ANALYSIS OF PEDESTRIAN HEAD KINEMATICS BASED ON CAR-PEDESTRIAN TEST RESULTS.

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ABSTRACT

In the frame of the program of pedestrian safety improvement made in MARSEILLE under collaboration between ONSER, MARSEILLE Medical University and CITROEN/PSA, 170 full scale pedestrian tests were performed (100 cadavers tests and 70 dummy tests).

This experimental program allowed us to analyze especially head kinematic in relation with car impact speed (10 to 40 km/h) impact configuration (facing and side) and vehicule type. This analysis takes into consideration high speed films, head acceleration, injury distribution, and mechanical characteristics of car areas hit by the head.

At the present time, the use of an experimental car platform, which has adjustable front shape, allows to relate head kinematic to car front profile (shape and stiffness). Moreover it allows a more complete analysis of kinematics as this platform does not include bonnet, windshield and roof.

This paper includes results of head kinematics pointing out the effect of impact speed, vehicle front profile, and describes head injury typology of pedestrian hit by a passenger car.

INTRODUCTION

The impacts experimentation program was carried out with mass production passenger cars hitting either anthropometric dummies or human cadavers, in simple experimental conditions in order to restrict the scattering of the results. The subjects (fresh dead body or ONSER 50 dummy) are hit either in frontal or in profile. The impact speed varies from 10 Km/h to 40 Km/h.(1)

The analysis of high speed films (500 and 1,000 frames per sec.), the recording of accelerometric measures together with the study of lesions noticed on the cadavers allow to appreciate the influence of several impact parameters and to approach injury mechanisms.(2)(3)

If the first objective of our team is to reduce the agressivity of the vehicles towards the lesions of the pedestrian's lower limbs(4)(5), we have always carefully dealt with the problems of the kinematic and the lesions of the cephalic segment(6). Actually these two bodily segments are the most frequently injured and very often their injuries determine the pedestrian's overall severity.

The work presents an approach of the head's kinematic, based on the results of the vehicle-pedestrian impact tests, carried out at MARSEILLE.

I - TESTS CONDITIONS :

The experimental conditions are voluntarily simplified so as to increase the repeatability of the impacts. It is not a matter of accident reconstruction involving pedestrians but only of experimental impacts, whose experimental protocol is set out here :

- The impacting vehicle is a mass production car whose design suspensions are overtighted in order to put the vehicle in a position corresponding to a braking of 6 m/s2 . This locking allow to obtain a constant height for the impact points on the subject.
- The braking of the vehicle is performed when the impact hits the pedestrian, through the original braking system.
- The windscreen fitting the vehicle is made of laminated glass so as to visualize the impact of the head.
- All the components of the vehicle involved in the impact are replaced before each test.
- The pedestrian is held in a standing position at the place of the impact, but completely released some millisecondes befor the impact.
- The subject is placed in the longitudinal axis of the vehicle.
- The kinematic analysis is carried out mainly with the help of high speed films(500 or 1,000 frames per sec.).
- When accelerometric measures are recorded, their number has been voluntary reduced (15 at the maximum) in order that the pedestrian kinematic should not be disturbed by the cable influence.
- The anatomic subjects are fresh human cadavers. Their preparation and the interpretation of the lesions are carried out by the medical team of the Anatomy Laboratory.

* Numbers with () refer to the bibliography.

Our team's first objective is the analysis of the first impact between the frontal face of the vehicle and the pedestrian's lower limbs,so as to assess the means of protection for frequent lesions and often serious at long term.
However,the results submitted here concern the kinematic analysis of the head according to different parameters of the impact(7) (impact speed,vehicle mass and profile,impact configuration...) as well as the lesions analysis of the cephalic segment.

II - KINEMATIC ANALYSIS :

The analysis of test films has enable to draw the head's tajectories for all the tests thanks to a graphic method (fig.N°: 2 and 3) and to determine the impact speed of the head on the vehicle (VTA).

Furthermore the impact point of the head on the frames has been noted and his position (L) has been located in comparison with the developed lenght of the vehicle profile.(Fig.N°1)

Owing to the scattering of the real impact speed and the dead bodies' height we have balanced these values by analysing the ratios:

- VTA/VO ,where VO is the impact speed of the vehicle.
- L/T ,where T is the subject's height.

For the tests where accelerometric measures have been recorded we have characterized the head's kinematic by the resultant acceleration value of the head (γ max), the maximum value of this acceleration for a period higher or equal to 3 ms (γ- 3 ms) and the calculation of the HIC.

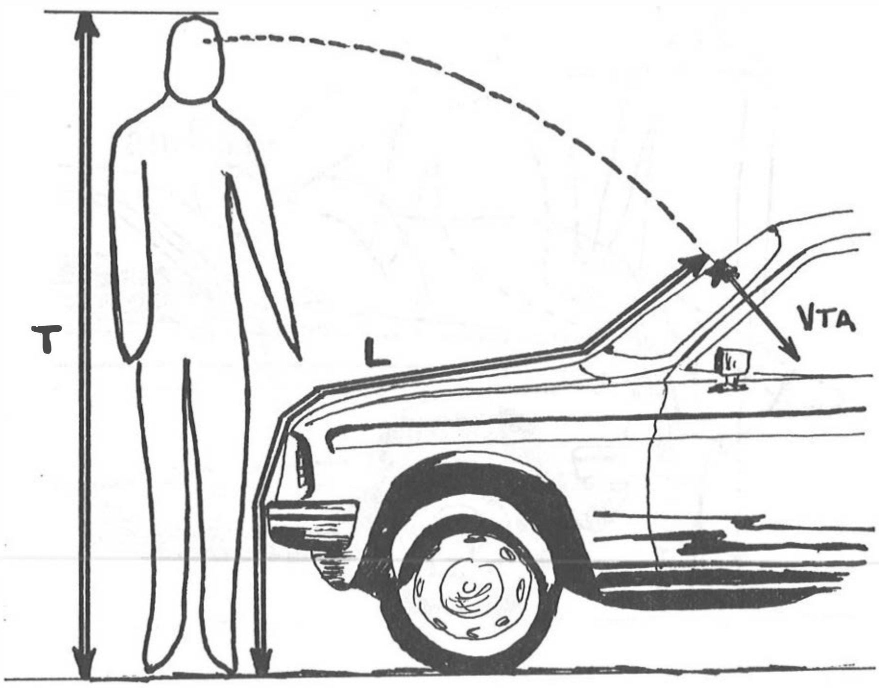


Fig.n°1:Definition of characteristic parameters

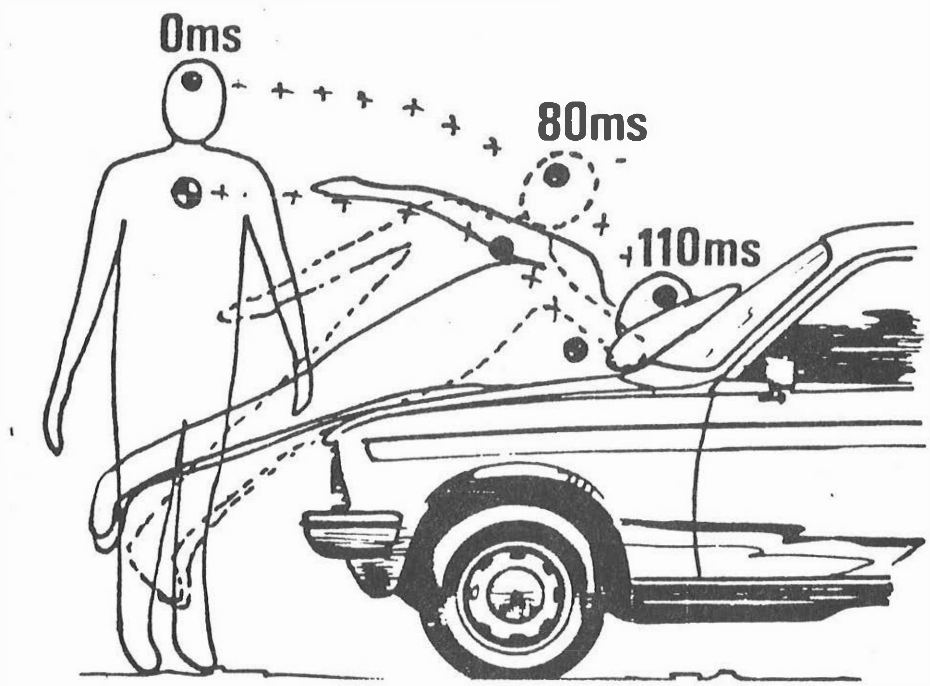


Fig.N° 2:an exemple of kinematics for the ONSER dummy

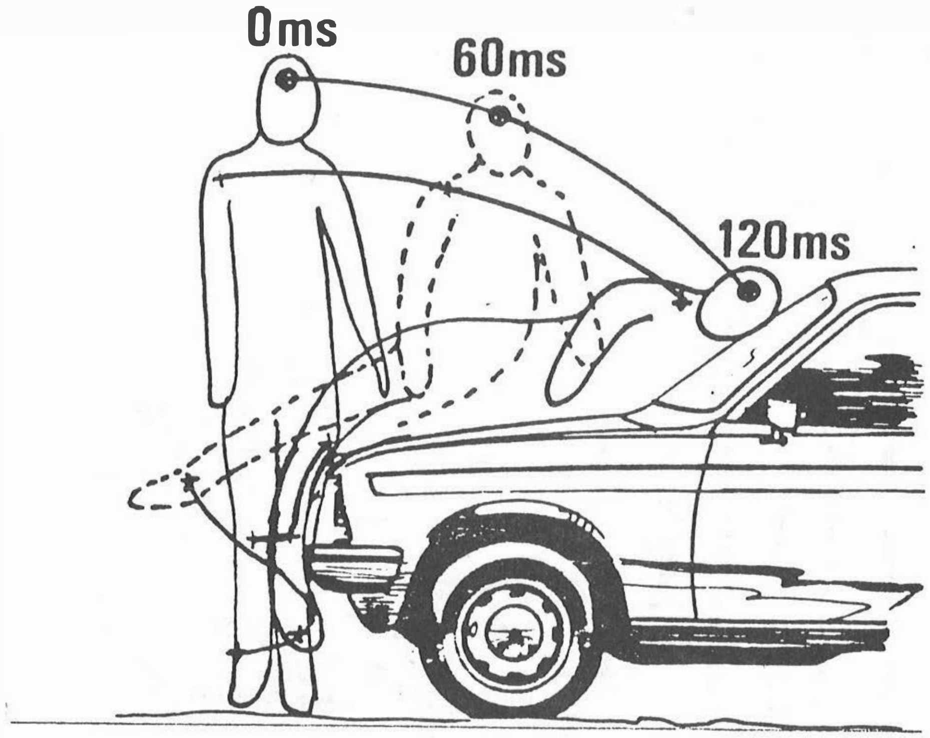


Fig.N° 3:an exemple of kinematics f■r a test with cadaver

II - 1. Influence of the vehicle speed on the impact speed of the head (VTA)

We have the results of 101 impact tests. The tests conditions are as following :

- pedestrians simulated by :
  . anatomic subject (58 cases),
  . dummy (43 cases).
- impact configuration : in frontal,
  in profile.
- vehicle : VISA saloon car (serial and modified)
  GSA saloon car
- speed at the time of impact: 25 Km/h (6.9 m/s),
  32 Km/h (8.9 m/s),
  39 Km/h (10.8 m/s).

Results are listed in Fig.N° 5 to 8.

No notable difference emerges between the results with cadavers and those with dummies when the subject is hit in frontal. The significant scattering observed in profile tests makes the comparison difficult in this kind of configuration.

The head's contact speeds are higher when the subject is hit in frontal. In this case the impact speed is generally higher than the speed when the vehicle is impacting (VO< VTA< 1.5 VO). In the profile configuration these results invert (0.5 VO<VTA<VO), this being mainly due to the arm's intervention between the body and the vehicle but also to a higher stiffness of the subjects in lateral bending.

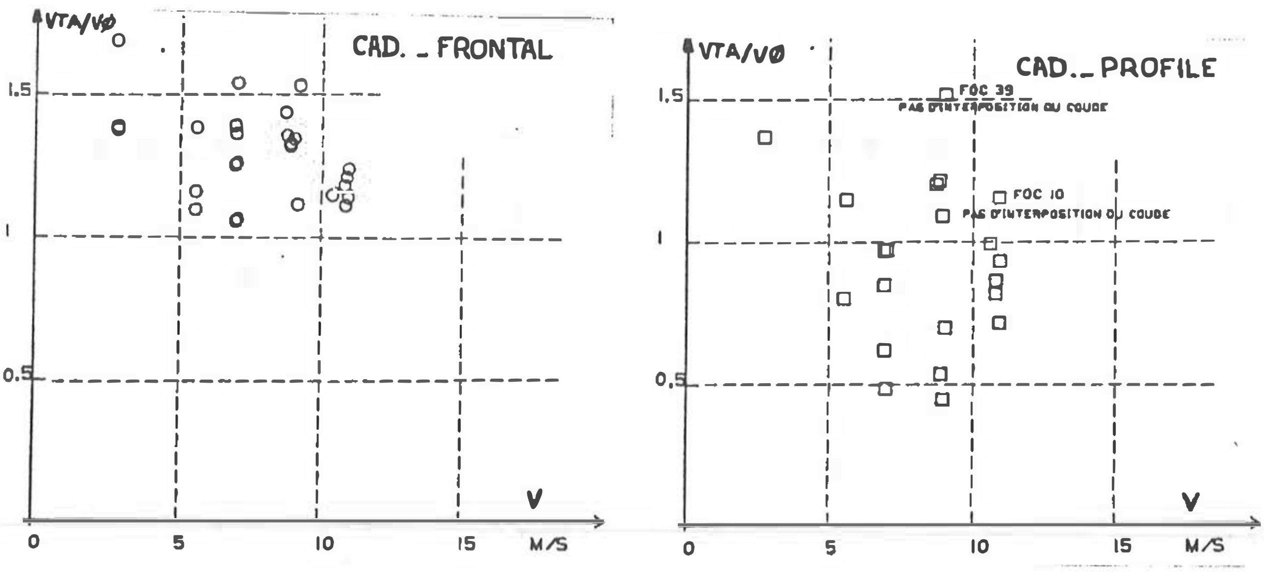


Fig.N°5 and 6 :distribution of VTA/VO according to impact speeds (crashes with cadavers)

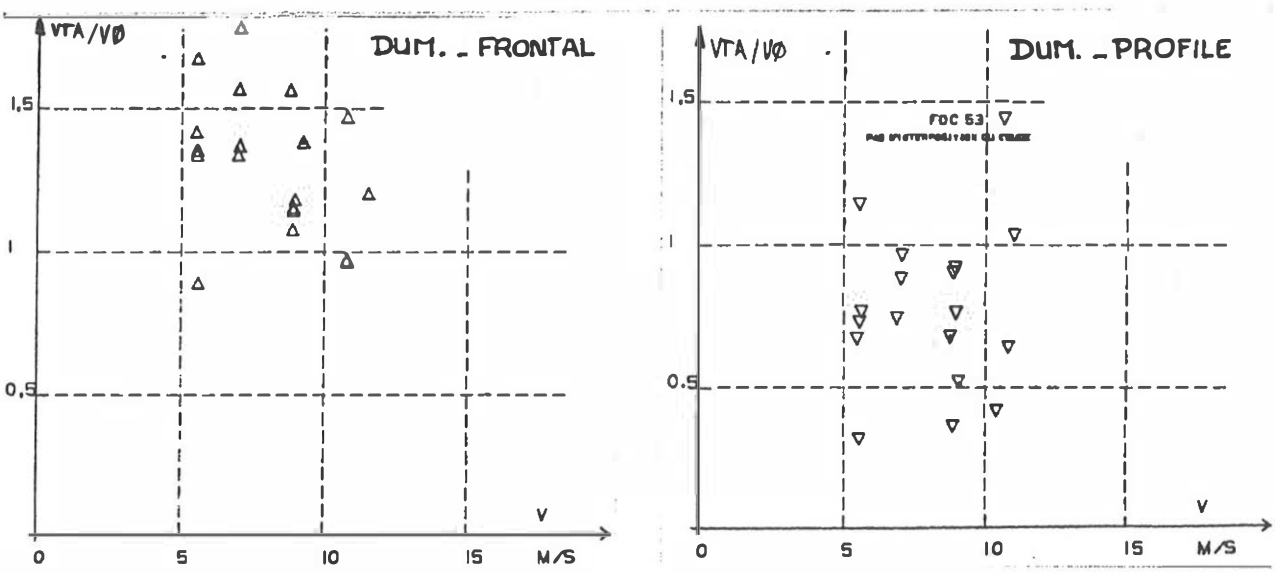


Fig.N°7 and 8:distribution of VTA/V0 according to impact speeds (crashes with dummies)

II - 2. Influence of the vehicle speed on the impact point of the head (L)

We have the results of the 101 impact tests, the conditions of these tests were presented previously. Figures N°9 to 12 show these results.

The cadavers and dummies' behaviour is comparable. Results are shared out in accordance with a curve, the summit of which corresponds to a speed of the vehicle of about 9 m/s at the time of the impact. This speed being probably due to the discontinuity of the slopes of the surfaces of the bonnet and of the windscreen.

The fact that the pedestrian should be hit in frontal or in profile does not alter noticeably the comparative position of the impact point.

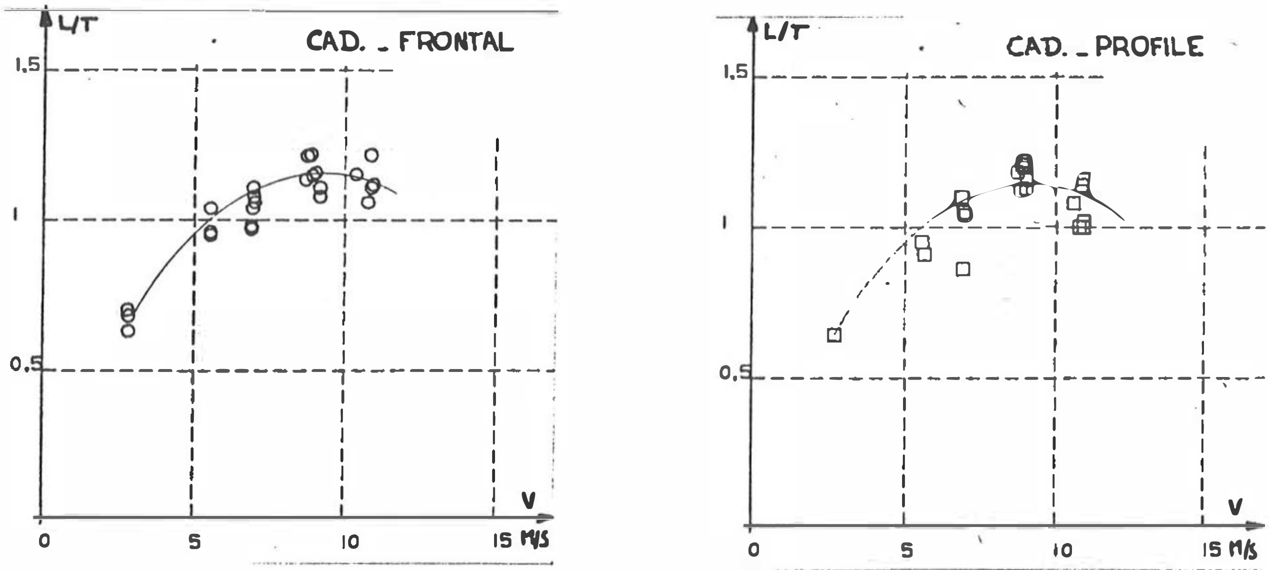
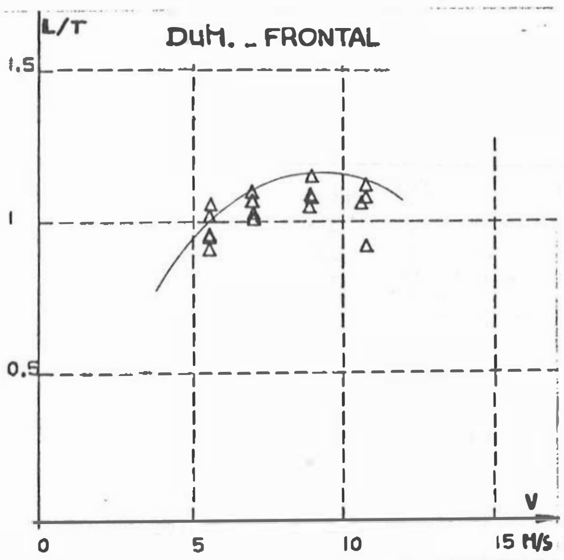


Fig.N°9 and 10 :distribution of L/T according to impact speeds (crashes with cadavers)



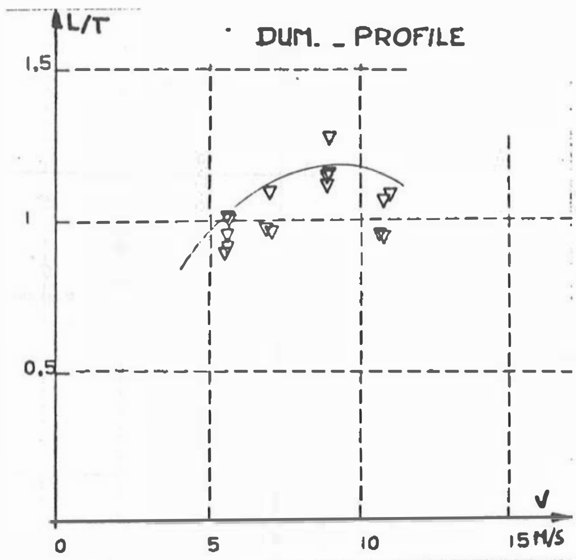


Fig.N°11 and 12:distribution of L/T according to impact speeds (crashes with dummies)

II - 3. Influence of the vehicle design on the impact speed (VTA)

We have the results of 50 tests carried out in the following test conditions :

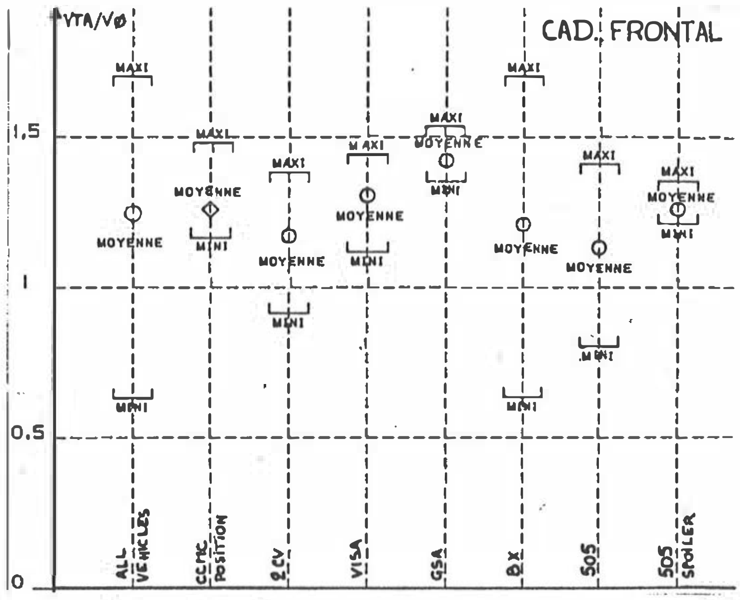
- pedestrian simulates by ccadavers,
- impacts configuration : in frontal,
  in profile,
  in CCMC'position .
- vehicles CITROEN 2CV : passenger car,
  vehicles CITROEN VISA : passenger car,
  vehicles CITROEN GSA : passenger car,
  vehicles CITROEN BX : passenger car,
  vehicles PEUGEOT 505 : passenger car, (normal and modified).

(The CCMC position is an intermediate position between frontal and profile).

Figures n°13 and 14 gather together these results.

The VTA average speed by vehicle is higher when the subject is hit in frontal, excepted in the 2CV case.

When the subjects are hit in frontal the VTA average speed is not very different from a vehicle to another. It is not influenced by the profile or the vehicle mass. It is always higher than the car impact speed (VO). When the subjects are hit in profile the VTA average speed is more scattered, but without apparent connection with the profile or the impacting mass of the vehicle.



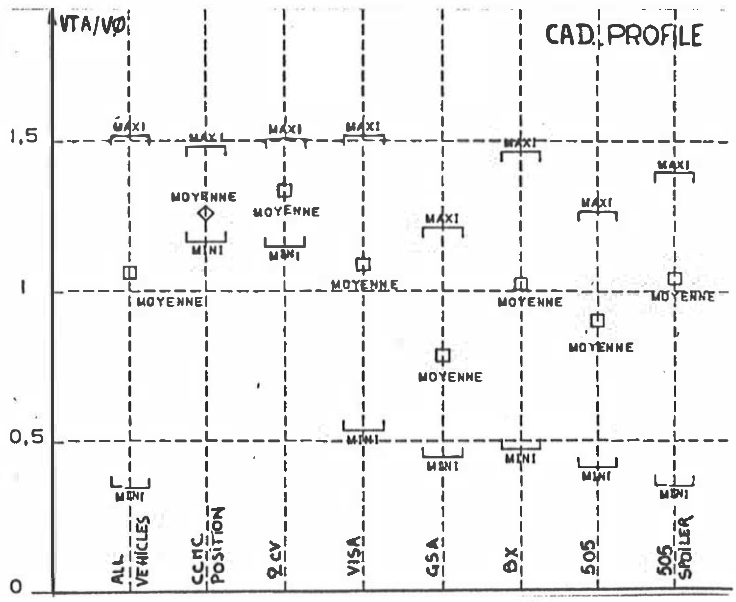


Fig.N°13 and 14:distribution of VTA:VO according to the vehicle design(tests with cadavers)

II - 4. Influence of the vehicle design on the head's impact point

We have the results of the 50 impact tests which test conditions were submitted in the previous paragraph. The results are gather together in Figures n°15 and 16.

The averages of these ratios L/T by vehicle and by configuration are very close together and do not allows to characterize the influence of a profile and/or of a vehicule mass. We note however that when the subject is hit in profile the scattering is more significant, mainly owing to the arm's interposition which emphasizes the body's rotation.

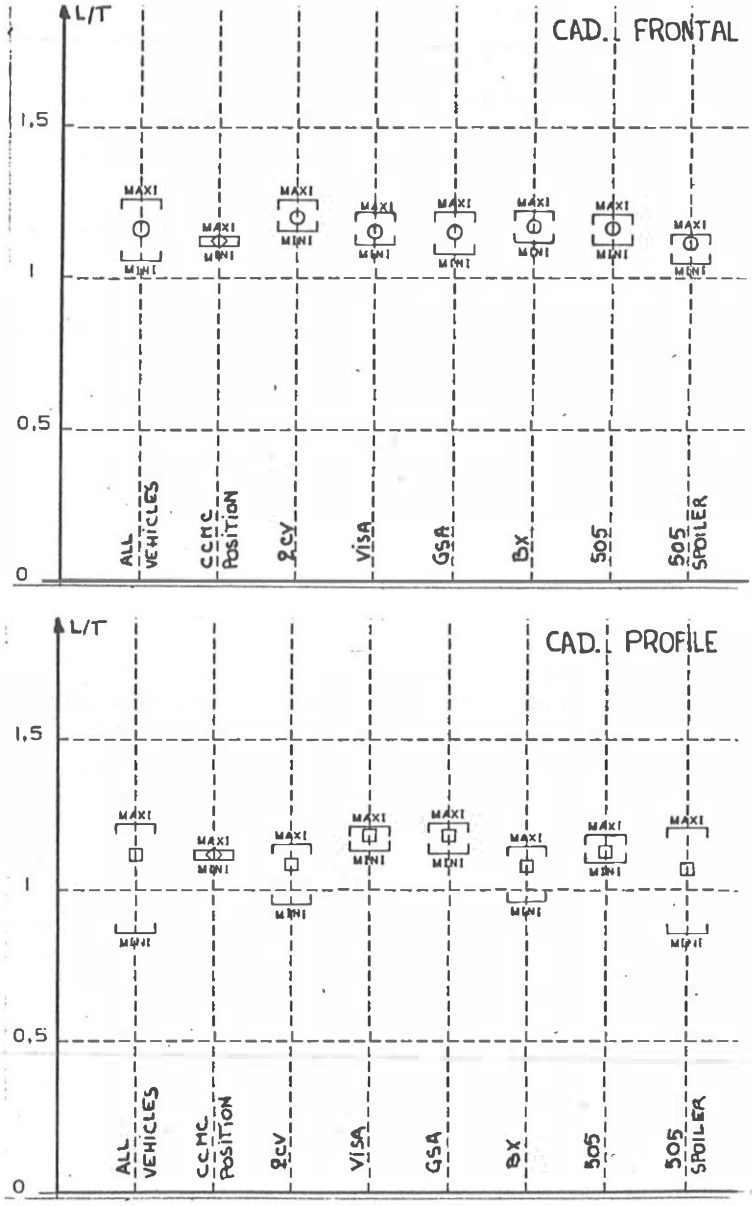


Fig.N°15 and 16: distribution of L/T according to the vehicle design(tests with dummies)

II - 5. Results of the accelerometric measures :

We have chosen to present the results of a 8 tests rank(8). (4 cadavers and 4 dummies) carried out with a PEUGEOT 104 saloon car, at a 39 Km/h speed (10.8 m/s) in profile, the average values of the results of which are given in the Fig. N°:17 .

average VTA/VO	average L/T	average HIC	average max	average -3ms
	TESTS WITH DUMMIES			
1.46	1.06	625	146g	74g
	TESTS WITH CADAVERS			
1.40	1.05	420	100g	39g

Fig.N°17:Results of accelerometric measures.
(average values for 8 tests with 104 PEUGEOT)

We notice that the values obtained are in the same order of magnitude for the dummies and for the cadavers, although the values recorded with the dummies seem generally slightly higher.

The low values of the HIC come from the fact that the head's impact occurs on the windscreen.

II - 6. The kinematic of the fall on the ground :

The analysis of all the tests carried out pointed out that the ground fall phasis is very uncertain. No connection with the tests parameters has been set up. We give some examples of ground fall position and the values of the head's speed in comparison with the ground according to the vehicle design (VTC) in Fig. N°18 and 19.

However we notice that the vertical component of the head's contact speed with the ground is always close to 5 m/s. We must jot down that the height of the upper part of the vehicles bonnets used are about 1 m. and that a body falling in free fall at this height reachs a 4.4 m/s speed.

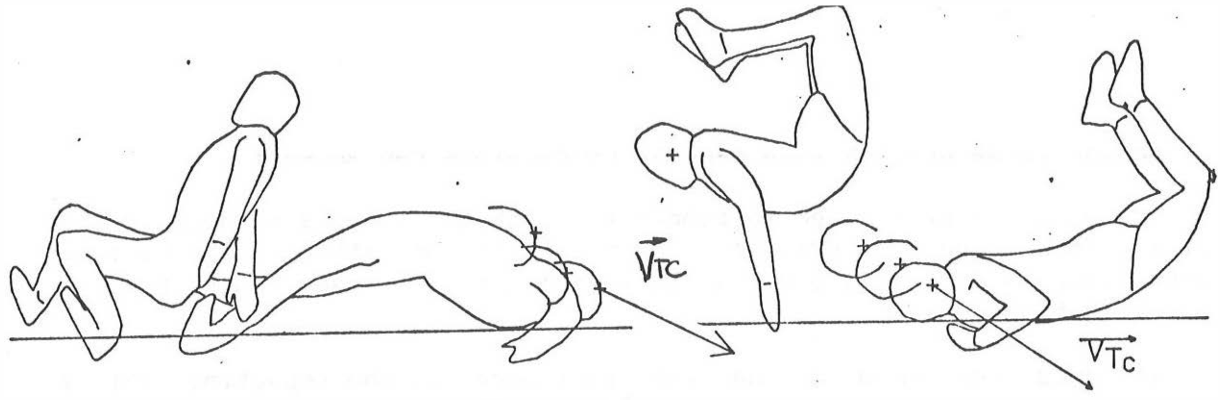


Fig.N°18: examples of kinematic of the fall on the ground

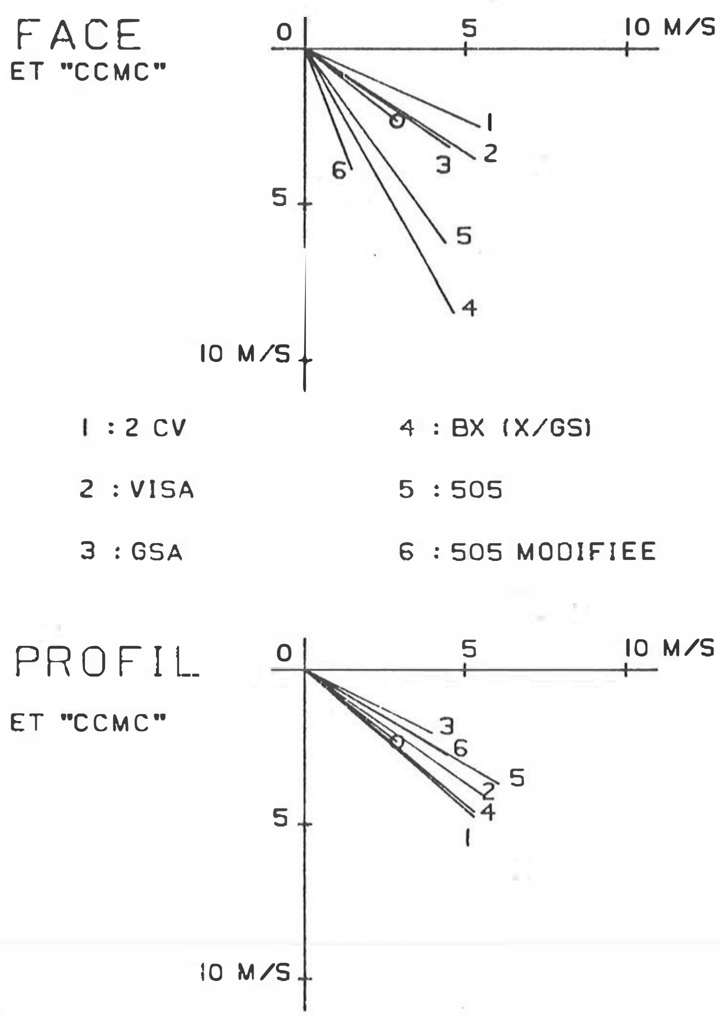


Fig.N°19:distribution of the head impact speed according to the vehicle type (vehicle impact speed:8.8m/s tests with cadavers)

Behind these results some general conclusions can appear:

The head's impact speed in comparison with the vehicle is next to the vehicle impact speed (VO). It is higher to the latter in the case of frontal impacts ($VO < VTA < 1.5\ VO$) while it tends to decrease for the profile impacts ($0.5\ VO < VTA < VO$).

It does not seem to be very influenced by the impacting vehicle profile or mass, in the case of the 6 passenger cars used in those tests. The arm's interposition at profile impacts as well as the higher lateral rigidity of the subjects, widen the scattering of the values recorded in this configuration.

The area impacted by the head depends on the initial speed at the time of the impact, on the subject size and on the developed length of the vehicle profile.

The distribution of the position of the impact point, according to the vehicle speed at the time of the impact, reaches its maximum for about 9 m/s. However this feature can be an outcome of the shapes nearly next to the vehicles used.

The impact point position (L) measured alongside the profile of the vehicle is well connected with the pedestrian's size parameters (T) and the impact speed (for 32 Km/h : $T < L < 1.3\ T$).

In our rank the HIC values are relatively low owing to the head's impact in the windscreen, this because of the position of the subject in relation to the vehicle, chosen in the case of these tests. The impact on more agressive frames should worsen the head acceleration levels.(9)

The ground fall phasis seems very uncertain and not much influenced by the impact parameters.

In our tests rank the head impact speed on the ground remained less high than the head impact speed on the windscreen.

III - ANALYSIS OF THE CEPHALIC SEGMENT INJURIES :

We have the results of 93 tests with cadavers experimented in the two impact configurations, at impact speeds between 10 and 39 Km/h, with the help of 6 mass production passenger cars.

After each test the subject is examined by the anatomic laboratory's team. The list of lesions are drawn up with the help of X-Ray pictures and the autopsy's result. This investigating protocol is satisfactory at the level of the resolution of the osseous lesions. On the other hand it remains inadequate to evaluate lesions of the encephalon. The use of the scaling of the severity of head injuries with the help of the AIS is therefore only an estimate owing to the importance of the conscience level in the severity of cephalic lesions.

We have kept as estimation elements the number of lesions noticed, the typology of these lesions as well as the assessment of the severity with the help of the AIS, without considering the changes of the index due to the loose of consciousness.
The results of these analyses are given in Figures 20 and 21.

We notice that the occurrence of the head and the neck's lesions is frequent. This frequency is higher in the frontal impacts case (80 % of the cases) than in profile impacts (69.6 %).

The protection offered by the arm's interposition and the reduction of the head's impact speed on the vehicle, in this configuration, can explain this difference.

Legend of the figures N°20 and 21:

I1:Contusions (head and neck)

I2:Wounds (head and neck)

I3:Fractures of the skull

I4:Fractures of the face

I5:Fractures of the cervical spine

I6:Ruptures of ligaments (cervical spine)

O.I.:Injuries of the other segments
(Thorax;Pelvis;Upper and Lower Extremities)

Fig.N°:20 FOC**INJURIES HEAD & NECK

Number of injuries:FACE

NUMBER	VEHICLE	SPEED	I1	I2	I3	I4	I5	I6	O.I.
FOC9/2	G+VD	10	0	0	0	0	0	0	0
FOC 9/3	G+VD	10	0	0	0	0	0	0	0
FOC 11/1	G+VD	10	0	0	0	0	0	0	0
FOC 14/4	G+VD	20	0	0	0	0	0	0	3
FOC 17/4	G+VD	20		1		2			2
FOC 20/4	G+VD	20		1					3
FOC 22/3	G+VD	25							2
FOC 26/1	VISA	25							0
FOC 43/1	VISA	25							0
FOC 43/4	VISA	25							1
FOC 46/3	VISA MO	25							0
FOC 02	VISA MO	25		1		1			5
FOC 04	VISA MO	25		1		1			5
FOC 27	GSA	25		1					10
FOC 30	GSA	25		1					5
FOC 31	GSA	25		1	1	2			
FOC 13	GSA	32		1					2
FOC 15	GSA	32		1	1	4			3
FOC 16	VISA	32		1					8
FOC 18	VISA	32		1		3			10
FOC 43	VISA	32		1					15
FOC 54	GSA	32	2	2					6
FOC 61	VISA	32		1			1		12
FOC 63	X/GS	32	2		1		1		9
FOC 66	X/GS	32			1	1		1	15
FOC 67	X/GS	32	2		1	1	1		12
FOC 68	X/GS	32		2		1	3		7
FOC 69	X/GS	32	1				1		9
FOC 78	505	32		1	1	1			7
FOC 81	505	32		1					6
FOC 88	505	32		2					14
FOC 90	505	32		1					5
FOC 92	GSA	32		1		1			2
FOC 100	2CV	32	1		1		2		10
FOC 104	2 CV	32	2						3
FOC 105	2 CV	32	2			1			8
FOC 107	505 MOD	32		2	1				14
FOC 108	505 MOD	32		2					11
FOC 109	505 MOD	32		1					8
FOC 110	505 MOD	32		1					9
FOC 96	2 CV	32	4	1	1				16
FOC 05	VISA	39		1	1				5
FOC 07	VISA	39		1					17
FOC 09	GSA	39		1		2			10
FOC 11	GSA	39		1		2			14
FOC 50	GSA	39	1	1	1	2	1	1	12
FOC 73	VISA	39	1				1		15
			18	35	11	25	11	2	330

FICHIER	1
DATE	24/05/84
NOMBRE	47

Fig.N°:21 FOC**INJURIES HEAD & NECK

Number of injuries :PROFILE

NUMBER	VEHICLE	SPEED	I1	I2	I3	I4	I5	I6	O.I.
FOC 9/1	G+VD	10	0	0	0	0	0	0	0
FOC 11/2	G+VD	10	0	0	0	0	0	0	0
FOC 14/5	G+VD	20	0	0	0	0	0	0	0
FOC 17/5	G+VD	20		1					3
FOC 20/3	G+VD	20					1		4
FOC 22/4	G+VD	25	1			1			0
FOC 26/2	VISA	25							3
FOC 26/3	VISA MO	25	1						2
FOC 43/2	VISA	25	1						2
FOC 46/5	VISA MO	25							2
FOC 03	VISA MO	25		1					4
FOC 32	GSA	25		1					3
FOC 35	GSA	25							3
FOC 38	GSA	25		2					0
FOC 14	GSA	32							11
FOC 17	VISA	32		1					14
FOC 39	VISA	32							15
FOC 46	VISA	32		1	1	3			6
FOC 55	GSA	32	1	1					23
FOC 56	GSA	32	1						17
FOC 62	VISA	32	1						4
FOC 64	X/GS	32	1						24
FOC 65	X/GS	32	1						4
FOC 70	X/GS	32	1		1				9
FOC 71	X/GS	32							9
FOC 72	X/GS	32		2					4
FOC 79	505	32		1					16
FOC 84	505	32		1					4
FOC 87	505	32		1					18
FOC 89	505	32	2		2				8
FOC 91	GSA	32							19
FOC 97	2 CV	32	1						9
FOC 101	2CV	32		2	1				14
FOC 102	2 CV	32							15
FOC 103	2 CV	32							5
FOC 111	505 MOD	32	2						13
FOC 113	505 MOD	32							7
FOC 120	505 MOD	32		1					8
FOC 121	505 MOD	32					1		6
FOC 06	VISA	39		1					15
FOC 08	VISA	39		1					8
FOC 10	GSA	39		1	2			1	19
FOC 12	GSA	39		1	2	1			6
FOC 41	VISA	39		1					7
FOC 45	VISA	39		1			1	1	12
FOC 52	GSA	39	1		1	1			13
			15	22	10	6	3	2	388

FICHIER	1
DATE	24/05/84
NOMBRE	46

III - 1. Distribution of the lesions :

The "minor" lesions (AIS $\leqslant$ 2 : bruises and wounds) represent 57 % of the number of injuries recorder (Fig.N°22).

Number of injuries		CONT. H&N I1	WOUND H&N I2	FRACT SKULL I3	FRACT FACE I4	FRACT CER.S I5	RUPT. CER.S I6	TOTAL
FRONTAL:	Nbr	18	35	11	25	11	2	102
	%	17.4	34.3	10.8	24.5	10.8	2.0	100.0
PROFILE:	Nbr	15	22	10	6	3	2	58
	%	25.9	37.9	17.2	10.4	5.2	3.4	100.0
TOTAL:	Nbr	33	57	21	31	14	4	160
	%	20.6	35.6	13.1	19.4	8.8	2.5	100.0

Fig.n°22:Distribution of the number of injuries (head and neck-93 tests with cadavers)

The fractures of the skull are more frequent in profile impacts whereas the fractures of the face are more numerous in the frontal impacts. This is in accordance with the results of the kinematic analysis.

The frontal impacts seem to induce more lesions of the cervical spine than in the other configuration.

We notice that the fractures of the skull and of the face as well as the lesions of the cervical spine are only appearing for impact speeds equal or greater than 32 Km/h.

We did not take note of any influence of the car design impacting at the generation of the head and neck's lesions level.

III - 2.Typology of the lesions :

The detail of the lesions of AIS > 2 is given in Figure N°23.

FRACTURES OF THE FACE (31 cases)

fracture of nasal bones	:13
fracture of the socket	: 5
fracture of the maxillary	: 2
fracture of the malar	: 2
fracture of the ethmoid	: 4
fracture of the teeth	: 3
fracture of the maxillary sinus	: 1
complex fracture	: 1

FRACTURE OF THE SKULL (21 cases)

ethmoido-frontal fracture	: 2
fracture of the frontal sinus	: 2
fracture of the occipital	: 1
temporo-occipital fracture	: 1
fracture of the parietal	: 2
occipito-parietal fracture	: 3
parieto-frontal fracture	: 2
fracture of the frontal	: 3
parieto-temporal fracture	: 2
fracture of the temporal	: 3

FRACTURE OF THE CERVICAL SPINE (14 cases)

fracture of the vertebral body	C4:	3
	C5:	3
	C6:	4
articular fracture	C7/D1:	2
	C5/C6:	1
	C4/C5:	1

Fig.N°23:Typology of head and neck injuries (93 tests with cadavers)

We notice the diversity of the lesions found. For the face the osseous fracture specific to the nose is dominating whereas for the skull the fractures are distributed on the whole brain-box letting suppose that some are attribuable to the ground fall (at the occipital level for example).

The cervical spine injuries are mainly fractures of the vertebral body or of the apophyses. We notice that the lesions are only appearing below the 4th cervical vertebra.

III - 3. Assessment of the injuries severity :

Although it is difficult to appreciate completely the severity with the aid of the AIS applied to the cadavers, we notice that a predominancy of the low severity lesions (AIS $\leqslant$ 2) particularly outstanding for the profile impacts, as the Figure N° 24 shows it.

AIS		0	1	2	3	4	5	TOTAL
FRONTAL:	Nbr	4	19	8	9	7	0	47
	%	8.5	40.4	17.0	19.2	14.5	0	100.0
PROFILE:	Nbr	17	20	1	3	4	1	46
	%	36.9	43.5	2.2	6.5	8.7	2.2	100.0

Fig.n°24:Distribution of tests with cadavers according to the severity of the injuries of head & neck

In general conclusions from the lesions analysis, we notice :

- The cephalic segment (head and neck) is very exposed during pedestrian-vehicle impact whatever the impact speed, the vehicle design or the impact configuration is. We notice however that the serious osseous lesions are appearing from 32 Km/h. In 31 % of the cases where the subject is injured, the head and the neck's lesions were the most serious lesions.

- Profile impacts are those producing the highest number of lesions and the lesions of highest severity.

- If the influence of the impact configuration and the impact speed is obvious, on the other hand we have noticed no connection between the generation of head and neck's lesions and the type of the impacting vehicle.

IV - DISCUSSION :

We notice that it is possible to know better the head's kinematic from experimental impacts. The influence of some impact parameters can be put in a conspicious position whereas for other, chosen tests conditions, in particularly the choice of the vehicles used, do not allow it.

The knowledge, according to the impact conditions of the characteristics such as the ratios VTA/VO and L/T is important. This allows to assess the behaviour of vehicle structure components during splitted up tests. It is then possible to have notions of shape and/or of stiffness of these structures brought in to try to protect the cephalic segment during vehicle-pedestrian accidents.

It is interesting to notice that the dummy's behaviour is quite satisfactory, particularly at the kinematic level. This recording meets other similar works.

The assessment of the lesions severity is made difficult for a quotation with the aid of an index (AIS) inadequate to the use with cadavers. The taking in mind of tolerance notions, clinical recordings and the research of equivalences between the observed lesions on the living and on cadavers will allow to refine this analysis of the consequences of the pedestrian-vehicle impacts in terms of injuries. The problems of similarity of mass production cars, at the level of shapes, sizes and building technological solutions have brought us to follow our research program by using an experimental platform fitted with a modifiable and evolutive frontal face. This allows us to analyse the pedestrian's kinematic according to the isolated or joint influence of each structure component, according to its situation and/or its stiffness.

It is then possible to visualize the pedestrian's whole kinematic without being constraint by a freezed position of the bonnet, the windscreen or the wing of a normal vehicle. As well, the difficulty of realistic assessment of the lesions severity noticed during an experimental impact with dead-bodies, orientate us towards taking into account the clinical cases analysis in order to characterize better the importance of the lesions noticed.

Finally, the better knowledge of the pedestrian's kinematic parameters allow us to carry out splitted up research tests on the biomecanical tolerance of different bodily segments during impacts such as those met during pedestrian-vehicle tests.

BIBLIOGRAPHY:

1. EXPERIMENTAL STUDY OF INJURIES OBSERVED ON PEDESTRIANS:
P. BOURRET et al. - IRCOBI, GOTEBORG 1979.

2. EXPERIMENTAL STUDY OF PEDESTRIAN KINEMATICS AND INJURIES:
D. CESARI et al. - IRCOBI, BIRMINGHAN 1980.

3. ANATOMICAL AND BIOMECANICAL STUDY OF INJURIES OBSERVED DURING EXPERIMENTAL PEDESTRIAN-CAR COLLISIONS:
J. FARISSE et al. - IRCOBI, SALON 1981.

4. EVALUATION OF PEDESTRIAN LOWER LIMBS SEVERITY: PROPOSALS FOR A DETAILLED SCALE:
J. FARISSE et al. - SAE, DETROIT 1983.

5. A DETAILED INJURY SEVERITY SCALE FOR LOWER LIMBS BASED ON ANALYSIS OF INJURIES SUSTAINED BY PEDESTRIANS:
J. FARISSE et al. - STAPP/IRCOBI, SAN DIEGO 1983.

6. IMPROVMENT OF PEDESTRIAN SAFETY: INFLUENCE OF SHAPE OF PASSENGER CAR FRONT STRUCTURES UPON PEDESTRIAN. KINEMATICS AND INJURIES: EVUATION BASED ON 50 CADAVER TESTS:
C. CAVALLERO et al. - SAE, DETROIT 1983.

7. COMPARISON OF PEDESTRIAN KINEMATICS AND INJURIES IN STAGED IMPACT TESTS WITH CADAVERS AND MATHEMATICAL 2D SIMULATIONS:
S. BACKAITIS et al. - SAE, DETROIT 1983.

8. COMPARISON OF EXPERIMENTAL CAR-PEDESTRIAN COLLISIONS PERFORMED WITH VARIOUS MODIFIED SIDE IMPACT DUMMIES AND CADAVERS:
F. BRUN-CASSAN et al. - STAPP, CHICAGO 1984.

9. PROPER USE OF HIC UNDER DIFFERENT TYPICAL COLLISION ENVIRONMENTS:
D. LESTRELIN et al. - ESV, KYOTO 1982.