness of double impact to the same site would appear to be slight, and even unfavorable. That should be kept in mind for future regulations.

(3) Sites of impact - The head areas most frequently impacted are in decreasing order, the frontofacial area (47 %), the lateral area (30 %), the posterior area (20 %) and the top (3%). On the one hand, the French regulation concerns two test areas: the lateral area and the top of the helmet. The lateral test is easily justified (30 % of impacts), but test on the top of helmet seems rather unrealistic. On the other hand, the planned European Standard would take into account the both

* to the same area in the French regulation and within a radius of 20 mm in Std 22 amended.

areas most frequently struck on the shell of the helmet: three series of experiments are planned on the frontal and lateral areas and another one is left to the choice of the Laboratory. However, nothing is laid down concerning the face when 70 % of fronto-facial impacts included facial injuries. This fact reminds the need to improve the helmet in this area.

CONCLUSION

In a survey of 293 accidents involving moped riders and motorcyclists who sustained head impacts, the types of struck objects and the head (or helmet) impact areas were classified in decreasing order for frequency and severity of head injuries.

The results highlight that objects of "plane" and "corner"-types are the most representative of two-wheelers' head impacts in road accidents.

The most frequently struck areas of the head (or helmet) are the fronto-facial area (47%) and the lateral area (30%). The top of the head (or helmet) is rarely struck (3%).

Multiple impacts to different sites vary in frequency according to the category of riders: 37 % of motorcyclists and 24 % of mopeds. Multiple impacts to the same site are very rare.

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