INJURY PATTERN OF PEDESTRIANS HIT BY CARS OF RECENT DESIGN

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AIMS OF THIS STUDY

The present studies treating the passive protection of pedestrians struck by passenger cars are based on accident study files dating back 10 to 15 years.

However, the design of these cars has considerably changed since these enquiries and it may be supposed that the new profile of cars which characterise the present-day parc have an influence on the kinematics of the pedestrians, and also, clearly, on the frequency of lesions to the different parts of the body.

The aim of this new study is therefore :

- to obtain a more up-to-date picture of the real-world crashes by analyzing collisions which involved cars designed recently (marketed after 1989),
- to compare this survey to the similar one conducted by the LAB at the end of the 1970's to assess the injury risk evolution.

PROPORTION OF PEDESTRIANS STRUCK BY CARS

Before analysing in greater detail only those accidents where cars strike pedestrians, it is useful to identify the proportion of pedestrians struck by other vehicles (motorcycles, vans, trucks).

The figure 1, drawn from the figures of the SETRA (French National file of personal injury crashes) shows that the percentage of pedestrians struck only by cars is between 74 and 80% according to the severity.

80% of the cases concern lightly and seriously injured cases and 74% are fatalities. Concerning the latter, it may be observed that the proportion of trucks is very high : 20%.

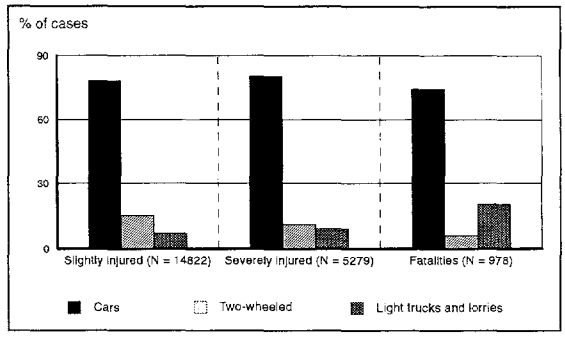


Figure 1. Percentage of cars as striking party in pedestrian collisions according to overall injury severity.

CHARACTERISTICS OF THIS PEDESTRIAN ACCIDENT FILE

File Used for this Study

Concerning only the cases of cars against pedestrians, the accidents analysed are taken from the accident reports of the National Gendarmerie for which the selection criteria were as follows :

- cars marketed after 1989,
- accidents happening between 1994 and 1995,
- accidents where original photos of the car were available, clearly an essential element for such an analysis,
- accidents where the medical files of the pedestrians were available.

The number of reports considered in this period was 594, and 529 of them were in fact taken into account for this analysis.

It is necessary to note that the selection of accidents occuring on the Gendarmerie network, for which photographs were available, clearly implies a sample of

pedestrian accidents where the mortality is superior to the national average.

Here, this mortality is four times higher to that observed in the whole of France. The advantage of such a file is evidently to be able to show rapidly, and in relatively few cases, the most representative serious lesions according to the speed and the zones struck by the car.

So, for each accident, the following parameters were studied :

- the calculated impact speeds according to : the braking marks, the stopping distances and the projection of the pedestrians, the interview with the parties involved (driver,witness,etc..)
- the zones impacted by the various body areas, notably the head.

Representativity of this File

Apart from the very high severity of this file, it is important to check that it is representative of all the accidents happening in France :

- firstly concerning the distribution of the size/classes of cars impacting,
- then the distribution of victims and fatalities by age category.

This table 1 compares the distribution of size/classes of cars of this accident file to those of two different sources :

- vehicles against pedestrians in 1995 (source SETRA),
- sale of cars in France after 1989 (source manufacturers).

Table 1.
Breakdown (%) of Striking Cars to Size/Class

N = 529	Studied sample %	Comparison with other sources	
		Car-to-pedestrian (%) France 95 (DOT)	French car sales after 1989 (%)
LOWER CLASS (Clio, 106, Twingo, Corsa, Punto, ...)*	**47**	45	43
LOWER AVERAGE CLASS (ZX, Escort, 306, Golf, Astra,...)*	**32**	24	27
UPPER AVERAGE CLASS (Xantia, Laguna, Mondéo, Primera, Audi, ...)*	**13**	20	20
UPPER CLASS (Safrane, Espace, BMW, Volvo 850, Saab, ...)*	**8**	11	10

It may be verified here that the cars taken into account in this selection are not fundamentally different in size from the reality of accidents in France.

We observe five to six points more pedestrians struck by cars of lower average class compensated by seven points more of upper average class.

The cars most representative of the classes are :

- the CLIO and 106 for the lower class,
- ZX, 306 and ESCORT for the lower averages,
- XANTIA,LAGUNA and MONDEO for the upper averages,
- SAFRANE, ESPACE and BMW for the upper classes,

If we now compare by age class the proportions of pedestrians struck by these cars selected from the Police files to those of all pedestrians struck by cars in France in 1995, we can observe a certain similarity, i.e. a few less pedestrians aged between 18 and 50 in our sample compensated by a few more aged pedestrians (figure 2).

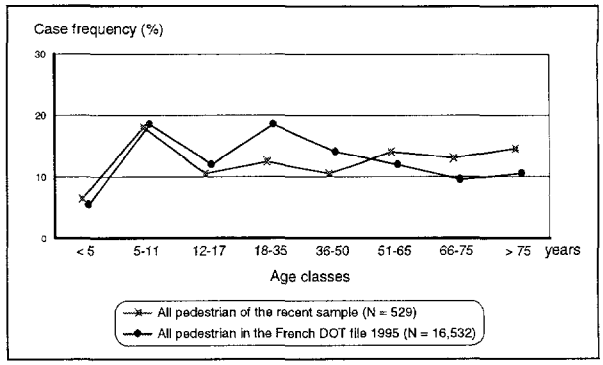


Figure 2. Breakdown of pedestrian involvement according to age classes

For the fatalities, the distributions by age class are essentially the same in our sample and for all the pedestrians killed in France (figure 3).

This file of 529 pedestrians struck by the cars is therefore representative of the severe accidents which will happen in France at the start of the years 2000s, in a parc principally composed of these cars.

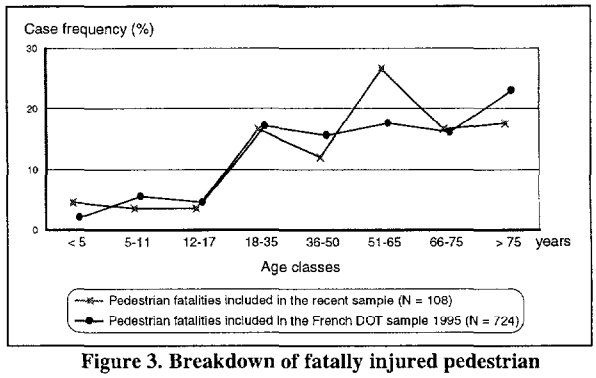


Figure 3. Breakdown of fatally injured pedestrian according to age classes

Frequency of Pedestrians Struck by the Front Face of Car

We will now study in greater detail the way in which these 529 pedestrians were struck by the car. It may be seen in figure 4 that , in many cases, the pedestrians are

not directly struck by the front face of the car, but are hit by the wings or by the wing mirrors without direct impact of the bumper against the lower limbs.

So, for these 529 pedestrians distributed here according to the gravity described earlier, 134 were not touched by the front face of the car, i.e. 25%. For those lightly or seriously injured, they amount to about 30%, and to only 11% for those killed.

The number of pedestrians thus taken into account in this study is 395.

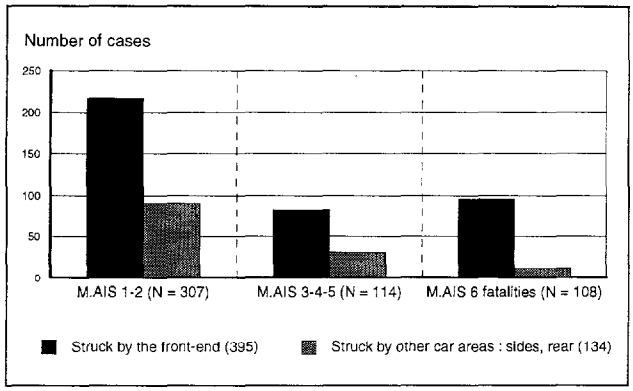


Figure 4. Total number and overall injury severity of pedestrians struck by the car front-end.

RESULTS FOR THESE 395 PEDESTRIANS STRUCK BY THE FRONT FACE

Gravity According to the Impact Speeds and the Age Classes

We have defined three age classes in the following : children under the age of twelve years, « young » adults between twelve and forty nine, and the pedestrians aged more than fifty years old.

Figure 5 shows that for these three different age classes, important differences in impact tolerance exist at the same vehicle impact speed.

Therefore the gravity, i.e. the percentage of dead and seriously injured (MAIS 3+) amongst those involved, increases with the speed for each age class, which is logical, but for a given impact speed the children are more tolerant up to 45 k.p.h..

The most aged evidently present the highest risks for the same category of speed.

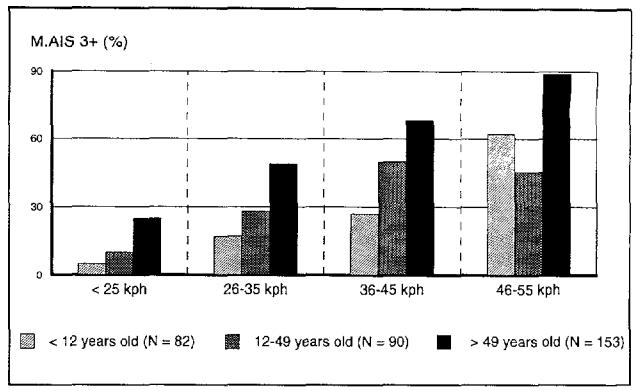


Figure 5. Percentage of severely and fatally injured pedestrians according to striking car speed and age classes.

Zones Struck by the Head for Serious and Fatal Lesions

For this corporal zone which is the site of 80 to 85% of the fatal lesions, it is worthwhile to state the hypotheses which were used to attribute head lesions, either to impact with the vehicle, either with the ground.

Evidently, if no impact with the car has been recorded, the head lesion is attributed to the ground impact.

If a head impact on the car is found, the gravity of this impact of the head is systematically attributed to the car, and not to the ground at the moment of falling. Beaving in mind the results of other accidentology studies, we may suppose that this hypothesis is the most likely to be true for serious and fatal (AIS3+) injuries.

For head lesions of level AIS 1 and 2, it is certainly difficult to decide the car or ground responsability for a simple loss of consciousness or a cut to the head.

In any case, these hypotheses maximise the car as the source of serious or fatal lesions to the head, as well as for light and moderate lesions.

Therefore, where only serious and fatal (AIS3+) lesions to the head are concerned, and for all pedestrians, the frequencies of the zones impacted on the car, all speeds included, are as follows (figure 6) :

- 17% of cases by impact on the hood and the upper fenders,
- 28% against the zone where the windscreen meets the hood (the scuttle),
- 25% against the windscreen supports (A pillars).

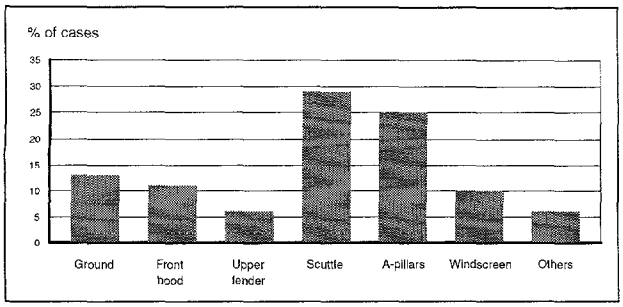


Figure 6. Breakdown (%) of pedestrian head AIS3+ injuries according to car contact locations.

It may be seen that the proportion of serious lesions attributable to the windscreen are not frequent (10%) and are observed exclusively for the most aged pedestrians.

The proportion of serious and fatal lesions avising from ground contact is less than 15%, as is shown by most of the former accidentology studies.

If we calculate, for each zone of the car as defined earlier, the gravity rate, i.e. the percentage of serious and fatal lesions (gravity rate) from all impacts detected, we can see, on figure 7, a risk which increases as a function of the average " stiffnesses " of the zones impacted, the most A pillars followed by the scuttle.

The gravity rates of the impacts against the windscreen and the ground are here the lowest.

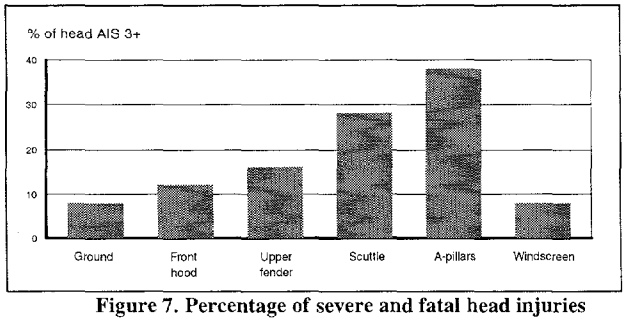


Figure 7. Percentage of severe and fatal head injuries according to car contact locations.

Frequency of Moderate to Fatal Lesions (AIS 2+) According to the Age of the Pedestrians (figure 8)

We will now study, by body areas, the percentage of pedestrians presenting moderate to fatal lesions (AIS 2 and more) amongst all the pedestrians struck, for two age classes : under twelve and over twelve years old.

It should be underlined here that this file is considerably more severe than the national average and that this frequency of lesion is fortunately not that observed in France for all pedestrians.

We have defined different anatomical territories in this table, which are :

- the head and the neck,
- the trunk, comprising the thorax, the abdomen and the dorsal-lumbar column,
- the upper limbs,
- the pelvis including the head of the femur and the neck of the femur,
- the femur not including the condyl and the head of the femur,
- the knee including the joint, knee ligaments, tibial plate and femural condyl,
- the tibia and the fibula,
- the foot and the ankle including the articulations and malleolus.

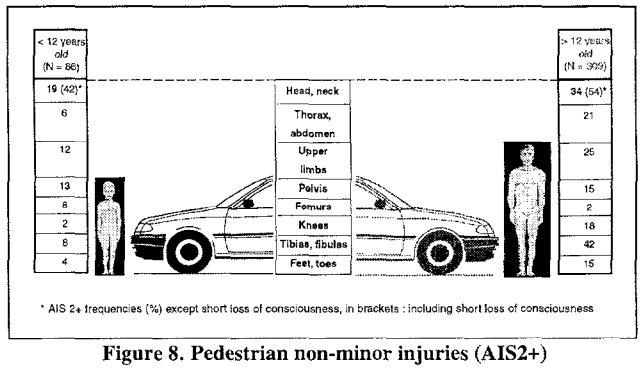


Figure 8. Pedestrian non-minor injuries (AIS2+) frequency (%) versus age.

It may be seen, for all speeds, that the lesional frequencies are very different. These differences are due, in part, to the greater tolerance of the children, but also to the frequently much more severe impacts sustained by the adults, notably those less than fifty years old.

For these two age classes, the head and the lower limbs are the most exposed territories.

For the head, 19% of AIS 2+ lesions for the children are noted, against 34% for the other age class without counting the isolated brief or initial losses of consciousness. If they are counted, the frequencies are therefore 42 and 54%.

Concerning the lower limbs in the wide sense, the principle zones of lesions are very different.

The pelvis is priority for the child (13%), then comes the femur and the tibia with 8%.

The tibia zone for the adults is by far the territory most often concerned (42%), followed by the knee (18%) and the pelvis (15%).

These lesions of the knee, are in half of the cases fractures of the tibial plates, the other half being lesions of the ligaments.

The fractures of the pelvis, we will see later, are very much linked to the age where adults are concerned.

The fractures of the femur for the adults are very rare here (2%).

If we were only interested in the fatal lesions, the head is by far the most exposed territory with 85% of the cases with fatal lesions whatever the age.

Distribution of those Involved According to the Pedestrian Severity and the Speed

It was interesting to know the distribution of impact speeds according to the pedestrian injury severities.

This figure 9 allows us to see the populations implicated according to the different speed classes and for each level of severity.

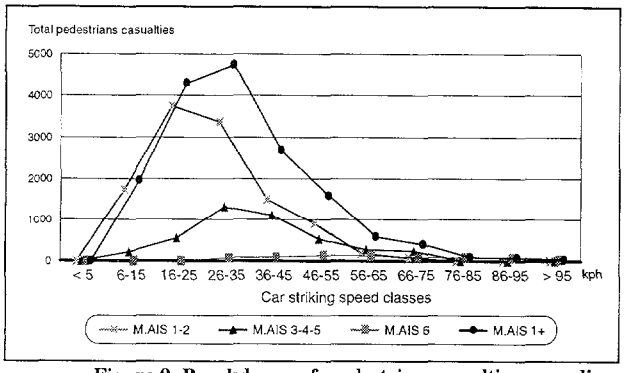


Figure 9. Breakdown of pedestrian casualties according to overall injury severity and striking car speed.

These distributions are deduced from the severities given by the SETRA, and grouped according to the speeds calculated in our study.

The distributions for the 16458 pedestrians struck (MAIS 1+) by the cars have been defined as follows :

- the lightly and moderately injured of the SETRA correspond to the MAIS 1-2,
- the seriously and very seriously injured to the MAIS 3-4-5,
- those killed at the MAIS 6.

It may so be observed that the average of the impact speeds for all the pedestrians involved is 25 k.p.h., and 35 k.p.h. for the seriously injured, while the vast majority of those killed are situated at very high speeds.

Number of Pedestrians Presenting Serious Head Lesions as a Function of the Zones Impacted

We will now examine, for the two age classes defined earlier, the number of serious lesions and fatal head lesions attributable to the engine hood and to the hood surroundings, to the zone where the hood meets the windshield, and to the windshield pillars.

Now, to have a more precise idea of what happens on a national level, we make a projection of the different results found earlier in the sub-sample of 529 pedestrians, to all of the pedestrians killed or seriously injured in France in 1995.

Firstly, the pedestrians killed in 1995 numbered 1021, and 987 in 1996.

We may see that 93% of those killed are over twelve years old (952) taking all striking vehicles into account (figure 10). Then we find the number of pedestrians :

- struck by the cars,about 74%,
- struck by the front face of the cars, close to 90%,
- struck by the front face of the cars and presenting serious or mortal lesions to the head, 85%.

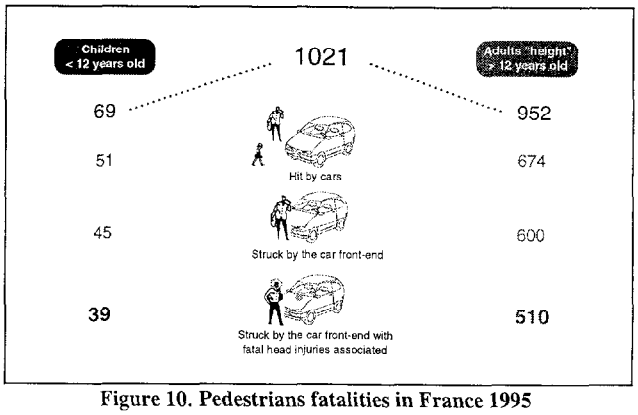


Figure 10. Pedestrians fatalities in France 1995

Overall, for one hundred pedestrians killed, a little over 50% were struck by the front face of the car and presented fatal lesions to the head.

Now, for these fatal head lesions, we can see the different zones impacted by the head (figure 11).

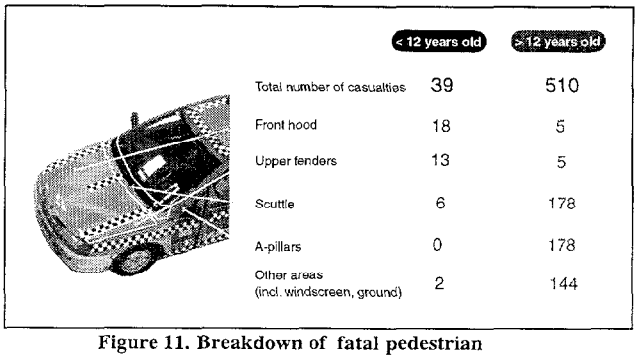


Figure 11. Breakdown of fatal pedestrian « head -vehicle » contact locations.

The total number of fatal impacts against the hood and upper fenders is 41 from a total of 1021 pedestrians, i.e. 4%, including all speeds and principally for the children.

As for the adults, they strike principally the scuttle and the A pillars (180, or about 18% of all the pedestrians killed for each zone).

In the same manner, for the 5500 seriously injured pedestrians in France in 1995, we make the same distribution.... Here, close to 20% of the seriously injured are less than twelve years old, taking all vehicles into account (figure 12).

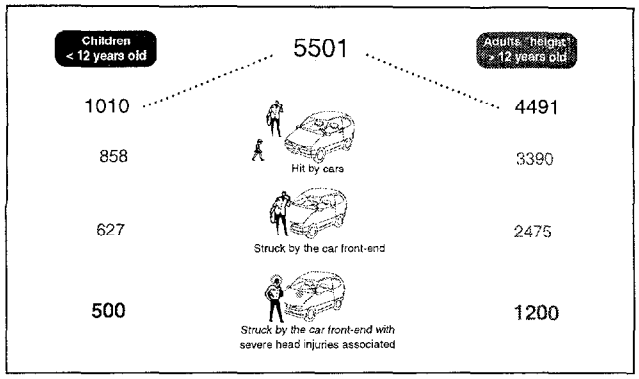
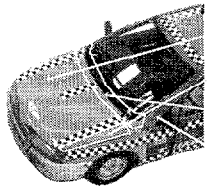


Figure 12. Severely injured pedestrians in France 1995.

The proportions of pedestrians struck by the front face of the cars and presenting serious injuries to the head are 50% for those less than twelve years old and of the order of only 25% for those over twelve.

This may be quite simply explained by the greater frequency of serious lesions to the lower limbs in adults, often isolated lesions when compared to children.

The results (figure 13) concerning the serious impacts of the head against the hood are of the same order as for those killed, 6% of all the seriously injured and practically exclusively for the children (324 from a total of 5500).



	< 12 years old	> 12 years old
Total number of casualties	500	1200
Front hood	200	12
Upper fenders	100	12
Scuttle	100	360
A-pillars	0	360
Other areas (incl. windscreen, ground)	100	456

Figure 13. Breakdown of severe pedestrian « head -vehicle » contact locations.

As for the scuttle, this represents 8% of the serious injuries (total of 460 lesions), for all speeds, it should once again be mentioned.

COMPARISON OF THE GRAVITY AND FATALITY RATES BETWEEN THIS FILE AND THE 1980 LAB FILE

Having studied these accidents of pedestrians struck by the front face of cars of recent design, it was interesting to check if the risk of lesions had changed compared to an older file.

To do this, we have used the accidentology file of the LAB which comprises 282 pedestrians struck by the front faces of car; the study was made between 1974 and 1983, and is also of a severity close to that analysed before with a mortality rate around four times superior to the national average for these years.

To be able to make these comparisons of gravity between the different corporal territories for the three age classes as defined at the beginning of the presentation, it was essential that for a given age class, the distributions implied by class of speed should be identical. These corrections were made systematically wherever needed. We should specify that the same methods for evaluating the impact speeds against the pedestrians were used for the two files.

Comparisons of Gravity Rates Between the two Files

Globally, concerning the seriously injured and killed (MAIS 3+), we observe a lesser aggressivity of these new cars for identical impact violence and for all three age classes (figure 14).

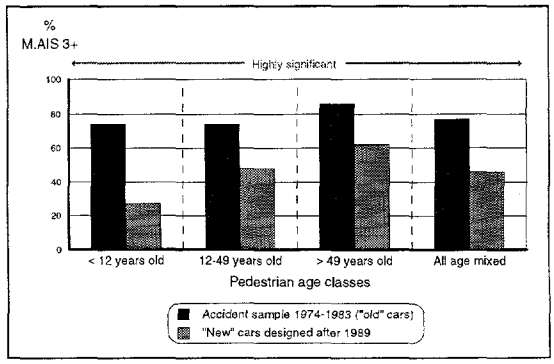


Figure 14. Comparison of frequency (%) of pedestrian sustaining MAIS3+ between old and new striking cars according to age classes.

These reductions of gravity rate are statistically very significant (test of the chi2) for the three age classes and of course for all the pedestrians (40% reduction). A more important reduction of gravity is noted among the youngest persons.

Comparisons of Fatality Rates Between the two Files

The comparison of fatality rates (% killed of those involved) does not show a significant difference for all the pedestrians, however for the most aged class we note a significant reduction of mortality rate (figure 15).

In fact, this efficiency seen for the new cars, and only for the most aged concerning mortality rate, may very certainly be explained by a reduction of the number of lesions of level AIS 2+ and AIS 3+ observed at many body areas, an association of lesions which, we know, may often imply a unfavourable vital prognostic for an aged injured person.

For the other age classes, the fatal lesions being practically all situated on the head, it is difficult to imagine a notable reduction in mortality rate only by modifications to the profile of the cars.

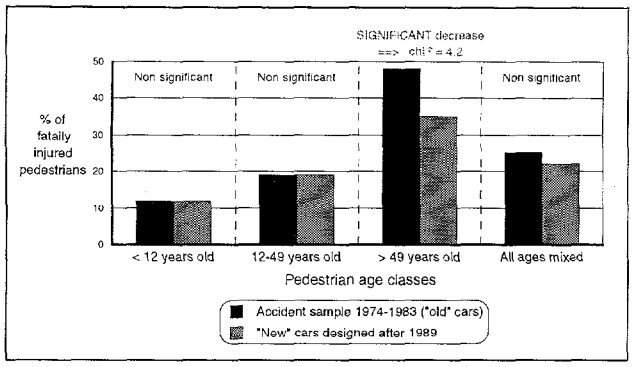


Figure 15. Comparison of frequency (%) of fatally injured pedestrian between old and new striking cars according to age classes.

Comparisons of Gravity Rates Between the two Files According to the Body Areas

In fact, these important reductions of the gravity rate MAIS3+ of almost 40% (as well as 15% for the MAIS2+) for the pedestrians struck by the cars of recent design are attributable to the reduction in frequency of level AIS2+ lesions in almost all the body areas, as may be verified on figure 16: the head, the trunk, the pelvis, the femur and the tibia are less frequently injured, only the knee lesions are not reduced. These observed reductions are statistically significant for all the territories (except the knee, of course) as well as the "trunk" zone which includes the thorax, the abdomen and the dorsal lumbar column.

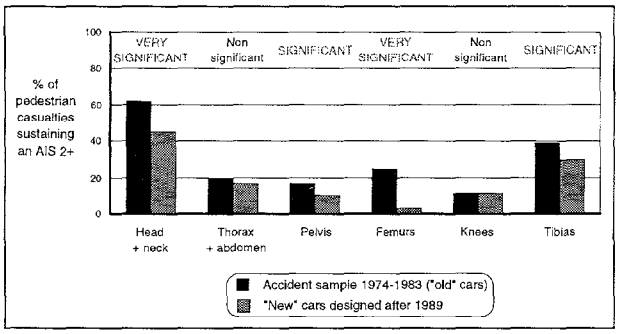


Figure 16. Comparison of percentages of pedestrian AIS2+ occurrence between old and new striking car designs by body area.

The reduction of gravity rate for the head/neck zone, all ages included, is 25% and is statistically very significant (chi²= 18). They are also significant for the youngest age classes (figure 17).

We may suppose that the profile of the newer cars has contributed to reducing the gravity rate of these impacts both for the adults as well as the children :

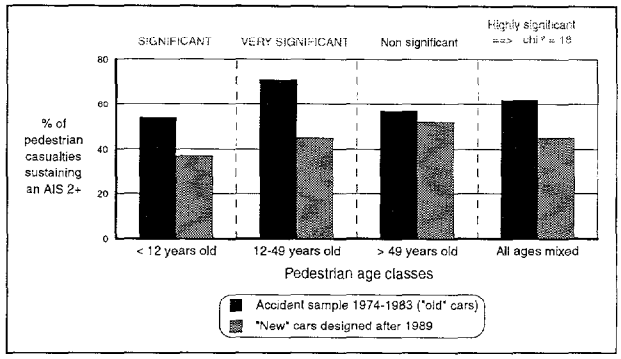


Figure 17. Comparison of percentages of non-minor (AIS2+) head injuries occurrence between old and new striking car designs by age classes.

- the more " profiled " hoods which reduce the direct impacts of the heads of the youngest children against the anterior panel of the hood, observed on the older cars.
- the more " enveloping " hoods which protect, for certain cars, the upper fenders as well as the more agressive windshield wiper pivots and the windshield bay.
- the more " laid-back " A pillars than before, for better car aerodynamics, which can have an influence also on the frequency and the severity of impact of the adults for a given impact speed.

We may also suppose that the glued-in place laminated windscreens on recent cars, compared to the toughened windscreens or the non-glued laminated windscreens, offer a better " shock absorbtion " of the head, so limiting the secondary impacts against the rigid elements of the passenger compartment.

The reduction of gravity rate for the trunk zone, for all ages, is 15%, but it is not significant for any age class.

Three territories merit a special attention.

The pelvis (figure 18) where overall there is a significant risk reduction (from 17 to 10%), but this is attributable only to the reduction in risk for the " young " adults, who go from 21 to 0%. No lesions were recorded in a population of 100 adults struck, compared to 22 lesion cases in the earlier file for a population of 106.

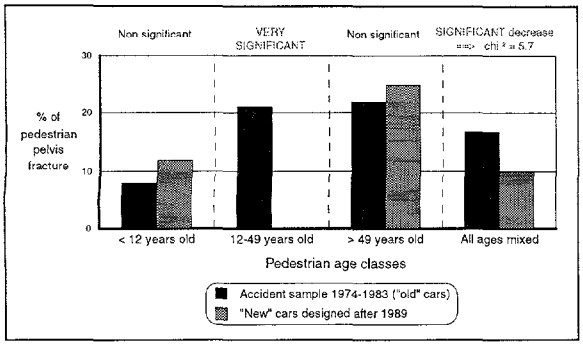


Figure 18. Comparison of percentages of pedestrian pelvis fracture occurrence between old and new striking car designs by age classes.

For the older pedestrians, where 90% of these lesions are observed between 60 and 80 years old (50% for the over 70s), the risk is not modified. The increase observed is not statistically significant.

It is known that the fractures of the hip joint happen easily when aged people fall an the ground. May we ask ourselves if these lesions are attributable to falls on the ground or on the hood which is now much less aggressive for those more tolerant.

We note an increase in risk for the children (but not significant), the bumpers and the " nose " of the hood are to blame for most of the cases, particulary for the youngest amongst them (8 out of 9 are less than years old).

The risk of fracture for the femur (figure 19) has, against these new cars, been reduced in a spectacular fashion, as we observe a 85% risk reduction for all ages (statistically very significant reduction for the three age classes).

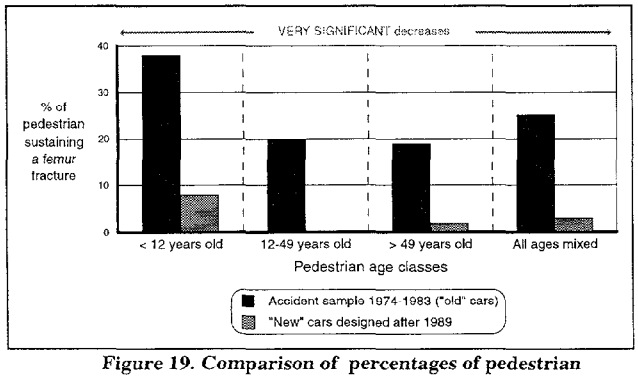


Figure 19. Comparison of percentages of pedestrian sustaining a femur fracture between old and new striking car designs by age classes.

The risks are zero for the young adults and extremely low for the older (2 cases for ages 70 and 84). We recall that the pelvic zone includes the lesions to the hip joint and the top of the femur.

For the children, the risk is now very low as it goes from 38 to 8%.

For the tibia (figure 20) the risks are reduced from 10 to 40% according to the age. For all ages, the 23% reduction observed is significant. For each age class, we note a reduction in risk but only that of the most aged is significant.

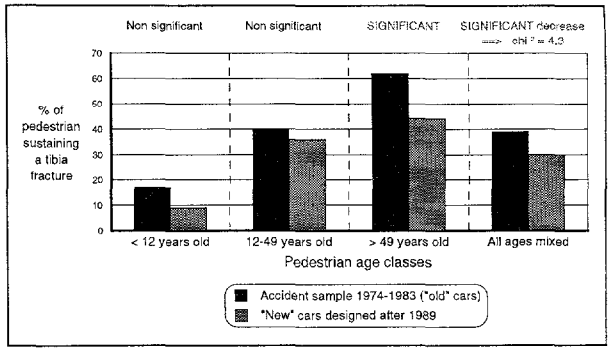


Figure 20. Comparison of percentages of pedestrian sustaining a tibia fracture occurrence between old and new striking car designs by age classes.

In fact, the more detailed analysis of the types of fractures in this corporal territory for the two samples is edifying, as may be seen on table 2.

For all pedestrians presenting fractures in this territory, the proportion of open fractures to one or both legs, attributable to the bumpers, goes therefore from 44% for the old cars to 9% for the new cars.

Table 2
Comparison of Percentages of Pedestrian Tibia Fracture Occurrence Versus the Old and New LAB Samples

		Old LAB sample 74-83 (93 injuries)	New LAB sample 1995 (86 injuries)
CLOSED fracture(s)	1 leg	54 %	84 %
	2 legs	2 %	7 %
OPENED fracture(s)	1 leg	31 %	6 %
	2 legs	13 %	3 %

The fractures of two legs goes also from 15 to 10%. This leads us to believe that the modifications to the bumpers have greatly contributed to reducing the gravity of these lesions.

This significant reduction of gravity rates for most of the body areas of pedestrians struck by cars of recent design therefore influences the overall gravity rate for all ages as well as the mortality rate for the most aged category.

CONCLUSIONS

This new accidentology study of pedestrians struck by cars shows :

- the positive effect of the design of new cars on the gravity rate of lesions compared to an older parc on which most of present-day accidentology studies are based,
- an extremely important reduction of fractures of the femur for all pedestrians, 85% less than with the older parc,
- the pelvis is no longer a preoccupation for young adults when the new parc is concerned,
- the problems bear essentially on the lesions of the head and the lower limbs,
- the only remaining pelvic lesions are mainly observed on aged pedestrians, between sixty and eighty years old, for whom more detailed studies would be needed to know if these lesions are due to falls on the ground or on the hood,
- lesions of the tibia/ fibula are clearly reduced (23%) and are also above all less serious (clear reductions in open fractures are often observed to the two legs),
- for adults, the majority of serious and fatal impacts to the head occur in the scuttle and A pillars.
- on the other hand, when only children are concerned, most of the serious head blows are located on the hood zone.

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