SAFETY OF MOPEDS. ACCIDENT SURVEY AND RIDER INJURIES (*)

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ABSTRACT

This report presents:

- on the one hand, a survey of national data on moped accidents which shows that it is a major problem in France,
- on the other hand, the results of a multipurpose investigation during 1976 in the Hauts de Seine Department which consisted in analysing obstacles collided with collision configurations and moped rider kinematics.

Frequency, severeness and location of injuries are studied as a function of their causes. The site of cranial-facial impact is given as well as the reasons of the low effectiveness of moped rider helmets at the present time in France.

INTRODUCTION

The increased improvement of safety on French roads over the past few years has benefited the various categories of users in an uneven way. Users of "two-wheelers" are those who have benefited the least (nothing contributed by the safety belt and not as much gained by reducing speed limits as for pedestrians). This is also true as the period in question coincided with the revival of the "two-wheelers".

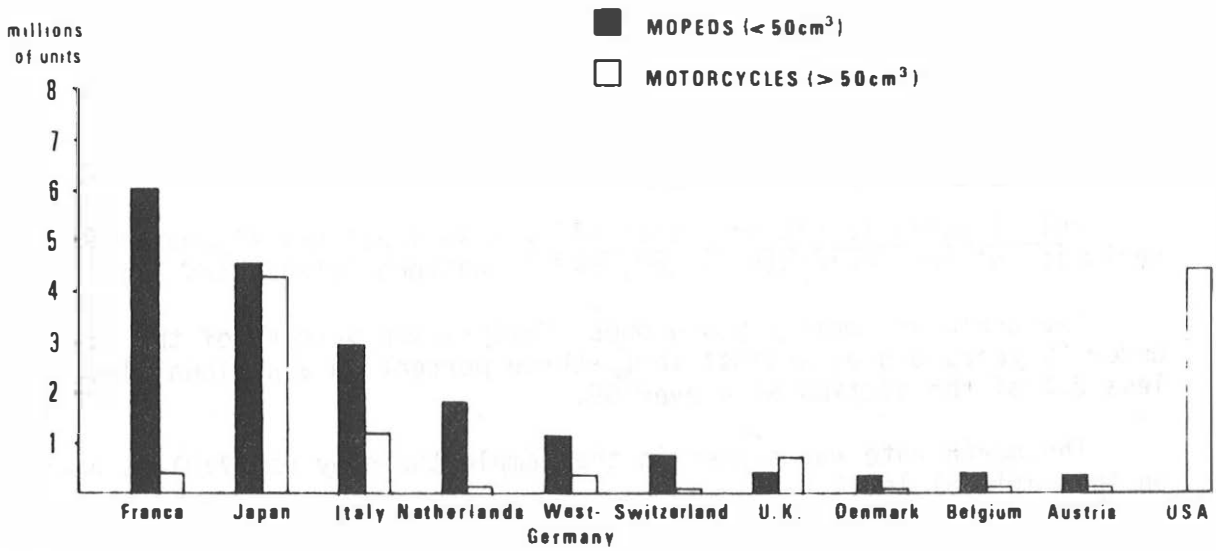
But "two-wheelers" are very heterogenous in nature particularly because of their speeds. And so, moped accidents should be specifically analysed.

Situation of Moped Riders Within All "Two-Wheeler" Accidents - In France, there were 2319 killed and 80,369 seriously injured in 1974 (1). Mopeds account for as many victims as pedestrians, cyclists and motorcyclists combined. Serious accidents on mopeds (killed plus seriously injured) represent 68 % of serious victims of "two-wheelers". This situation is of course related to the extent of the moped fleet in France, which in 1973, reached over 6 million units, in other words, 94 % of the total motorized "two-wheeler" fleet.

(*) study carried out within the framework of the contract signed with the Ministry of Equipment

Figure 1 depicts the moped fleet compared to the "two-wheeler" fleet of more than 50cm^3 in the countries with a high degree of motorized vehicles.

FIGURE 1 : MOPEDS AND MOTORCYCLES ON THE ROAD BY COUNTRY – 1973



	France	Japan	Italy	Netherlands	West-Germany	Switzerland	U.K.	Denmark	Belgium	Austria	USA
number of mopeds / 1000 inhabitants	114	43	50	134	16	107	8	87	44	62	–

sources (2) Japan (3) USA (4)

The "two-wheeler" engine-equipped fleet is strongly dominated by mopeds in France and in Holland. Inversely, in these two countries alone, there is a high proportion of "two-wheelers" of over 50cm^3. This particularly concerns the United States and to a somewhat lesser extent, Great-Britain. Japan has a large fleet of "two-wheelers" which is comparable in each category. The highest rates of moped owners per 100,000 inhabitants are found in Holland (134), France (114) and Switzerland (107).

Also it must be mentioned that laws concerning mopeds are slightly different from one country to another. Certain countries such as Federal Germany, Holland or Switzerland have a "low range" type moped called "light moped" whose main characteristic is not being able to exceed 20.25 or 30 kilometers per hour depending on the country in question.

In France, officially, only one type of moped exists which has the following characteristics:

- 1 : cubic capacity under 50cm^3
- 2 : speed limited by construction to 45 km/h
- 3 : fitted with pedals
- 4 : mopeds are not licensed

Furthermore, minimum age required to drive a moped is 14 years old.

Survey Equipment - The investigation was done in 1976 and not only concerned moped riders sent to the hospitals at Garches and Poissy but also the seriously injured moped riders who had accidents in the Department of Hauts de Seine, which is to the West end of Paris.

The sampling includes 178 moped riders of which were 7 passengers, i.e. 13 killed, 160 wounded and 5 uninjured. Fifty-five of these individuals were wearing helmets. Apart from the measurements and photos taken of all the elements involved in the accidents, the helmets were recovered in 22 cases and enabled a very thorough examination to be made (including cross sectioning and disassembly).

MAIN RESULTS

1 - Characteristics of accidents

Relationship to national statistics - We shall briefly mention the characteristics of our accidents as compared to national statistics (1).

The users are mainly young ones. Forty-seven percent of the victims were under 20 years old as against forty-three percent on a national level. Nonetheless 3 % of the victims were over 65.

The death rate was higher in the sample taken by us (7.0) as against (2.8) on the national level.

Intersection accidents are also very numerous for the sample taken by us as compared to the national level (over 50 % of the cases).

On the other hand, we can account for fewer accidents outside of towns (5%) as compared to the national level (18%). According to national statistics, the accidents account for 46 % of deaths (but in our survey 3/13 killed).

Night time accidents which are shown with respect to the extent of moped traffic represent 27 % of the cases in our investigation as against 24 % on a national level.

2 - Actual results taken from survey

Kinematics of riders - The seriousness of injuries is greatly influenced by the kinematics of the riders who can be split up into four different categories.

- with no slipping away: case where the speed variation of the rider is completely dissipated against the obstacle.

- with slipping away: case where the rider is subjected to initial speed variation on obstacle and then, because of relative speeds and configurations, continues past along initial course, which is often slightly modified by the initial impact. The moped undergoes a speed variation in collision with the obstacle, against which, in the majority of cases, it comes to a standstill.

- falls (including side-swipe with moving obstacles) : case of rider being put off balance due possibly to light collision (in terms of dissipated energy) with the obstacle.

- hitting when on the ground (including run-over by vehicles).

Figure 2 gives a schematic diagram of the various categories:

FIGURE 2: KINEMATICS OF MOPED RIDERS

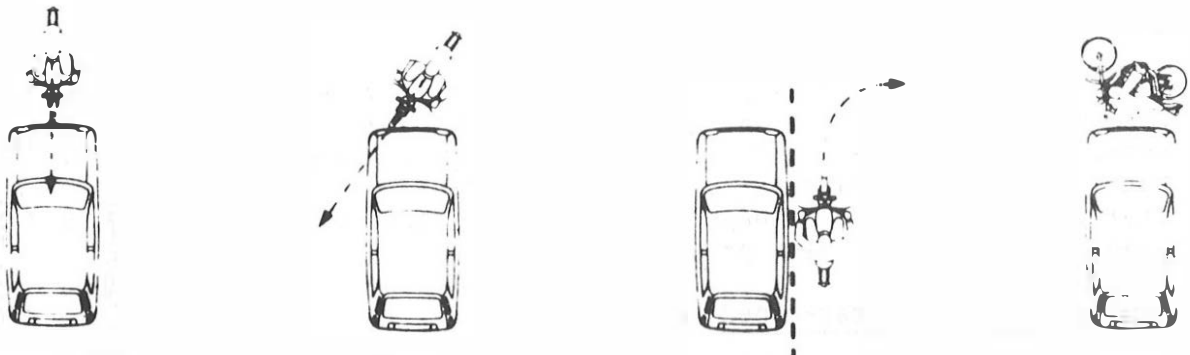


TABLE 1: FREQUENCY, GRAVITY AND KINEMATICS OF MOPED RIDERS IN RELATION TO OBSTACLES

		KINEMATICS				TOTAL		MEAN ISS*
		WITH NO SLIPPING AWAY	WITH SLIPPING AWAY	SIDE - SWIPE + FALLS	RUN OVER		%	
OBSTACLES	CAR	67	44	20	1	132	74	8.9
	GROUND (FALL)			18		18	10	7 2
	TRUCK	3		3	3	9	5	12
	FIXED OBSTACLE	5		1		6	3	17.2
	VAN	6				6	3	18.7
	PEDESTRIAN			4		4	3	7
	MOPED			3		3	2	5
	TOTAL	81	44	49	4	178		
	%	46	25	28	1		100	
	MEAN ISS*	12,8.	6.3	6.8	17.3			9 4

*ISS : Injury Severity Score

Almost half the cases (46%) are with no slipping away. This kinematic is twice as serious (Injury Severity Score (ISS)(5) average= 12.8) as those collisions with slipping away of rider or that falls (respectively the average ISS is 6.3 and 6.8).

The obstacles collided with (see Table I)

Frequency - The breakdown of the obstacles hit by riders in the sample is no different from the one observed at the national level. In seven cases out of ten this concerns private cars.

Seriousness of accidents - Measured by the average ISS, the highest degree of seriousness is observed for collisions against vans and cab-over-engine vehicles (average ISS = 18.7) and against trucks (average ISS = 17.2). The rates are twice as high as for passenger cars (average ISS = 8.9). The aggressivity of "rectangular" shaped vehicles with respect to pedestrians and two-wheelers has already been proved (6).

Configurations of "car-moped" collisions

Table II shows all configurations of collisions between cars and mopeds and, at the same time, gives the frequency and seriousness according to the type of kinematics, the speed categories for the moped and car covered by 50% of the cases for a single configuration.

Considering Table II, it can be seen that a collision of the "moped side-car front" type with no slipping away of moped rider is responsible for 26% of all the ISS (total which takes into account the frequency of cases and seriousness of injury). This characteristic configuration of intersection accidents occurs in 17 % of the cases, which is foremost as far as frequency is concerned and in the second category for severity (average ISS = 14.2) preceded only, as far as intrinsic severity is concerned, by the configuration involving "moped rear - car front" with no slipping away of the moped rider (average ISS = 18.5). This very deathly collision is characteristic of accidents occuring outside towns, particularly at night. It brings to mind the interest in cycling tracks outside towns and the increase in rear visibility for mopeds.

However, it is necessary to observe that, for a few cases of night accidents, the lighting equipment was not in operational condition.

The head-on and semi head-on configurations with no slipping away of the rider is serious (average ISS = 11.8) and frequent (10%).

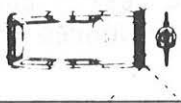
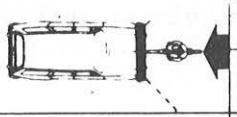
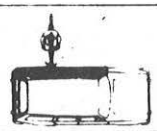
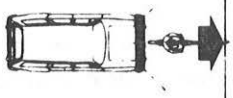
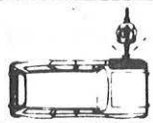
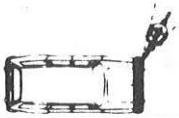
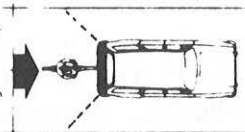
Side-swipes are also very frequent (15%) but not very serious (average ISS = 5.6).

Violence of collisions

Information about the violence of collisions is undoubtedly a very ticklish subject. Taneda (3) shows that in a sample of moped riders, 95 % had accidents at under 40 kilometers per hour. This indication of speed only does not take into account the severity. The violence largely depends on the speed of the vehicle collided with and therefore it is closing speed which has to be estimated based on analysis of the vehicle speeds. The methodology used for

estimating the speed of the car and moped is not very different from the techniques used for pedestrian accidents or those used by Whitaker (7) for two-wheelers, i.e. braking marks, throwing distance, reports by drivers and witnesses.

TABLE 2 BREAKDOWN OF CAR-2WHEELERS COLLISION CONFIGURATIONS BY TYPE. SEVERITY AND SPEED

PERCENTAGE ΣISS / ΣISS TOTAL (from col B)	PERCENTAGE FREQUENCY (from col A)	ORDER OF DECREASING MEAN GRAVITY	COLLISION CONFIGURATION	WITH SLIPPING AWAY	N (col.A)	MEAN ISS	ΣISS (col.B)	50% of collisions take place at speeds thought to be included within the following range (in km/h) MOPED	CAR
26	17	2nd			22	14,2	312	12 - 22	23 - 48
5	5	7th		X	7	9,3	65	21 - 27	7 - 21
14	10,5	3rd			14	11,8	165	20 - 28	13 - 35
10	10,5	8th		X	14	9	126	18 - 32	10 - 28
9	15	12th	SIDE-SWIPE	—	20	5.6	112	—	
7	6	5th			8	10,9	87	18 - 32	12 - 30
1	4	15th		X	5	3	15	18 - 34	8 - 28
6	3	1st			4	18,5	74	9 - 21	51 - 59
	1	15th		X	1	3	3	15 - 25	25 - 35
5	4	4th			5	11,4	57	15 - 25	7 - 29
3	4	10th		X	5	7,4	37	23 - 33	7 - 33
5	4	6th			6	9,5	57	15 - 25	7 - 29
2	4	13th		X	5	4,4	22	23 - 33	7 - 33
3	6	14th			8	4	32	17 - 28	0
3	5	11th		X	7	5,7	40	25 - 35	0 13
1	1	9th	RUN-OVER	—	1	8	8	—	
100	100	—	TOTAL	—	132	9,2	1212	—	

These techniques remain insufficient. The study of experimental collisions carried out in the Laboratory of the Peugeot-Renault Association (8) has enabled new methods to be developped, particularly by comparing vehicle deformations, the actual and experimental comparison of the kinematics of the various

elements involved and greater accuracy in evaluating the throwing distances. Reconstituting actual accidents remains the best way of verifying these evaluations.

Estimates according to speed group for the moped and car are given and cover fifty percent of the cases for a specific configuration.

The configuration for the "moped side-car front" with no slipping away occurs at a speed of 16 kilometers per hour for the moped and 38 kilometers per hour for the car. The degree of seriousness is less severe with slipping away and when these speeds are different, higher for the moped (24kilometers per hour) and lower for the car ($\leq$ 20 kilometers per hour).

When the car and the moped follow relatively parallel paths (in identical or reverse direction), the seriousness of cases with no slipping away is closely linked to the closing speed of both vehicles. The closing speed is included between 40 and 50 kilometers per hour for configurations with high degrees of severity (head-on and semi head-on or "moped rear - car front") and from 20 kilometers per hour for collisions with a low degree of severity such as for the "moped front - car rear" type.

One cannot help but notice the analogy between pedestrian accidents and configurations concerning the front part of the car with no slipping away of the moped rider (46 cases, i.e. 26 % of the total sample taken).

INJURIES (see figure 3)

Breakdown per body area according to degree of severity

Minor injuries: (AIS 1) (9): 29%, 26%, and 25% of injuries affect respectively the lower parts of the body, the head, and the upper parts of the body.

Moderate injuries: (AIS 2-3): 37%, 32%, and 13% of these injuries affect the lower parts of the body, the head, and the upper parts of the body.

Severe and fatal injuries (AIS 4-5): 70% and 18% of these injuries affect respectively the head and the abdomen.

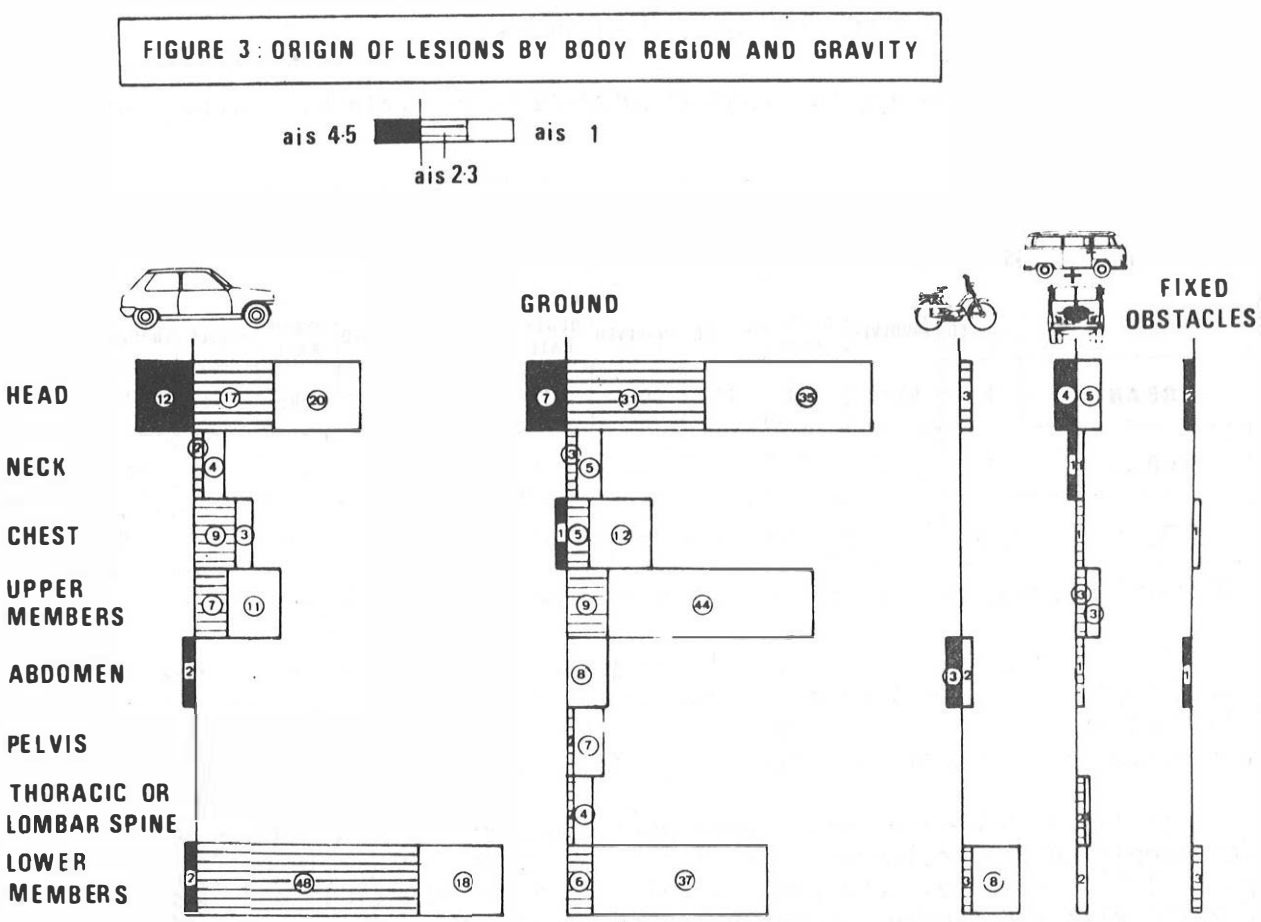
Causes of injury

Minor injuries: these occur on the ground in 65% of the cases and mainly affect the limbs.

Moderate injuries: there are 157 of these. It can be seen that 83 of them were caused by impact against the car (of which 48 through fracture of lower limb by hitting against bumpers) whereas 58 moderate injuries occur on the ground and affect the head and shoulder area.

Severe or fatal injuries: 12/25 head injuries of AIS 4-5 are caused by impact against car (9/12 against windshield frame). Out of 6 severe or fatal abdominal injuries, half were due to the two-wheeler itself and especially to the handlebars. Whitaker (7) makes the same remark (on a sample of 425 involved) and also reports that the moped actually gives rise to very little injury.

FIGURE 3 : ORIGIN OF LESIONS BY BODY REGION AND GRAVITY



The helmet and head-face injuries

Reminder concerning regulations and standards for moped riders' helmets - Helmets were made compulsory outside towns in December 1976. Also helmets sold in France are to meet the requirements of the French Standard (NF) which for absorption of energy required impact damping at the top of the head. This standard is being modified.

Lessons learned from studying national statistics - Valeix (10) analysed moped accidents occuring in 1974 concerning 10,927 cases with helmets and 65,597 without. The main results are as follows:

- death rate of cases without helmets 2.7 (1774/65597) slightly higher than that for cases with helmets which is of 2.4 (264/10,927). The test of χ^2 shows that the difference is not significant at the 5% level of significance (χ^2 = 2.91). Therefore it is not possible to talk about the effectiveness of helmets worn by riders in order to reduce the risk of death.

- Table III shows the influence of age, and where the accident took place on the death rate and according to whether helmet was worn or not.

TABLE 3 : INFLUENCE OF AGE AND ACCIDENT LOCATION ON THE DEATH RATE VERSUS HELMET USE

	WITH HELMET						NO HELMET					
	≤ 25 YEARS			>25 YEARS			≤ 25 YEARS			>25 YEARS		
	KILLED	INVOLVED	DEATH RATE	KILLED	INVOLVED	DEATH RATE	KILLED	INVOLVED	DEATH RATE	KILLED	INVOLVED	DEATH RATE
URBAN	58	5871	0 98 ①	71	3054	2 32 ②	356	33505	1 06 ③	616	23267	2 64 ④
RURAL	62	1207	5 1 ⑤	73	795	9 18 ⑥	218	4186	5 2 ⑦	584	4639	12 58 ⑧
	120	7078	1 69	144	3849	3 71	574	37691	1 52	1200	27906	4 3

χ^2 test : not significant for ①③ : 0,26 ②④ : 0,81 ⑤⑦ : 0,32 significant for ④⑧ : 5,94 ($0,02 < p < 0,01$)

It can be seen that the effectiveness of helmets worn in France in 1974 did not reduce the risk of death for 93% (5434/76524) of the individuals wearing helmets, i.e. in other words for victims with helmets involved in town accidents or in country accidents when involving young persons.

It can also be seen that among people under 25 years old the death rate for people wearing helmets is greater (1.69) than for people not wearing helmets (1.52). This may seem paradoxical and can be explained only by the increased risk and greater violence of the accidents which riders wearing helmets and under 25 years of age are involved. The seriousness of the accident is not compensated by effectiveness of the helmets.

Results of our investigation

The very disparaging remarks in regards to present day helmets have been confirmed by the cases in our own survey. We shall not go back on this subject but we notice that in no case was the helmet responsible of head and neck injury. We shall examine the incidence of approach to the sample of the cases observed and the reasons for the low rate of the effectiveness of the helmets studied. We shall end by evaluating the efficiency to be expected from an approved helmet.

- the biases: The most difficult one to eliminate is that cited by Ashton (11). How is a rider wearing a helmet to be considered when he comes out unharmed after a fall and for which the helmet was examined. This person will probably be excluded from all hospital and police statistics.

A second bias concerning violence can be studied in our example. The percentage of AIS ≥ 2 non head injuries is clearly higher for people wearing helmets (78%) than for people not wearing helmets (59%). It can be inferred that the violence of collisions in which helmets are implicated is greater, which to a large extent explains why the death rate is only slightly different than for people not wearing helmets. Our sample which is too small numerically will not allow an in-depth study on the efficiency of helmets with the same violence.

- Reasons why the helmets studied are less effective (13 "bowl shaped", 31 "jet style", 11 "full face" type).

1 - The shell does cover the most frequently affected parts of the head. As shown in figure 4*, the locations of impact taking all cases of seriousness into consideration, are above all in the forehead area (77% of cases). But the greater degree of injury severity, the more the places of impact are found in the side area. Out of 23 serious fatal injuries to the head (AIS 4-5) with indications of localizations, 12 were in the "side" area, 8 in the forehead area, 3 toward the back of the head and on top of the skull. Protection of the temporal areas (18% of injuries, 35% of serious injuries AIS 4-5) is not insured by "bowl" type helmets. Also, strictly facial impacts (25%) are not protected (or not insufficiently so) by present day helmets.

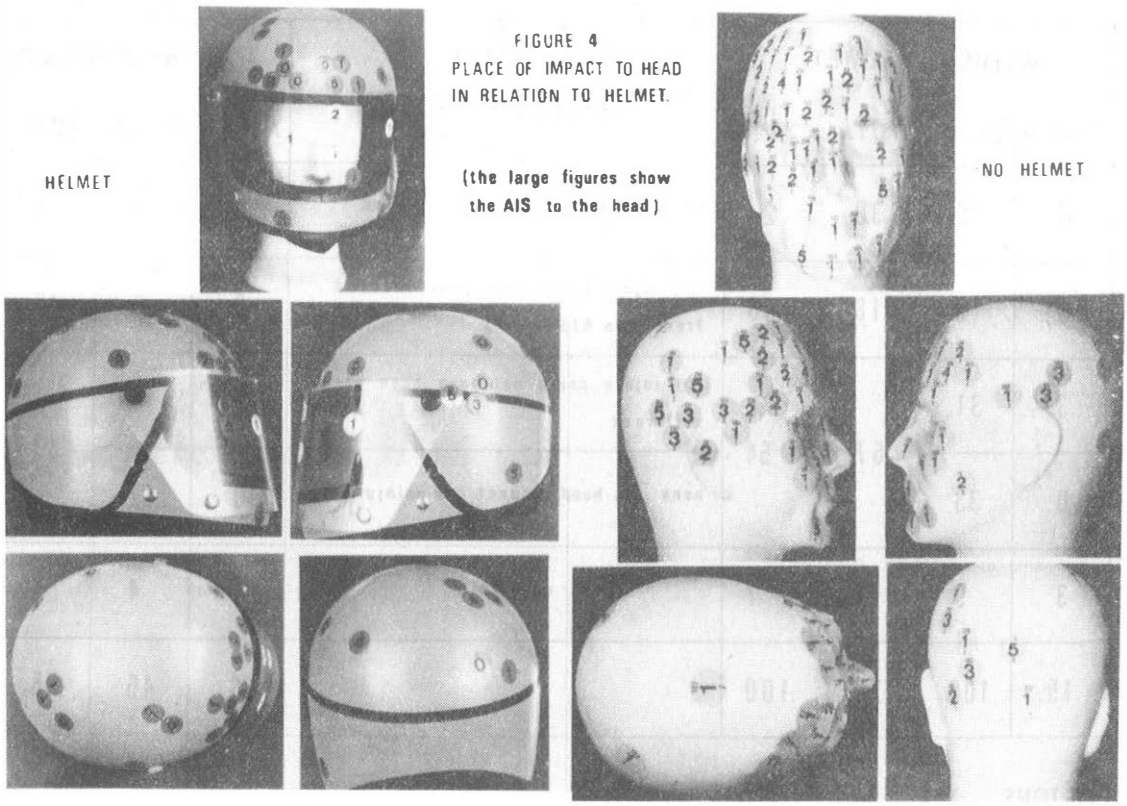


FIGURE 4
PLACE OF IMPACT TO HEAD IN RELATION TO HELMET.

(the large figures show the AIS to the head)

(*) based on the 126 first cases.

2 - The majority of the helmets complied to the French standard requiring protection by straps to the top of the head. The insufficiency of the damping which aims at protecting a single point, is obvious. Absence of quality shock-absorbing material was not observed in almost all cases. Half of the helmets had no absorbing material.

3 - Loss of the helmet occured in 14 cases/55 (25%) among which half before the main impact. This resulted in the following; 3 AIS 4-5 and 2 AIS 2-3 out of 14 cases. The most frequent causes are failure of the fastening system (4 cases) or "shell-liner" connection (3 cases), loose chin strap (3 cases), sliding off of chin piece in addition to loose buckling (2 cases).

- Estimate of gain to be expected from improved helmet

The new French standard is to enter in force in December 1977 (12) and foresees an increase in protected surfaces especially in the temporal area, and absorbing material about 20 mm thick on all areas covered by the shell as well as improved strength of chin strap.

Table 4 shows that a good helmet would make a notable improvement for 39% of unhelmeted moped riders and increase protection for 31% of helmeted moped riders.

Table 4: Helmet effectiveness estimated for 123 moped riders without helmet, and estimation of supplementary effectiveness afforded by an helmet in conformity with the futur standards for 55 helmeted riders

WITHOUT HELMET				HELMET EFFECTIVENESS	WITH HELMET			
AIS 4-5	AIS ≤ 3	TOTAL	%		AIS 4-5	AIS ≤ 3	TOTAL	%
0	30	30	24	the injury could have been avoided	0	5	5	9
9	9	18	15	the injury could have been reduced from two AIS levels	6	6	12	22
3	31	67	54	the injury could not have been very different	3	18	33	60
0	33			none (no head impact and uninjured)	0	12		
3	5	8	7	uncertain	1	4	5	9
15	108	123	100		10	45	55	100

CONCLUSIONS

1 - In France accidents with mopeds constitute a major problem (80,000 victims, in other words as many as other "two-wheelers" and pedestrian victims together) due to their large number.

2 - Over eighty percent of accidents occur in towns (55% of deaths). In more than half of the cases, these accidents happen at cross-roads and in a

quarter of cases at night (over-representation in relation to the traffic).

3 - The most important collision configuration consists of the "moped side -car front" type with no slipping away of rider from the car (26% of all the AIS - 17% of the collisions, in second place in order of severity).

4 - The ground is the cause of minor injuries (AIS 1) in 65% of cases. The car is the cause of over three quarters of fractures occuring on the lower limbs (bumpers) and half the serious or fatal injuries. Out of 25 head injuries of AIS 4-5, 12 are caused by the car (of which 9 against windshield surround). Out of 6 abdominal injuries AIS 4-5, 3 are accounted for by the handlebars of the moped.

5 - The efficiency of present day helmets in France is mediocre. This lack of efficiency can be explained by the absence of protection in the most highly affected areas of the head (forehead and temporal), and also the lack of shock-absorbing material as well as frequent loss of helmet (25%). Several different measures, notably increased violence for young people wearing helmets involved in accidents, lead to decreasing the recorded efficiency. An improved helmet (complying with the new specification to be issued) would decrease severity by 35 to 40% of the cases according to our estimates.

Improving helmets, reducing handlebar impacts and particularly modifying the front part of cars (bumpers and windshield surround) appear to be the most appropriate measures to be taken for reducing severe injuries of moped riders.

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