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COMPARATIVE KINEMATICS OF PEDESTRIAN SURROGATES

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INTRODUCTION

The motion of a pedestrian who is struck by a vehicle often exhibits a complex spatial pattern. Thus, test analysis methods have to be applied which are capable of coping with such complicated motion patterns because we attempt to simulate real world events in the impact laboratory as closely as possible. In particular, the variability and sensitivity of spatial trajectories of specific body parts, primarily of the center of gravity of the head are to be documented, furthermore, the positions of the entire body as a function of time is of interest. In test programs which involve the use of cadavers as surrogates, instrumentation possibilities may be limited, such that comprehensive high speed film analysis is of importance. In order to fulfill all of these needs to the best possible, the test methodology which is described in the following was developped:

METHODOLOGY

The head of the impacted surrogate is equipped with up to 30 markers of an adhesive foil of high-gain SCOTCHLITE material. The spatial positions of these markers with respect to a fixed point in the Frankfurt plane are measured with a special angular measurement device. The crash test is filmed from 4 high speed cameras at a frame rate of 500 frames per second.

In order to facilitate the application of close-range photogrammetry, a calibration grid consisting of 14 spheres is filmed prior to the impact. The tracking of a number of markers over 300 frames in 4 films requires several thousand image coordinates to be measured. In addition, camera calibration and reconstruction of trajectories in the object space have to be performed. For this pupose, a semiautomatic film analysis system was developed which consists of a computer-controlled stop-frame projector, a video image dissector whith a resolution of 4000 * 4000 points per frame, a high-speed digital image memory and a computer.

Details of this system and its performance were presented elsewhere (IRCOBI,1982) such that no further explanation need be given here.

Application of the DLT yields the spatial trajectories of individual markers. If the positions of at least 3 markers on the head are known at a given instant of time, the center of gravity of the head including its spatial orientation can be determined (VELDPAUS,1980) (Fig. 1). As a result the trajectory of the head as well as its rotation as a function of time is known, exept for some parts where the aforementioned condition is not fulfilled. These unknown fragments are interpolated using cubic spline functions (Fig. 2). Furthermore optimally regularized fourier series are applied for data smoothing and to estimate first and second-order derivatives (ANDERSSEN,1980). Because the temporal resolution of the acceleration obtained from film data is limited, no second order derivatives are used to calculate the HIC. Instead, linear acceleration measurements are used for this purpose. In contrast, we found that derivatives of displacement data were the best way to get reliable velocity information of the spatial motion of the head (Fig. 3).

Finally, the problem of visualizing the 3-D pedestrian motions remaind to be solved. For this purpose a measurement mannequin was constructed with a triplet of protracters built in at every joint. This mannequin has the structure of a 12 segment 3-D pedestrian model and corresponds to the Part 572 dummy with the neck pivot, the wrists and ankles fixed to a specified angle value (Fig 4).

The positions and directions of all body segments at a given instant of time are found by visioning the high speed film and adjusting the parts of the mannequin as closely as possible to the positions of the dummy at the corresponding time points during impact, typically 50, 100,150 milliseconds after beginning of the crash.

If additionally the dimensions of all segments and the spatial position of the head is known, the entire body configuration is known. Errors due to inevitable misalignment are not of significance as far as only the gross kinematics are concerned.

Once the positions and orientations of all segments are known, the surrogate can be visualized with the help of a plotting routine, which outlines the shadows of ellipsoids in a central projection. With the aid of this representation it is possible to compare the kinematics of different types of impacted surrogates and, in particular, a validation of the CALSPAN CVS program can be given (Figs.5-6).

TEST RESULTS

In the following a comparison is made between a modified Humanoid Part 572, an Ogle Mira ATD and a cadaver of approximately the same height. The test configurations have been chosen as follows:

IMPACT SPEED:	25 KM H
IMPACT LOCATION ON VEHICLE:	CENTER,OCCIPITAL
CAR FRONT:	MODFIED RABBIT

Because of a relatively loose hip joint but a stiff upper leg, the left leg of the Part 572 dummy is swung upwards at the beginning of the impact. Due to this circumstance, the hip of the dummy is loaded on the hood of the car. The ellbow prevents a direct head impact.

The Ogle Mira dummy has a hip construction which renders it quite stiff, such that the upper leading edge of the car virtually strucks the lower abdomen. This results in a higher axis of rotation of the body and thus in a head impact location closer to the front end of the car. A similar head trajectory is obtained with the part 572 dummy and an impacting car with a higher upper leading edge (Fig.7).

The cadaver which was used in this particular test already showed signs of rigor mortis such that it is not necessarily representative with regard to its kinematics. Nevertheless the example is of interest. If one compares the acceleration curves of the Ogle Mira and the cadaver, one finds that they resemble each other in practically every detail. Yet this does not imply that also the associated kinematics are similar.

For the following reason, only three cadaver testes were conducted in this project up till now. One question which in our opiniion is of particular interest is to what extent accelerations of the head center of gravity correlate with subdural pressure measurements. In order to conduct meaningful pressure measurements, part of the circulatory system of the cadaver needs to be pressurized to a physiological value. It turned out that due to all the manipulation which is necessary to bring the cadaver into the desired upright test position, the brain pressurization could not be maintained reliably. We therefore felt that the pressurization methodology had to be brought into a more reproducible form before a systematic cadaver program should be conducted.

COMPARISON TO THE CALSPAN 3D CVS PROGRAM

The advantage of this program in simulating pedestrian impacts consists in its flexibility for defining the crash configuration moreover the number of allowable segments is virtually unlimited. Difficulties however arise from the input to the model, which consists of anthropometric data of the body segments as well as data on vehicle geometry and functions describing force-deflection characteristics of the contacts between the body segments and the vehicle surfaces. Besides, initial conditions are required to start the simulation. The formatted input scheme in the original CALSPAN Program for such a big data set is very awkward for the user.

An interactive preprocessing program was therefore written to allow for an easier handling of the input data and signifcantly reduce the probability of errors that yield wrong results or even stop execution.

Together with a postprocessing program, which picks up all calculated data of interest, i.e. data, which can be compared to the results found in experimental crash tests, a helpful tool has been created to extensively validate the simulation model.

Some further results of CALSPAN runs when varying the vehicle geometry and speed as well as dummy positioning are shown in Figs 8-11.

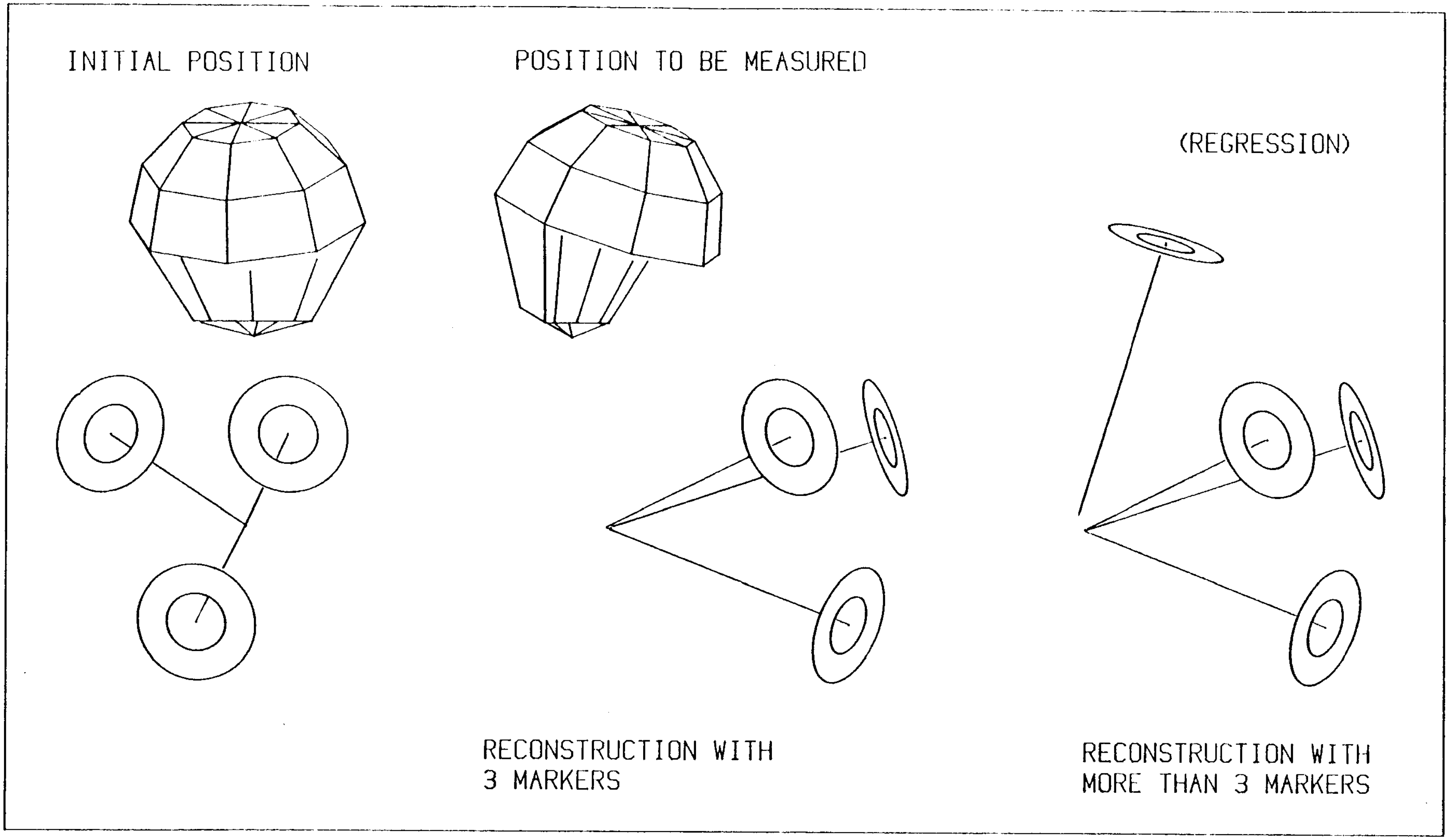
In conclusion, we found that the CALSPAN program together with pre- and post processor can be used as an efficient and reliable tool to simulate vehicle-pedestrian impacts.

REFERENCES

ANDERSSEN,R.S. BLOOMFIELD,P. (1974) Numerical differentiation Procedures
for non-exact data. Numer. Math. 22, 157-182

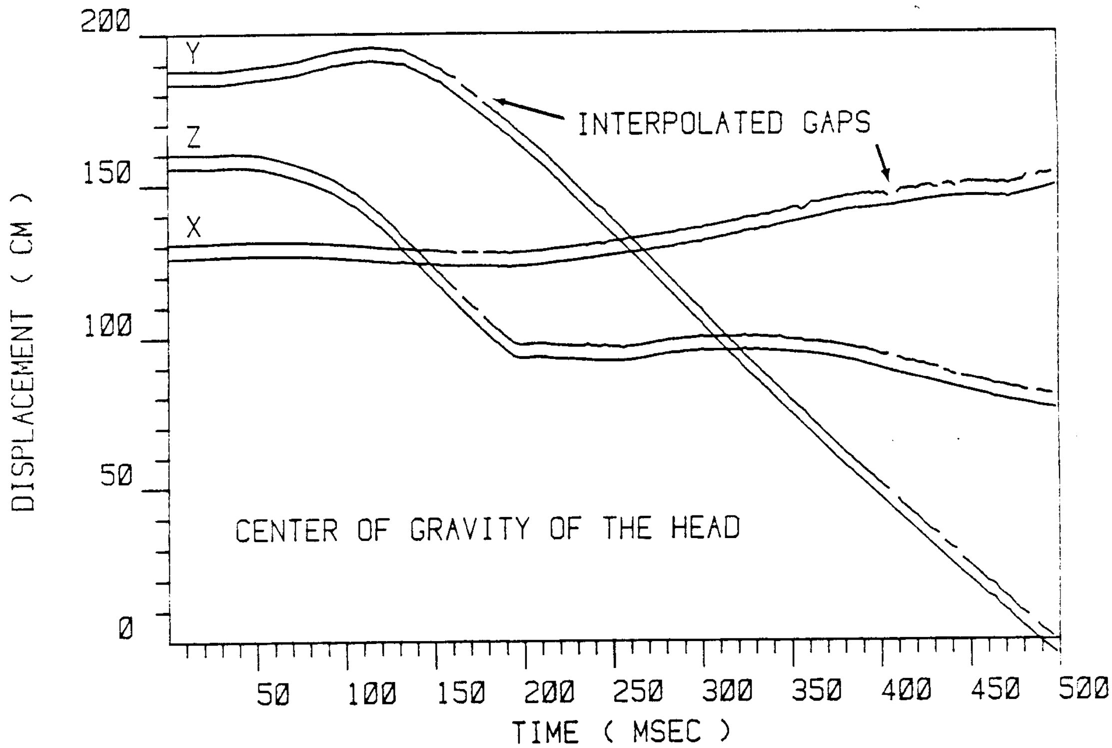
VELDPAUS,F.E. (1980) Biomechanics Vol. 13, 391-393

IRCOBI (1982) Automated motion analysis of simulated pedestrian
Impacts with the aid of digital high speed film processing.

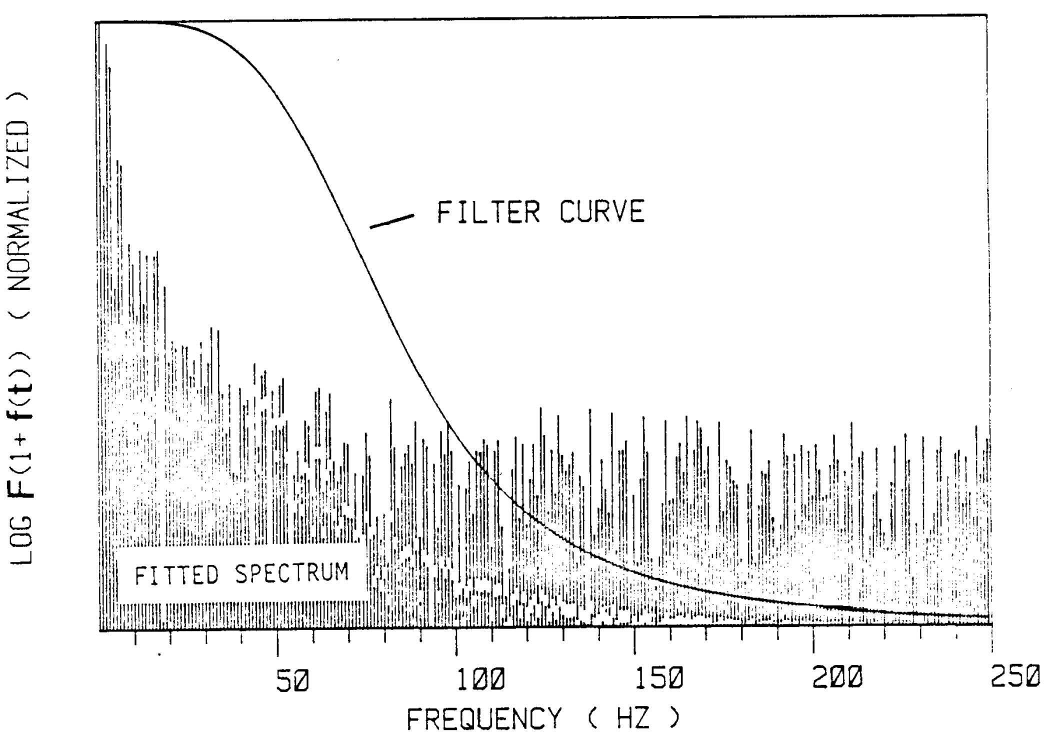


CALCULATION OF THE CENTER OF THE HEAD FROM THE SPATIAL COORDINATES OF THREE OF MORE MARKERS

Fig. 1

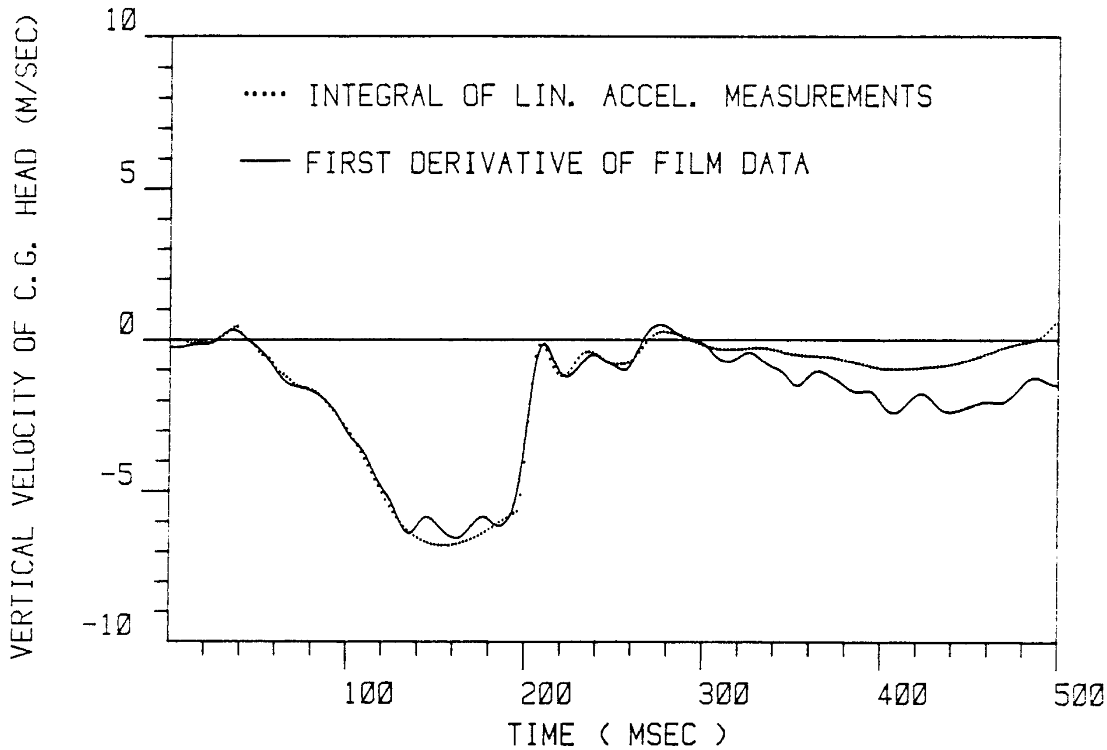


200
150
100
50
0
DISPLACEMENT (CM)
Y
Z
X
INTERPOLATED GAPS
CENTER OF GRAVITY OF THE HEAD
50
100
150
200
250
300
350
400
450
500
TIME (MSEC)



LOG F(1+f(t)) (NORMALIZED)
FILTER CURVE
FITTED SPECTRUM
50
100
150
200
250
FREQUENCY (HZ)

Fig. 2


VERTICAL VELOCITY OF C.G. HEAD (M/SEC)
10
5
Ø
-5
-1Ø
INTEGRAL OF LIN. ACCEL. MEASUREMENTS
FIRST DERIVATIVE OF FILM DATA
1ØØ
2ØØ
3ØØ
4ØØ
5ØØ
TIME (MSEC)

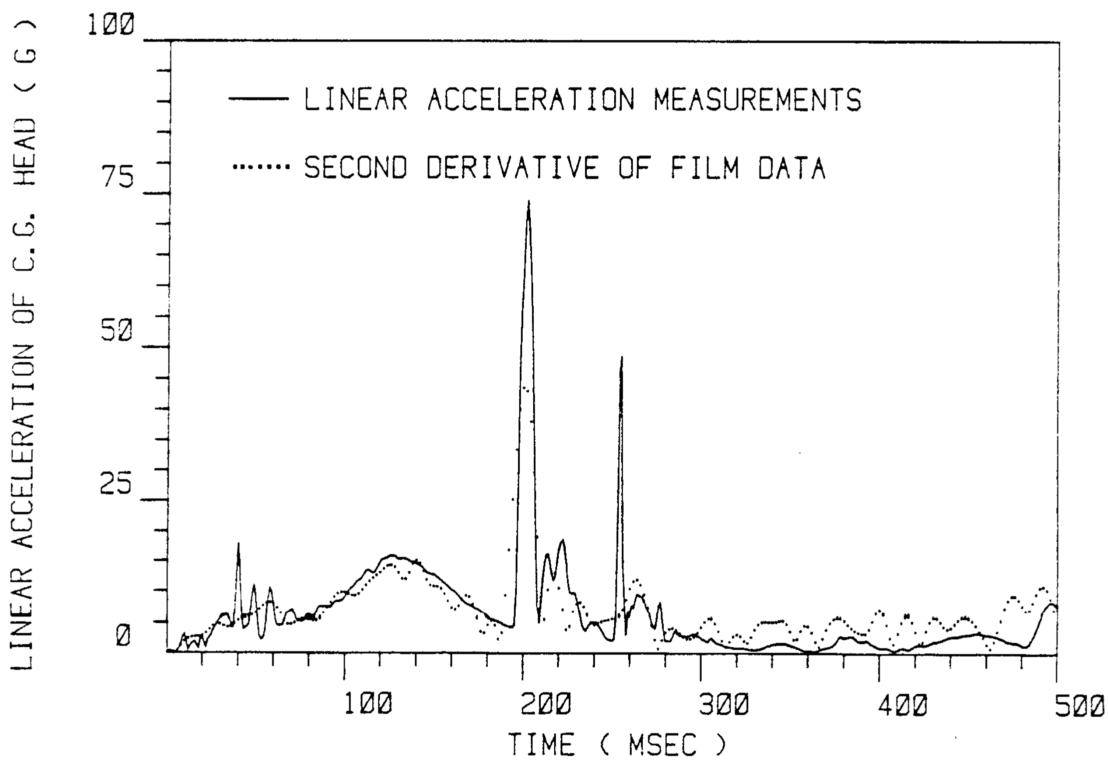
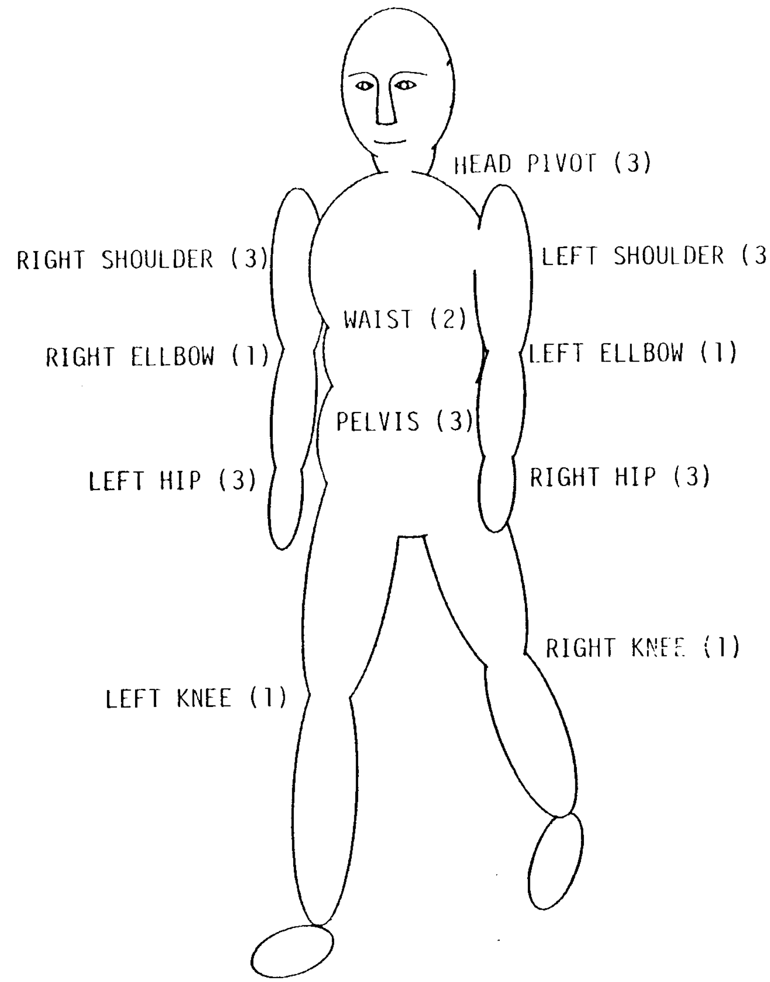
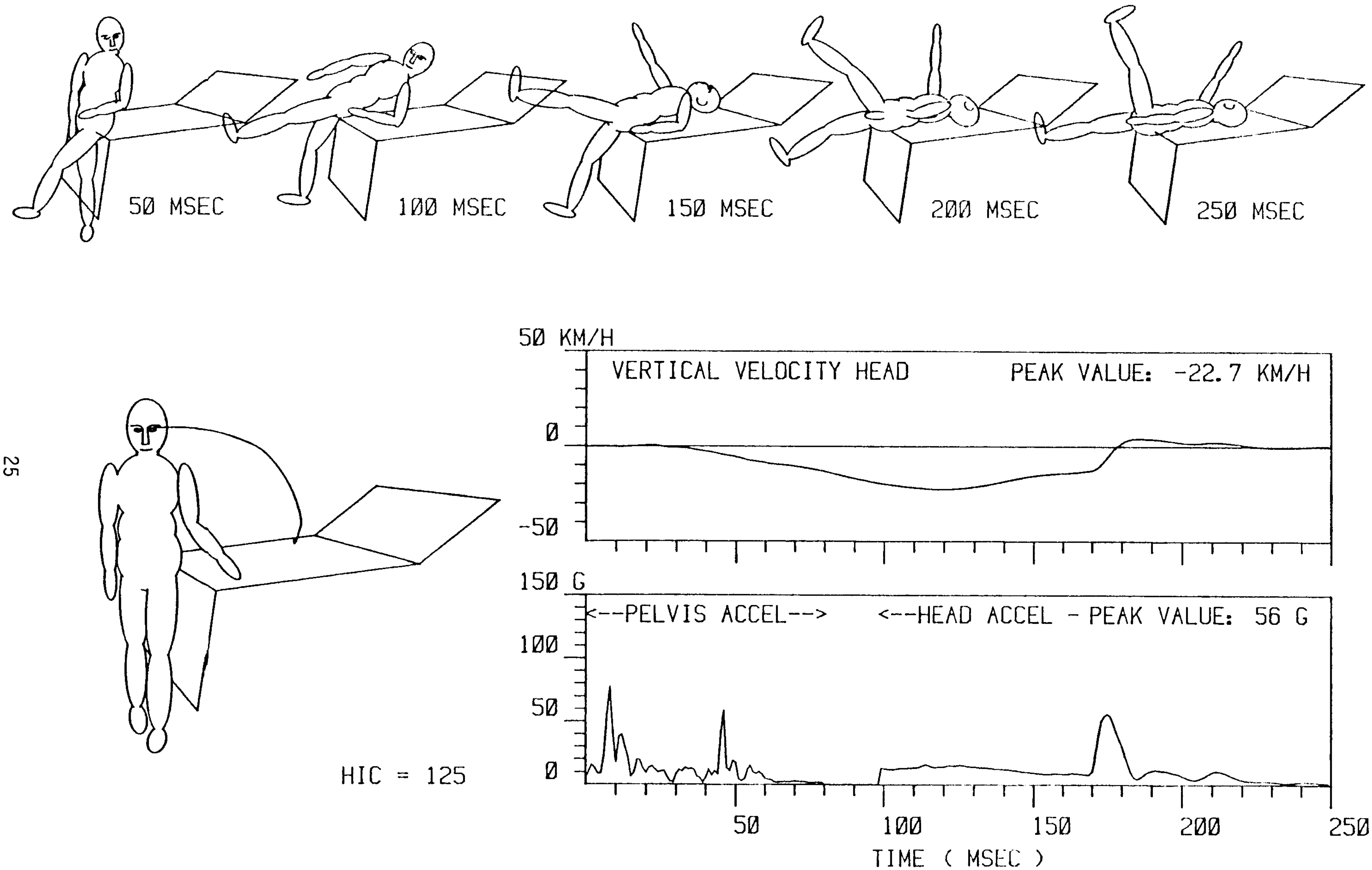

LINEAR ACCELERATION OF C.G. HEAD (G)
1ØØ
75
5Ø
25
Ø
LINEAR ACCELERATION MEASUREMENTS
SECOND DERIVATIVE OF FILM DATA
1ØØ
2ØØ
3ØØ
4ØØ
5ØØ
TIME (MSEC)

Fig. 3

Number and location of the angles which define the positions of a 12 segment dummy. These angles are adjusted with the help of the measurement mannequin.

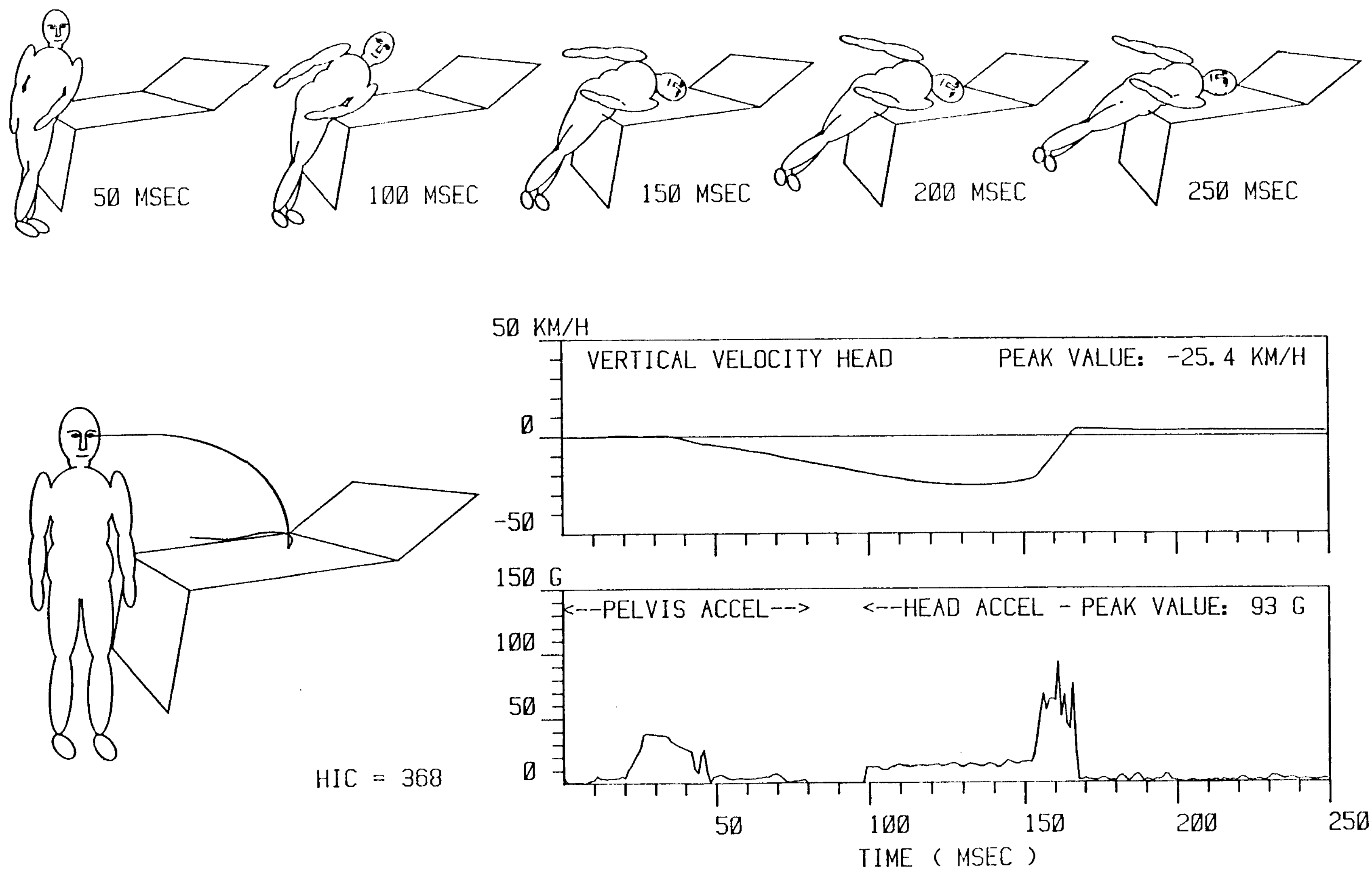
Fig. 4





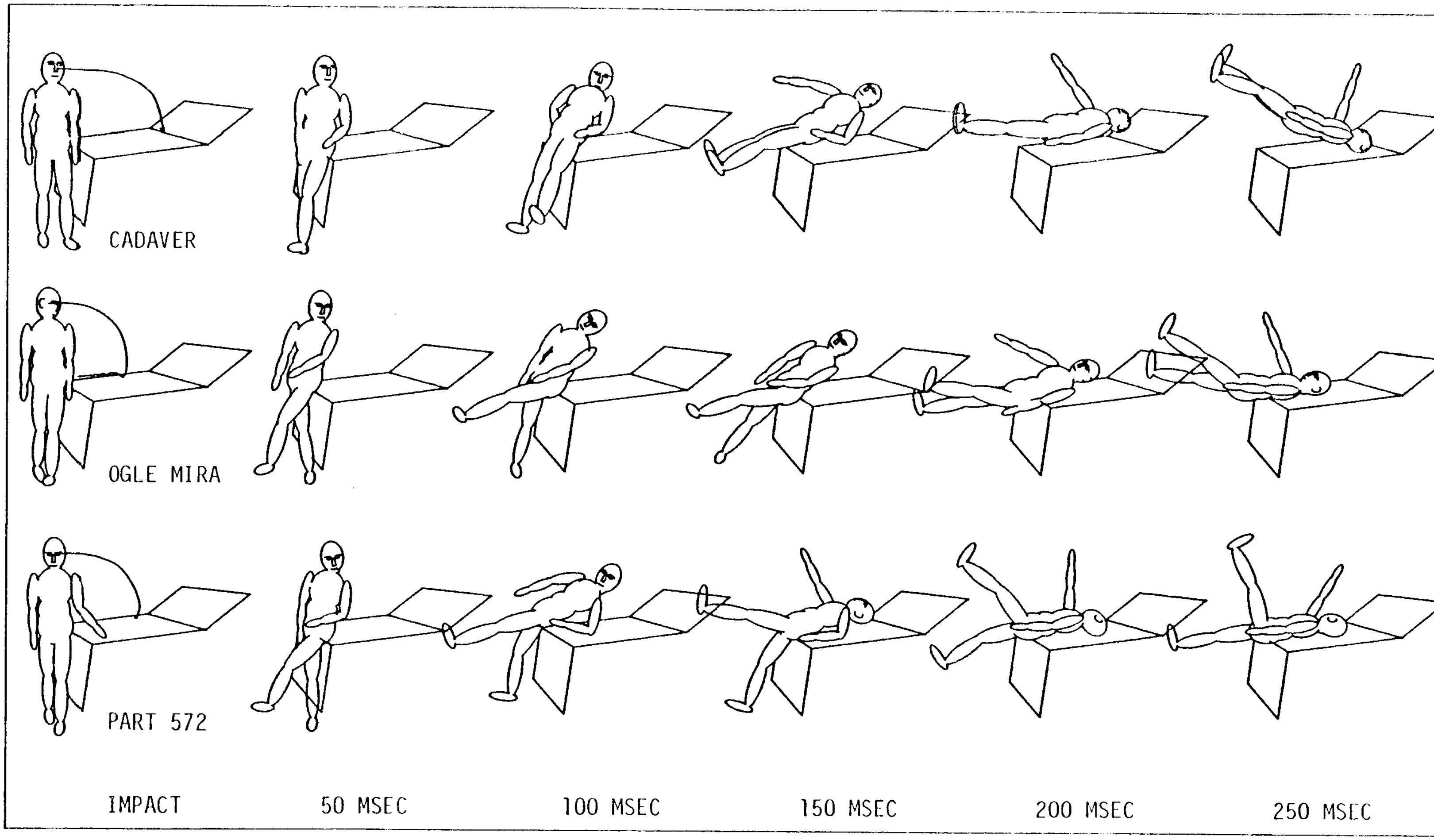
CRASH TEST : VICTIM: Part 572, Position: Central, Occipital
VEHICLE: Modified Rabbit (ULE = 85 cm, BLA = 82 deg), v_o = 25 km/h

Fig. 5



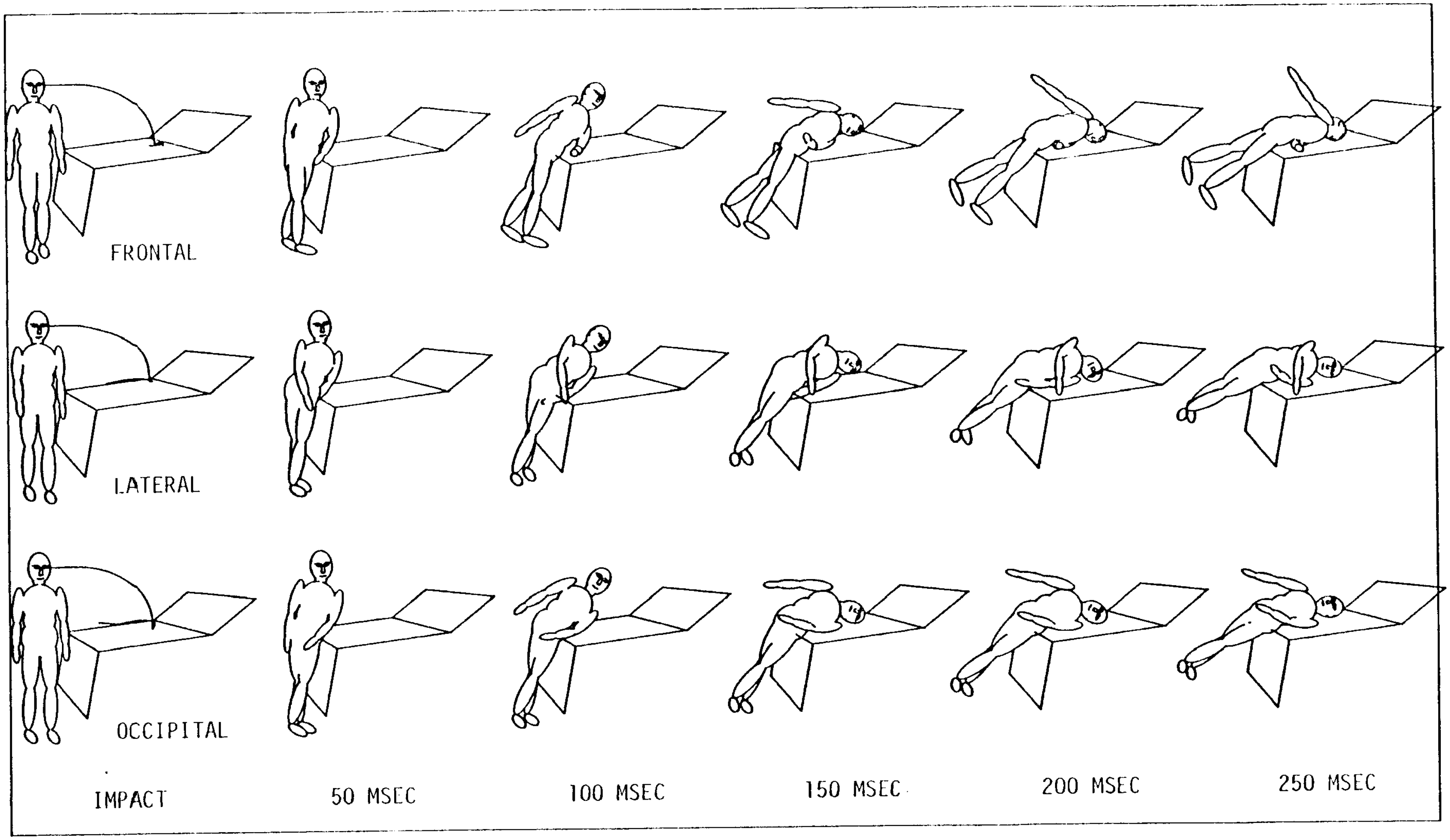
CALSPAN SIMULATION : VICTIM: Part 572 (Dimensions & Weights), Characteristics: CALSPAN
VEHICLE: ULF = 85 cm, BLA = 82 deg, v_o = 25 km/h

Fig. 6



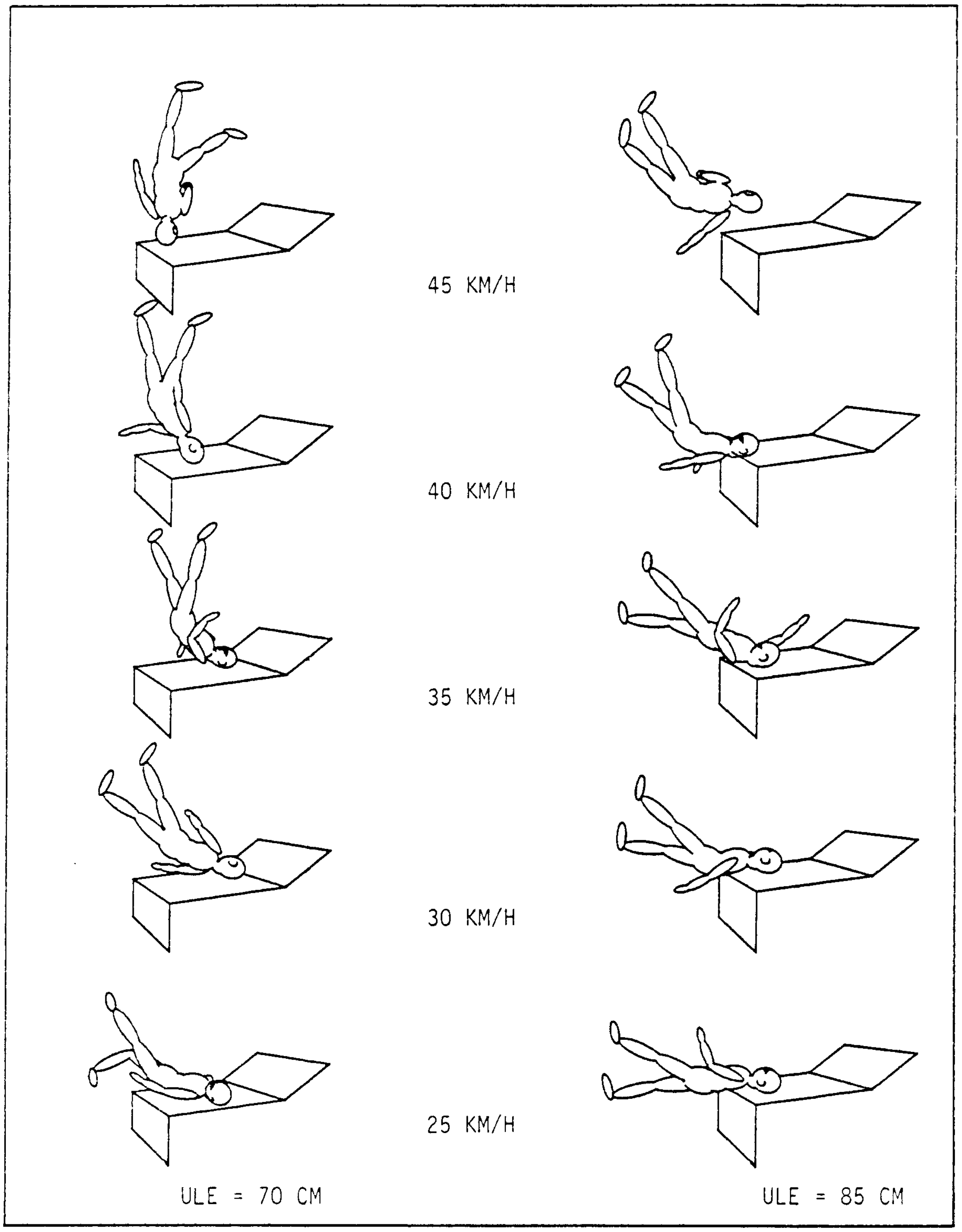
COMPARISON OF SURROGATES

Fig. 7



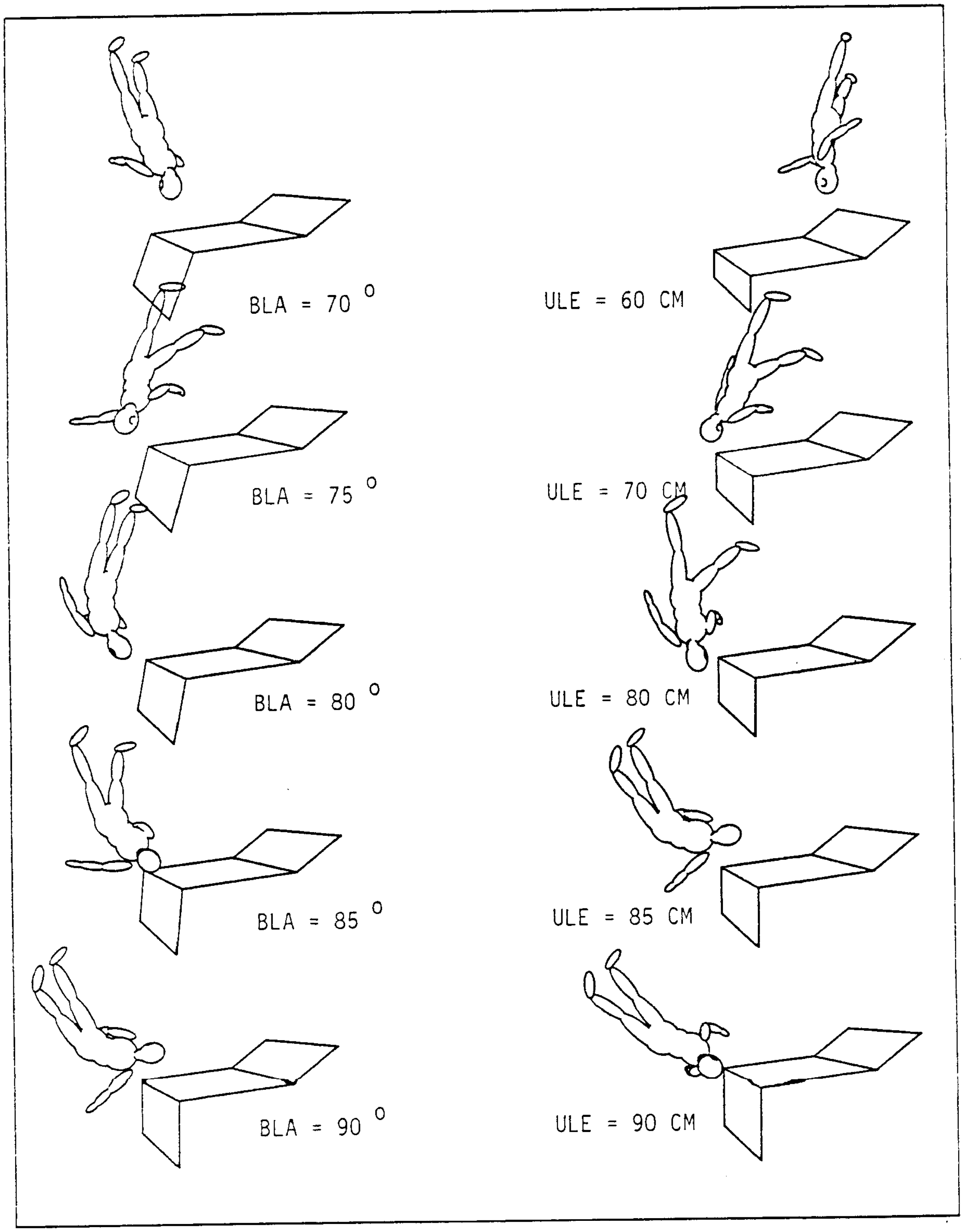
INFLUENCE OF LEG POSITIONING

Fig. 8



INFLUENCE OF IMPACT SPEED

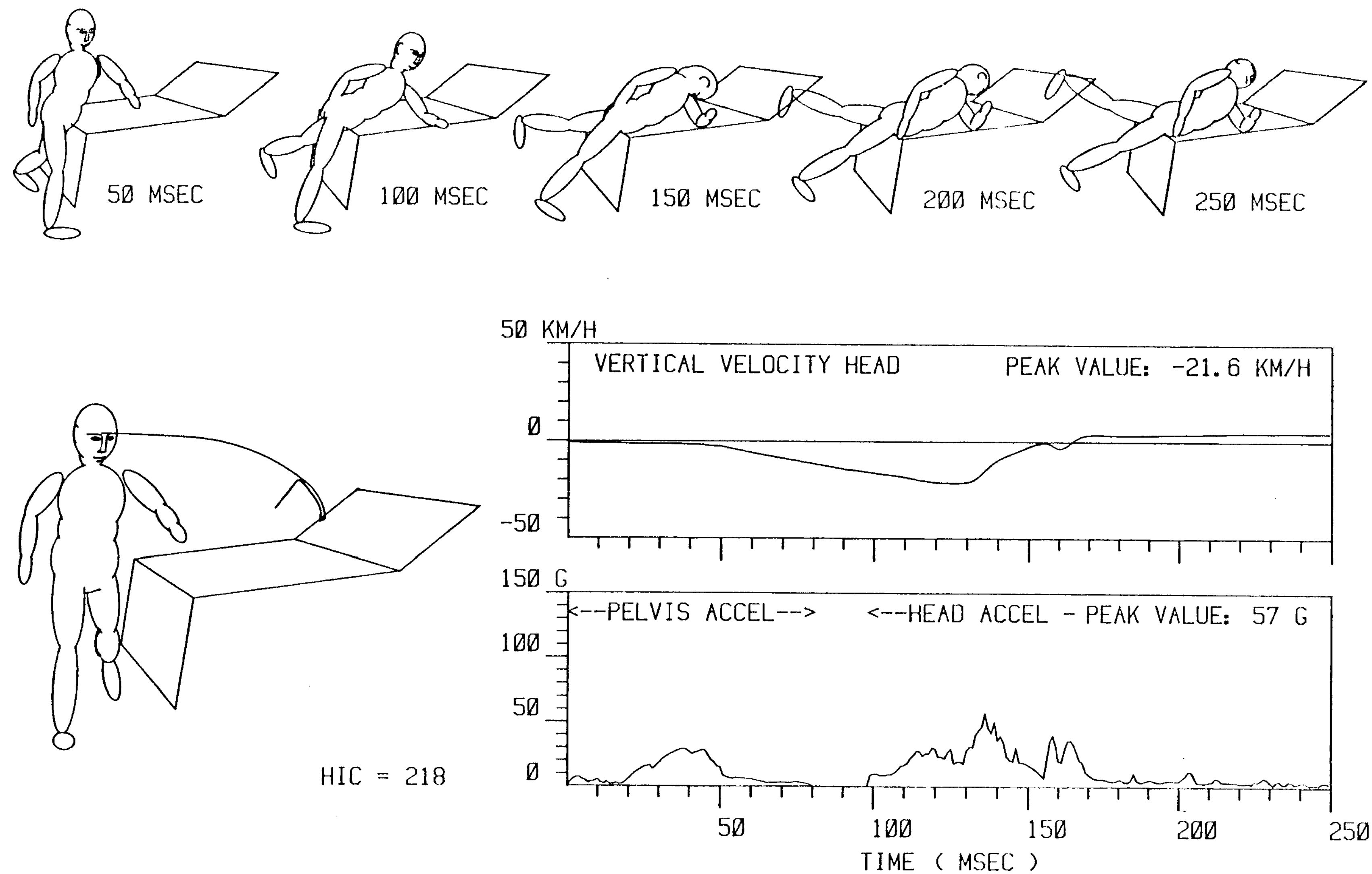
Fig. 9



LEFT SIDE: INFLUENCE OF BUMPER LEAD ANGLE (BLA)

RIGHT SIDE: INFLUENCE OF UPPER LEADING EDGE (ULE)

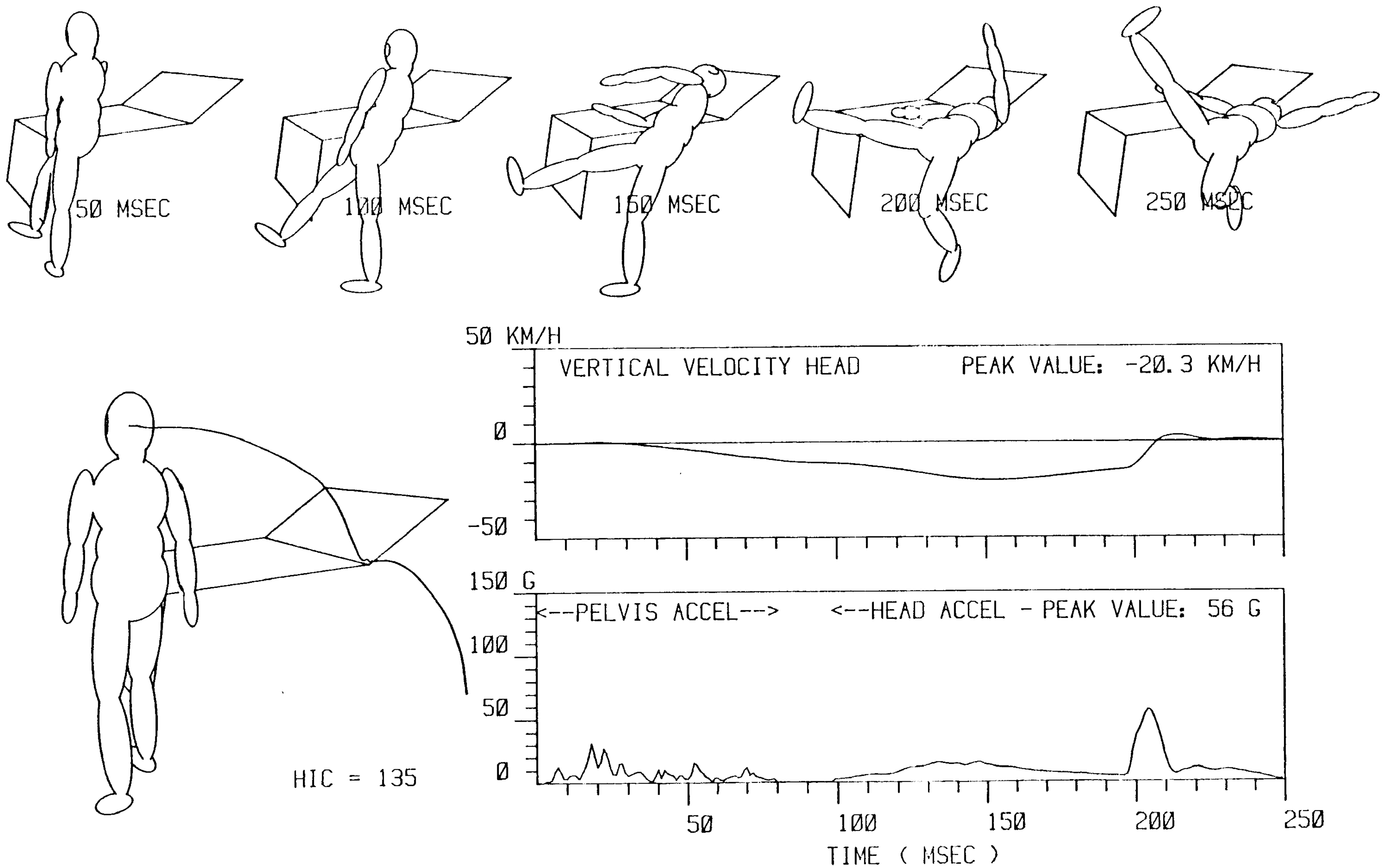
Fig. 10



CALSPAN SIMULATION : VICTIM: Part 572 (Dimensions & Weights), Characteristics: CALSPAN
VEHICLE: ULE = 85 cm, BLA = 82 deg, v_o = 30 km/h

('REAL WORLD ACCIDENT' : Running Pedestrian)

Fig. 11



CRASH TEST : VICTIM: Part 572, Position: Corner
VEHICLE: Modified Rabbit (ULE = 85 cm, BLA = 82 deg), v_o = 25 km/h