Abstract - Low Speed Collision TOPTEC
Tuesday, August 20, 1996

Rear End Collisions: Dummy Development, Seat Testing and Experimental Neck Injury Research

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Neck injuries in car accidents are usually classified as AIS-1 but they often cause long term pain, disability, etc. The number of these injuries is on the increase and the costs for the society and the insurance companies are huge. Rear impacts give the largest contribution to the number of neck injuries.

The injury symptoms have been well documented but the actual injury, causing the symptoms, has not yet been established. Consequently, the relationship between head-neck motion and injury risk is unknown. Head-restraints offer little protection against neck injuries in rear-end impacts and there is a lack of tools for testing their performance.

A research program to address these problems is ongoing at Chalmers University. Experimental neck trauma studies on anaesthetized pigs are done to investigate a hypothesis by Professor Bertil Aldman. His hypothesis predicts that transient pressure changes in the spinal canal during swift extension-flexion motion of the neck would cause injuries in the nerve root region. Transient pressure changes have been measured and injuries to the cervical spinal ganglia have been found. These injuries could well explain many of the typical "whiplash" symptoms.

It is still to be shown whether the transient pressure changes found actually cause the ganglion injuries. If this would be the case, it is likely that the injuries occur very early on during the rearward head-neck motion. This would, in turn, mean that the head-restraint would have to be close behind the head during the accident to be effective. A new dummy for rear impact testing is under development and as a first step, a new RID-neck (Rear Impact Dummy-neck) was designed and validated. This dummy neck was used to investigate the head-neck motion in various standard car seats during rear impact. The results revealed significant differences between all of the different seats tested and the rearward head-neck motion. By means of a test seat in which several seat properties could be varied, it was shown that minor changes to current seat designs would significantly reduce the head-neck motion during a rear-end impact. At the moment, a new rear impact dummy torso is under development.

Biography - Low Speed Collision TOPTEC

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Dr. Mats Svensson began his career in the field of impact bio-mechanics in 1985 when he did his M.Sc. thesis work on car-moose collisions. This work was done at Volvo in Göteborg, Sweden. Dr. Svensson continued the work on car-moose collisions at Volvo until 1987, developing and validating a moose dummy for crash testing.

Dr. Svensson started working on a neck injury project at the Department of Injury Prevention, Chalmers University of Technology in 1987. The aim was to investigate a theory by Professor Bertil Aldman regarding injury mechanisms in so-called "whiplash injuries." anaesthetized pigs were subjected to experimental whiplash motion and the results gave support to Aldman's hypothesis.

In parallel with the animal experiments, a new dummy neck was developed and validated for rear-impact crash testing at low Δv:s. The new RID-neck (Rear Impact Dummy-neck) was used to investigate the kinematics and kinetics of the head and neck during rear-end impacts for various standard car front seats. The findings indicated that not only the head-restraint design but the whole seat design influences the head-neck motion. An experimental seat was used to investigate the influence of some seat properties on the head-neck motion. It was found that the head-neck motion could be significantly reduced with small changes to current standard seat designs.

Dr. Svensson finished his Ph.D. thesis in 1993. He now continues his work on neck injuries at the Department of Injury Prevention, focusing on dummy development and animal testing to investigate injury mechanisms.

Rear End Collisions: Dummy Development, Seat Testing and Experimental Neck Injury Research

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- Neck Injury Mechanisms

  Injury site
  Tissue type
  Relation between neck motion and injury risk

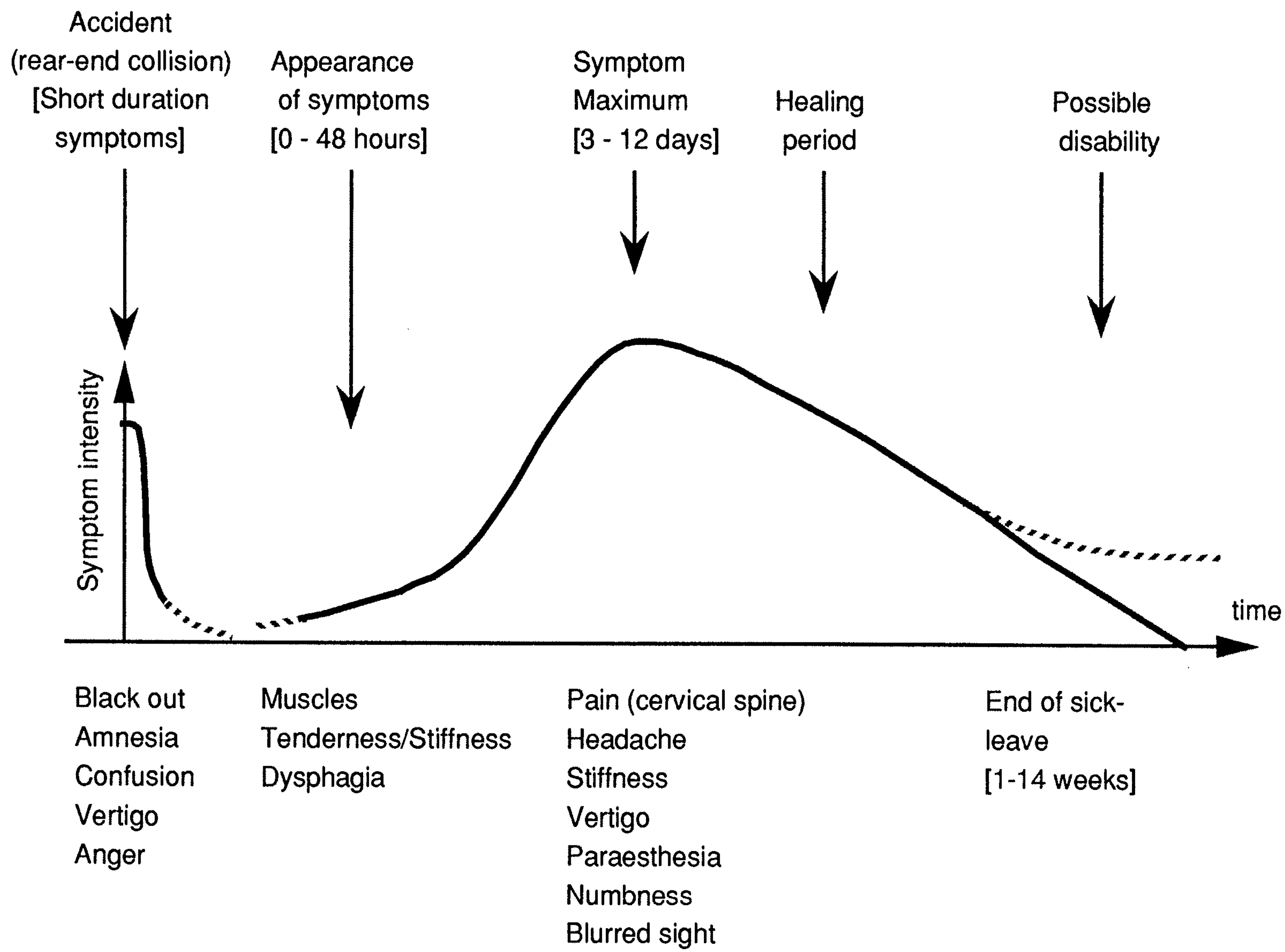
- Rear-impact Dummy Development

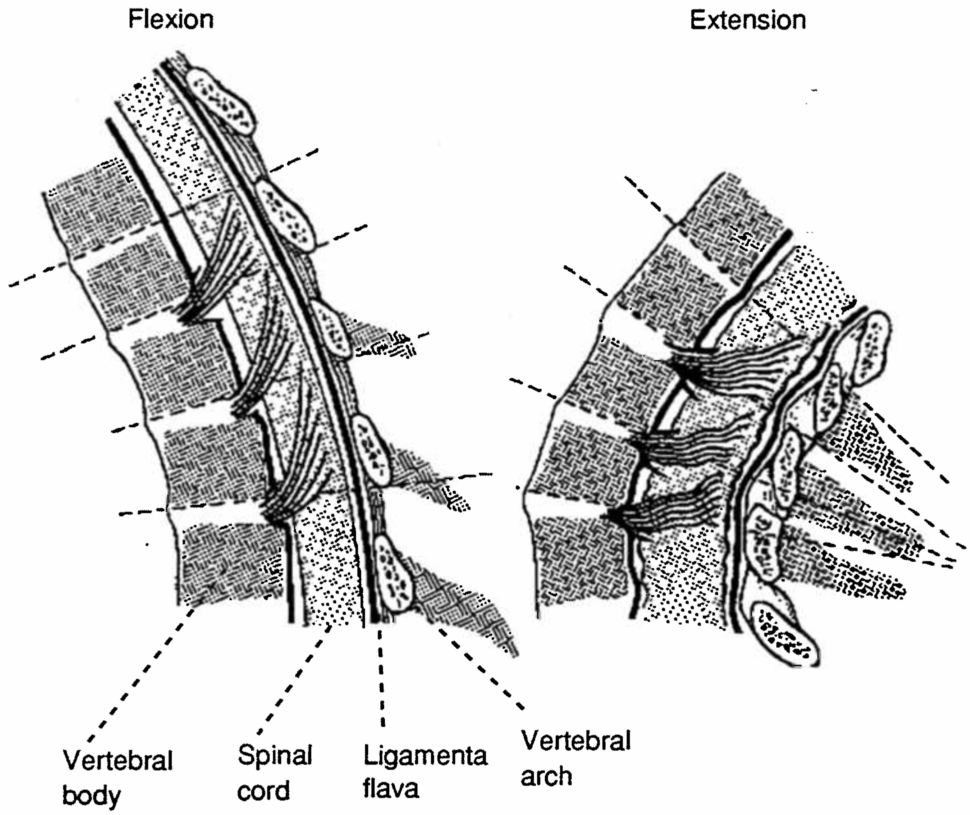
  Volunteer testing
  MADYMO modelling
  Cervical spine development
  Torso development

- Seat Design

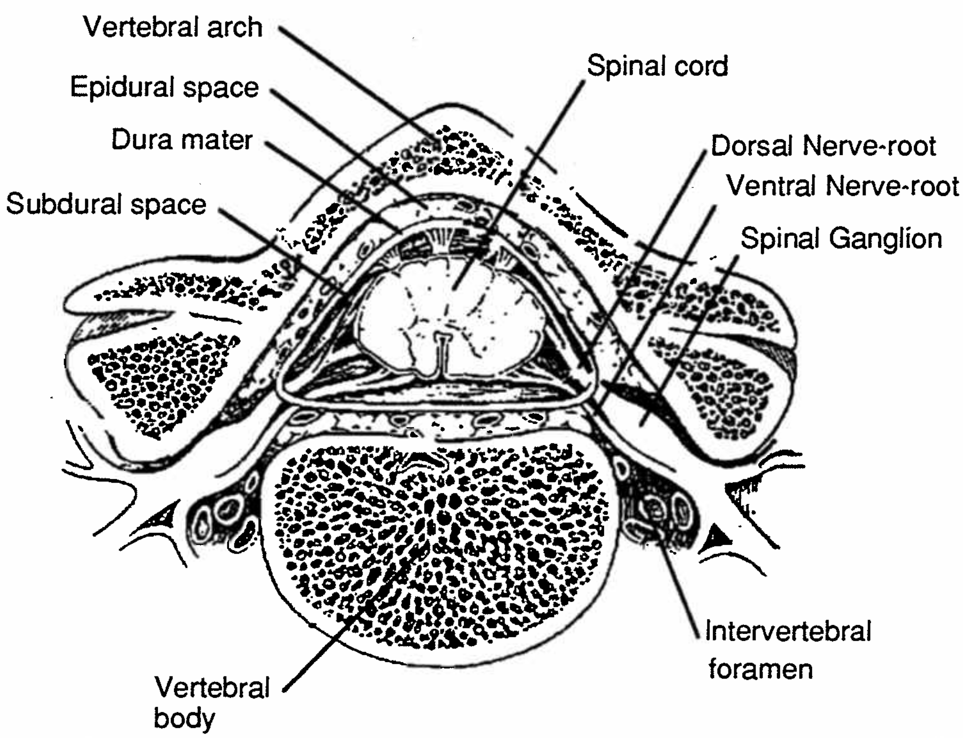
  Performance of current designs
  Modified designs, development and testing

The stages of the neck injury symptoms sustained in a rear-end collision (Spangfort, 1985)

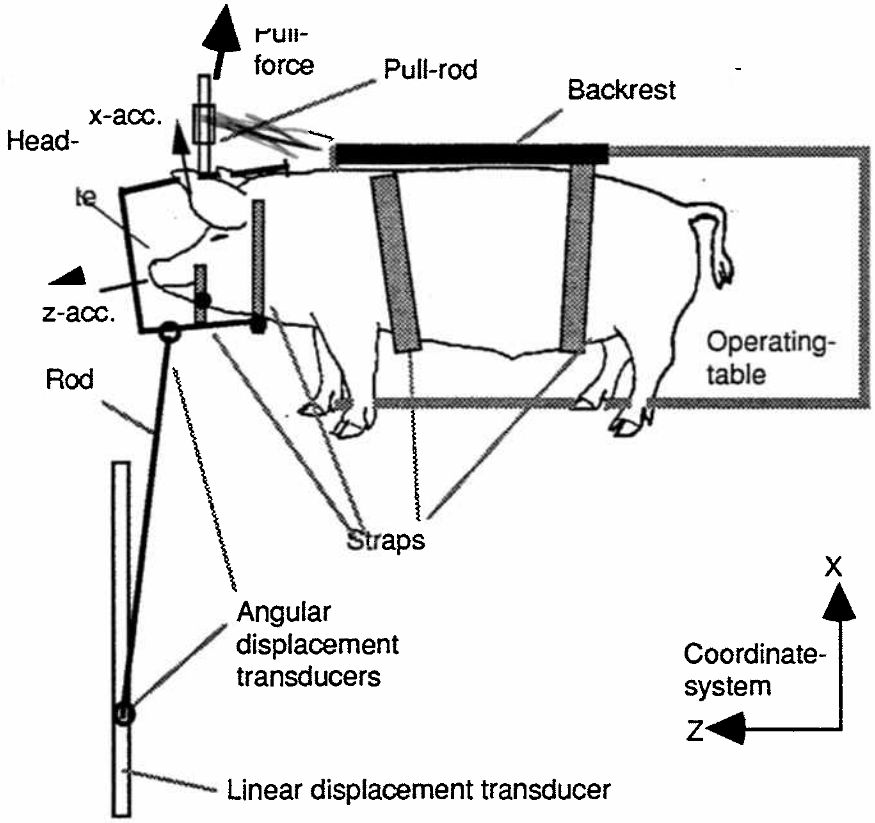




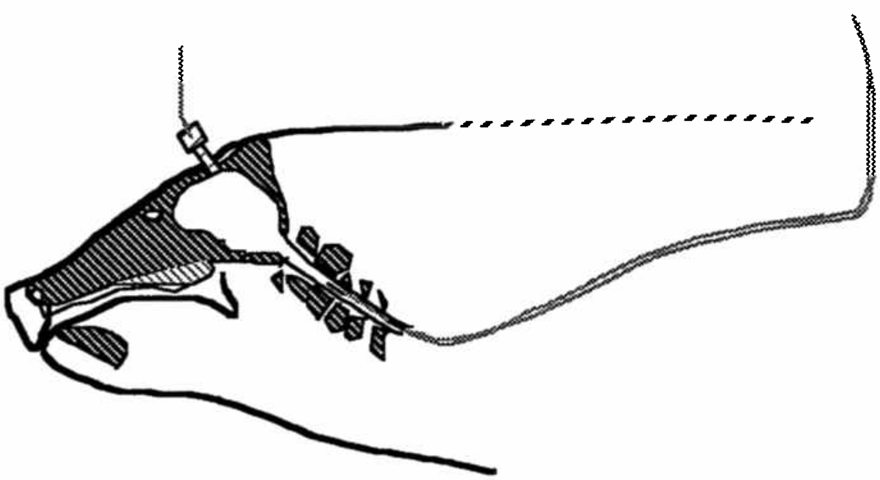
A sagittal cross-section of the lower cervical spine (C7-C3), in flexion and extension (adapted from Breig, 1978).



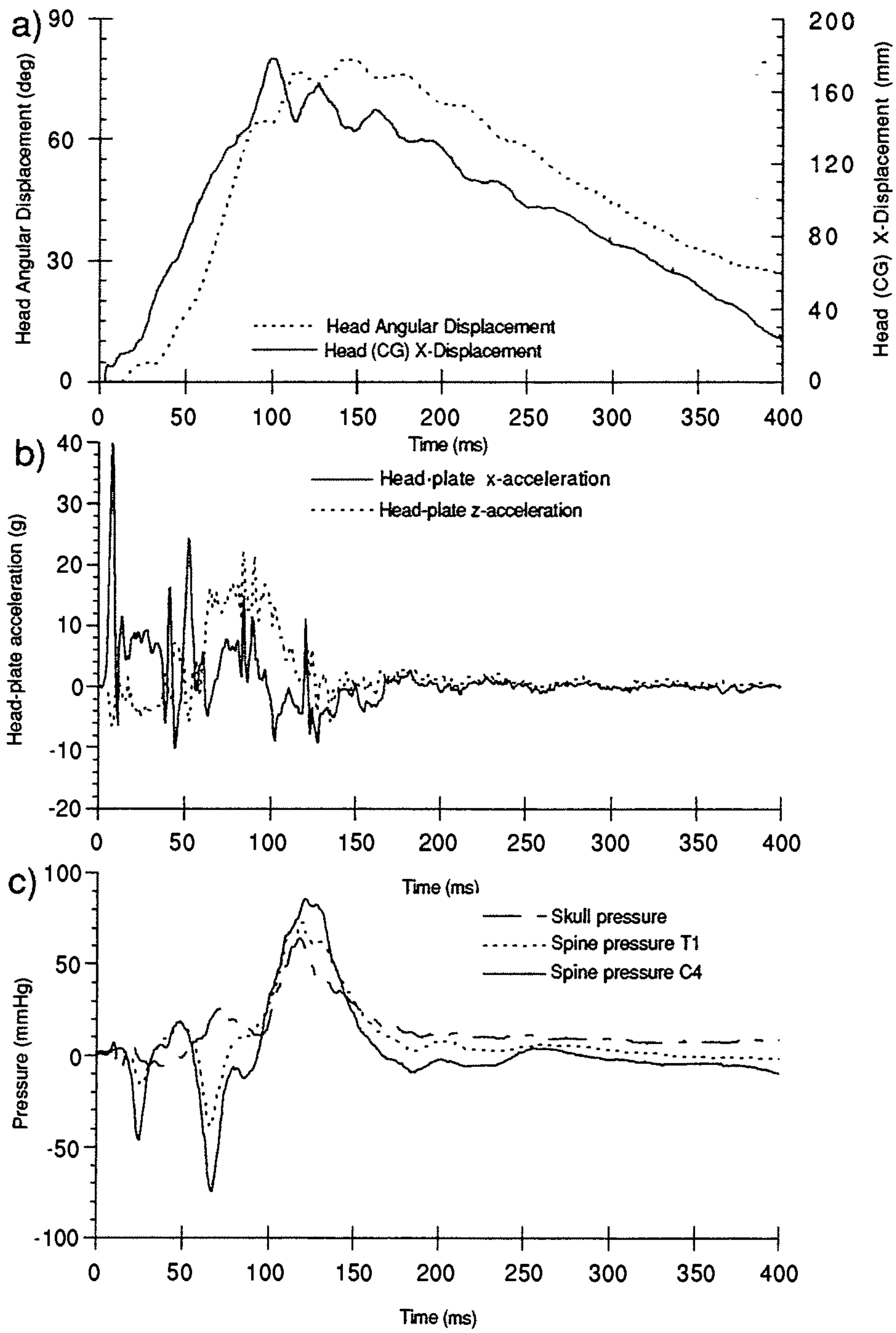
A horizontal cross-section of a cervical vertebra with the soft tissues of the spinal canal and intervertebral foramina (adapted from Sances et al., 1984).



Test set-up seen from above. The anaesthetised animal is lying right side down on the operating-table, strapped to the backrest. The head is strapped to the bolts in the horizontally movable head-plate. During the experiment a pre-tensed rubber-strap pulls the head-plate by the pull-rod. The pull force is active until the pull-rod is disconnected and thereafter the head moves in the sagittal plane due to its inertia (Örtengren et al. 1996).



Schematic sagittal cross-section of the pig head and cervical spine displaying the positions of the three pressure transducers, one in the frontal skull bone and two in the cervical spinal canal. (Svensson et al., 1993)

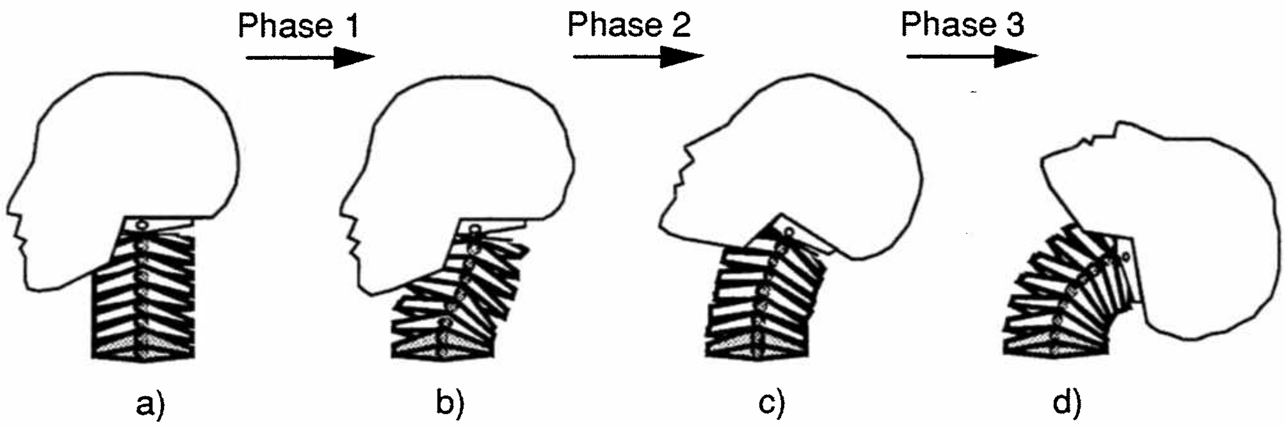


The results from one whiplash extension run with pressure measurements. The applied pulling force on the head-plate was 600N (Svensson et al.1993).

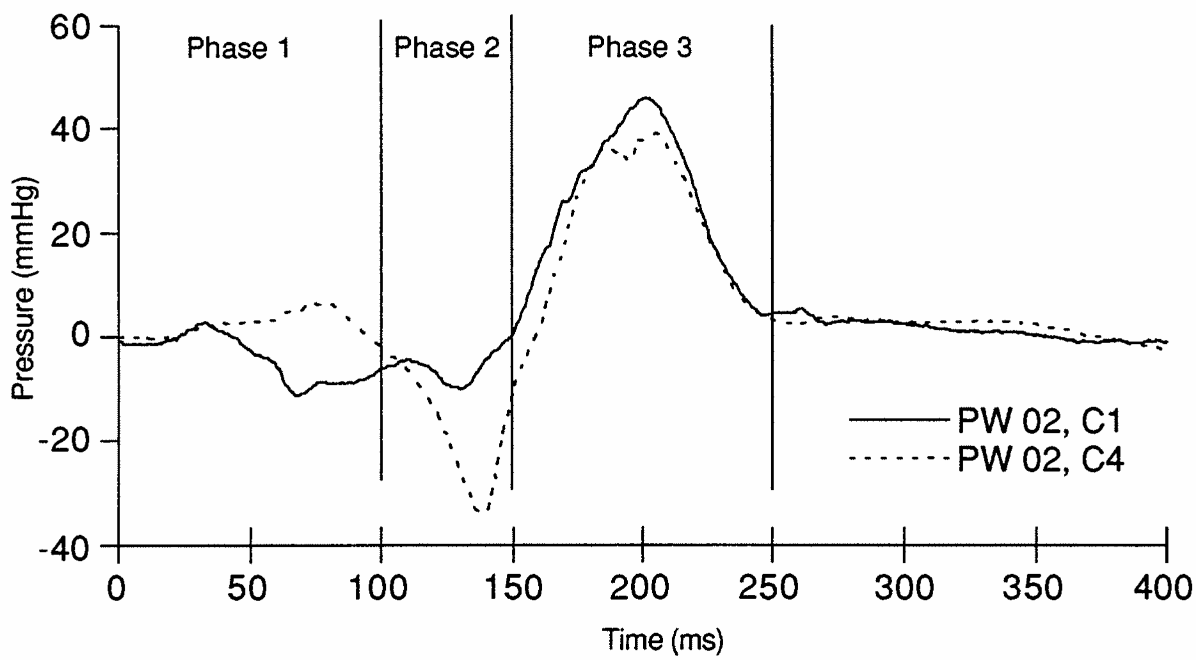
a) Angular displacement and the linear X-displacement of the head CG (Centre of Gravity) versus time.

b) Accelerations versus time of the head-plate versus time.

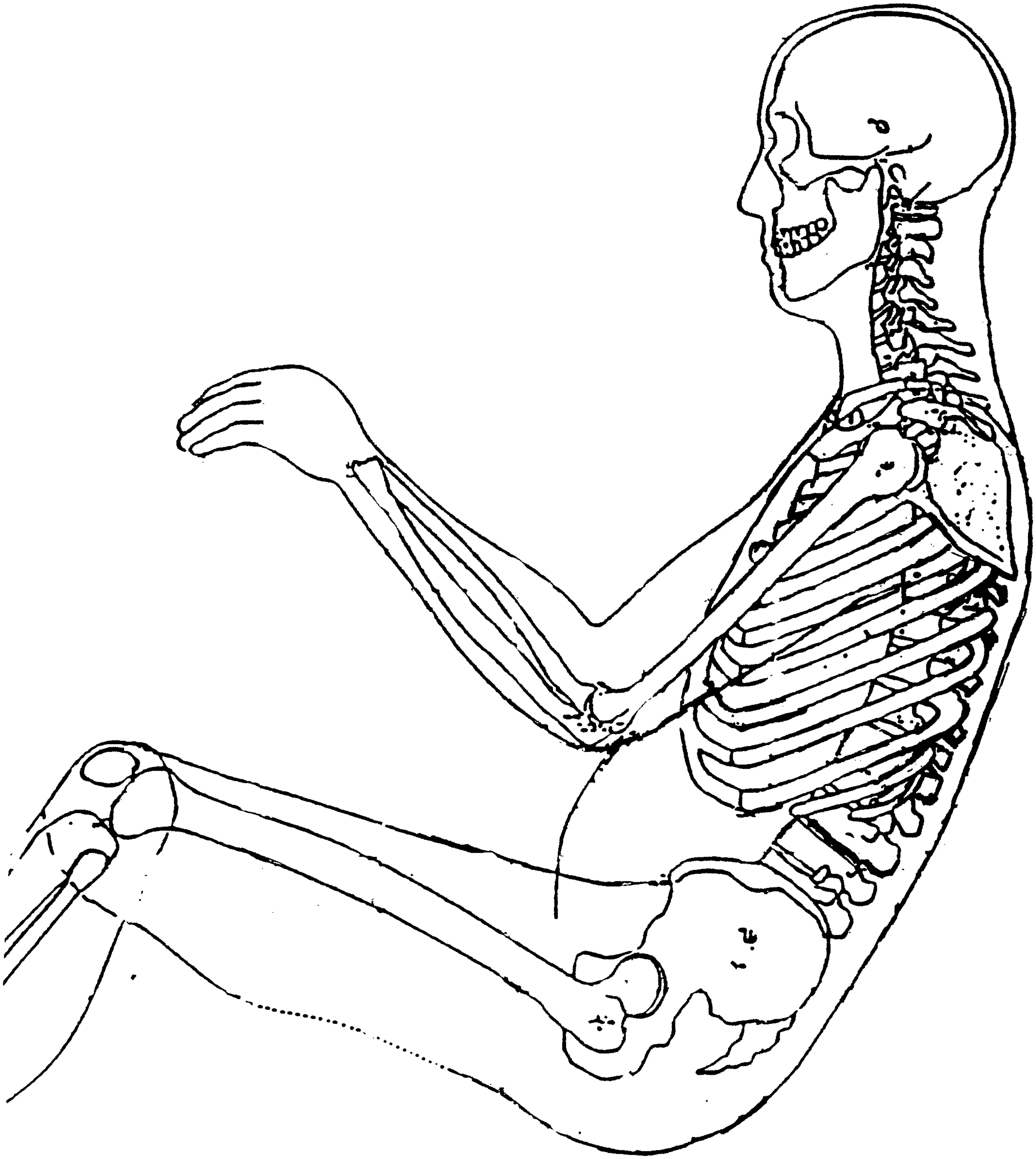
c) The pressure versus time in the CNS at three levels: skull, C4, and T1.



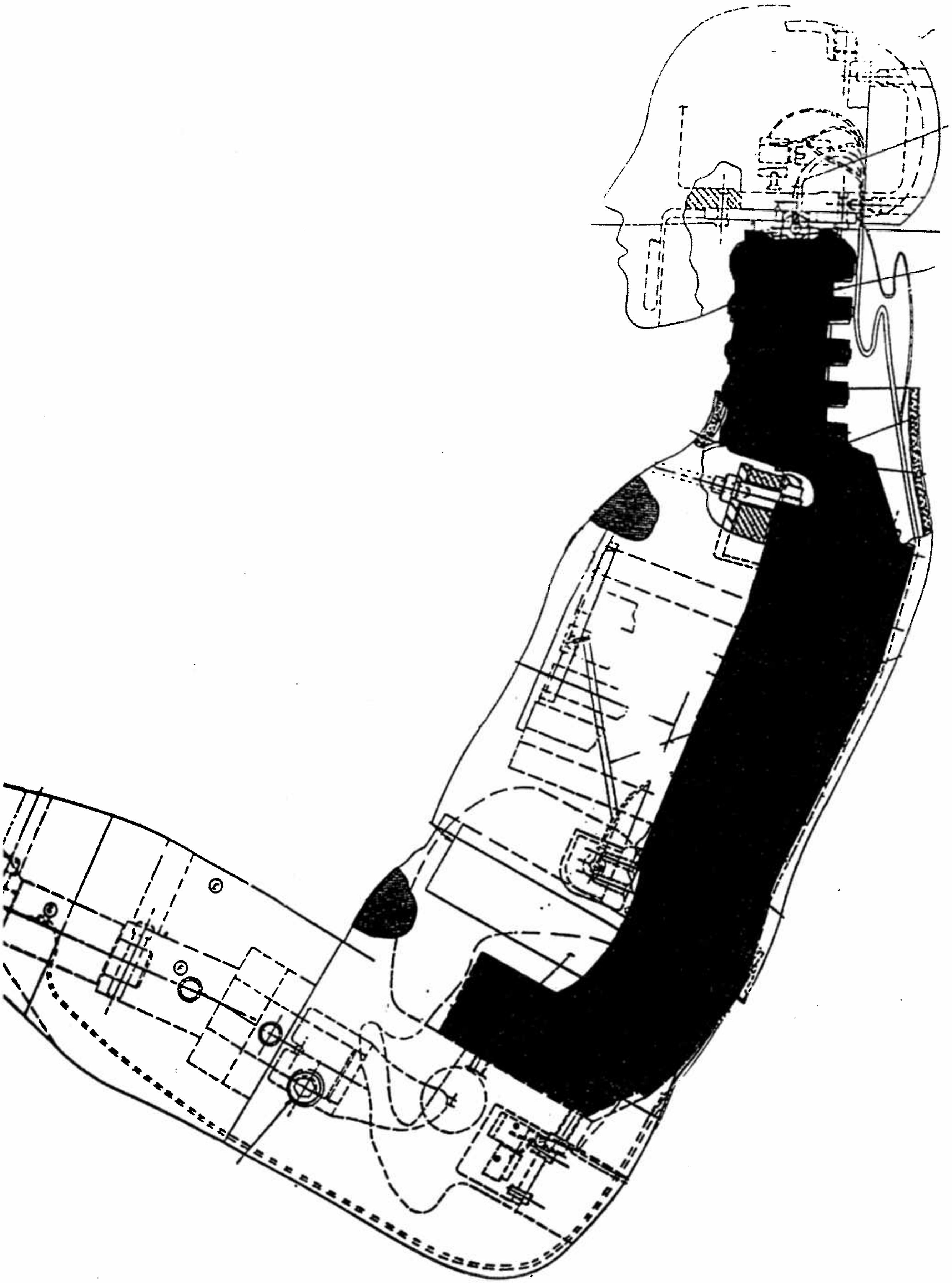
Schematic view of four parts of the whiplash extension motion (Svensson et al., 1993); a) initial posture; b) maximum rearward translational displacement of head; c) Maximum rearward angular velocity of the head is reached, d) Maximum extension angle of the neck is reached.



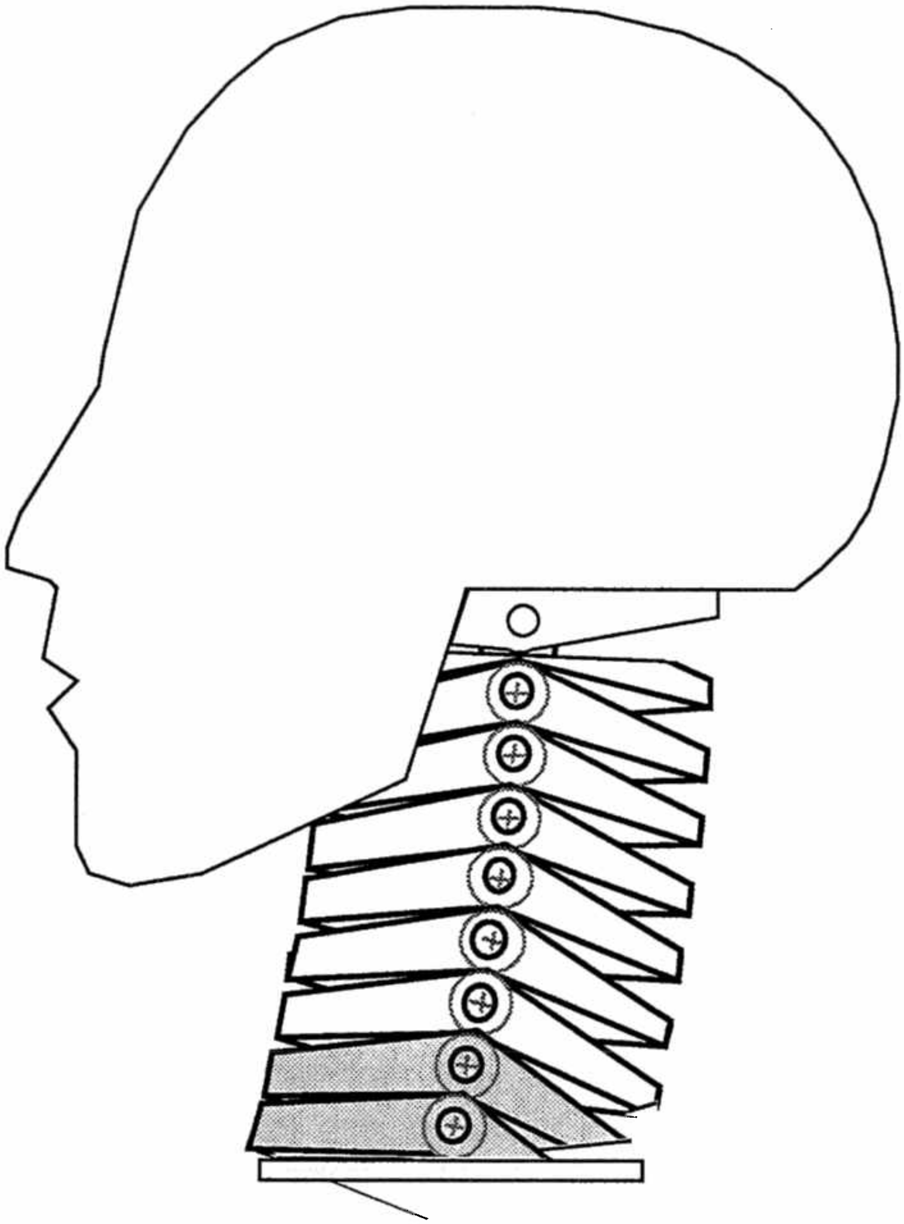
The average pressures of PW 02.01, 02.02, and 02.03 at C1 level and of PW 02.04, 02.05, and 02.06 at C4 level versus time. The different phases of the head-neck motion according to Figure 11 are displayed (Svensson et al., 1993).



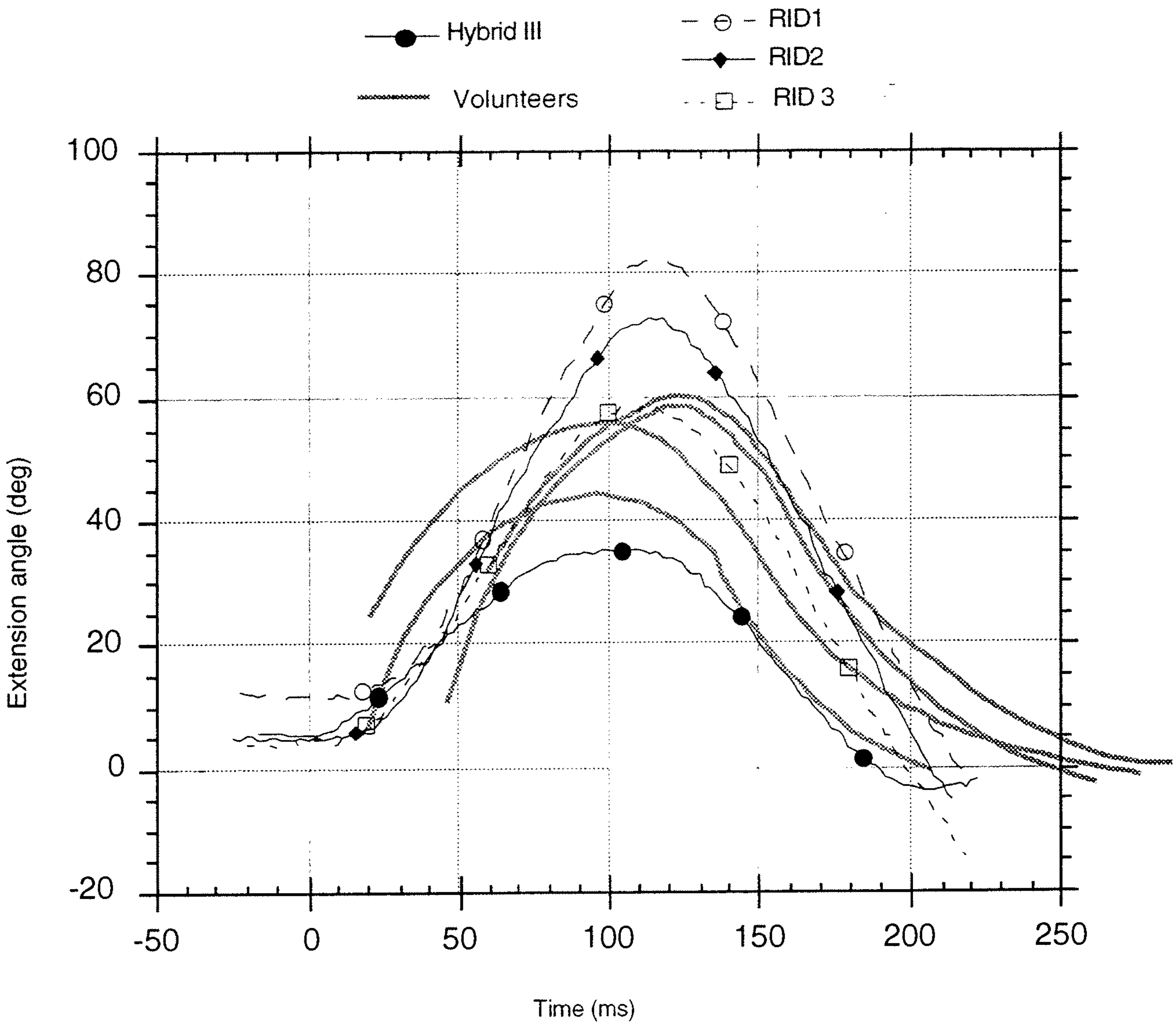
The human being in seated posture



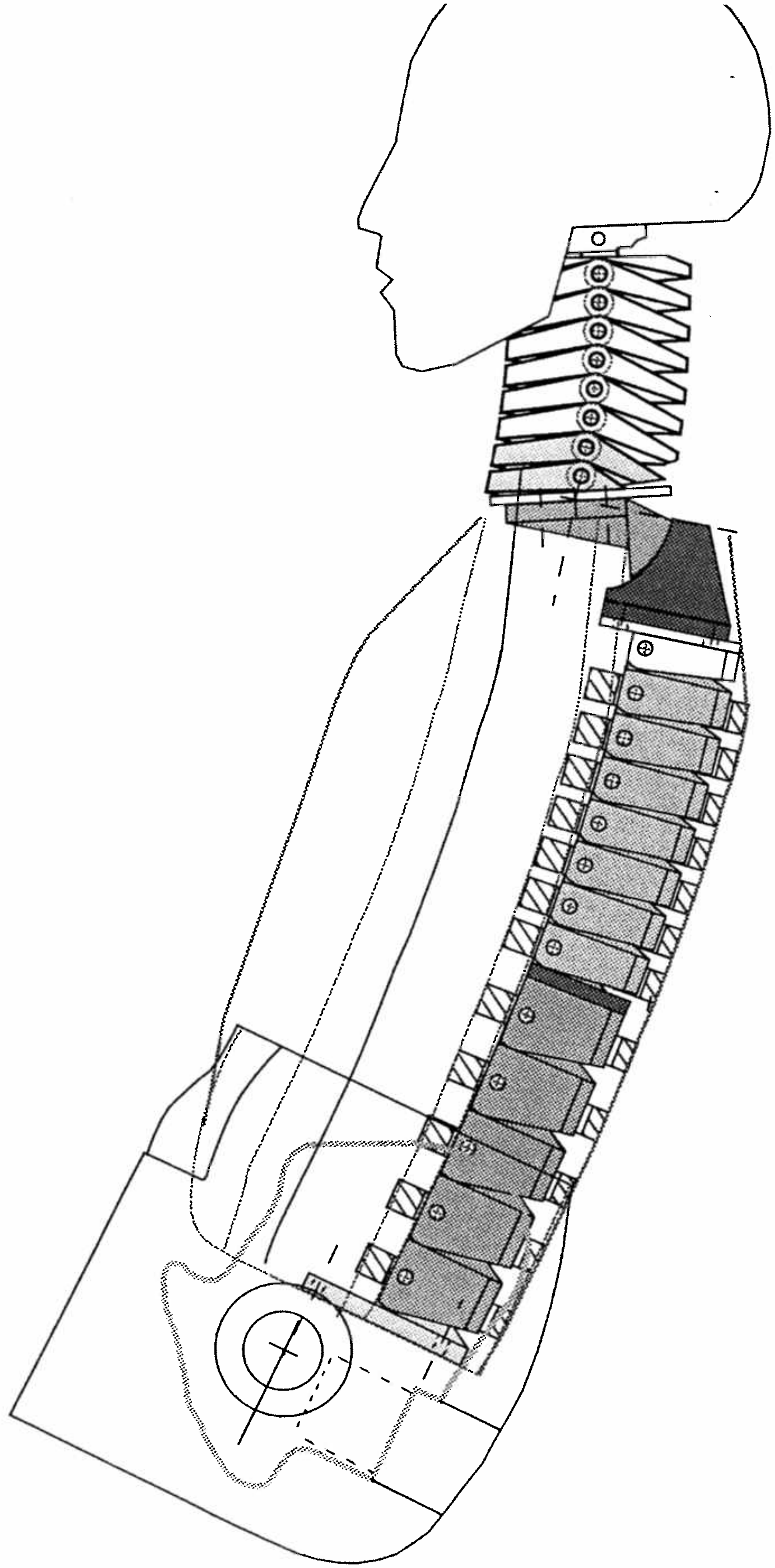
The Hybrid III-dummy



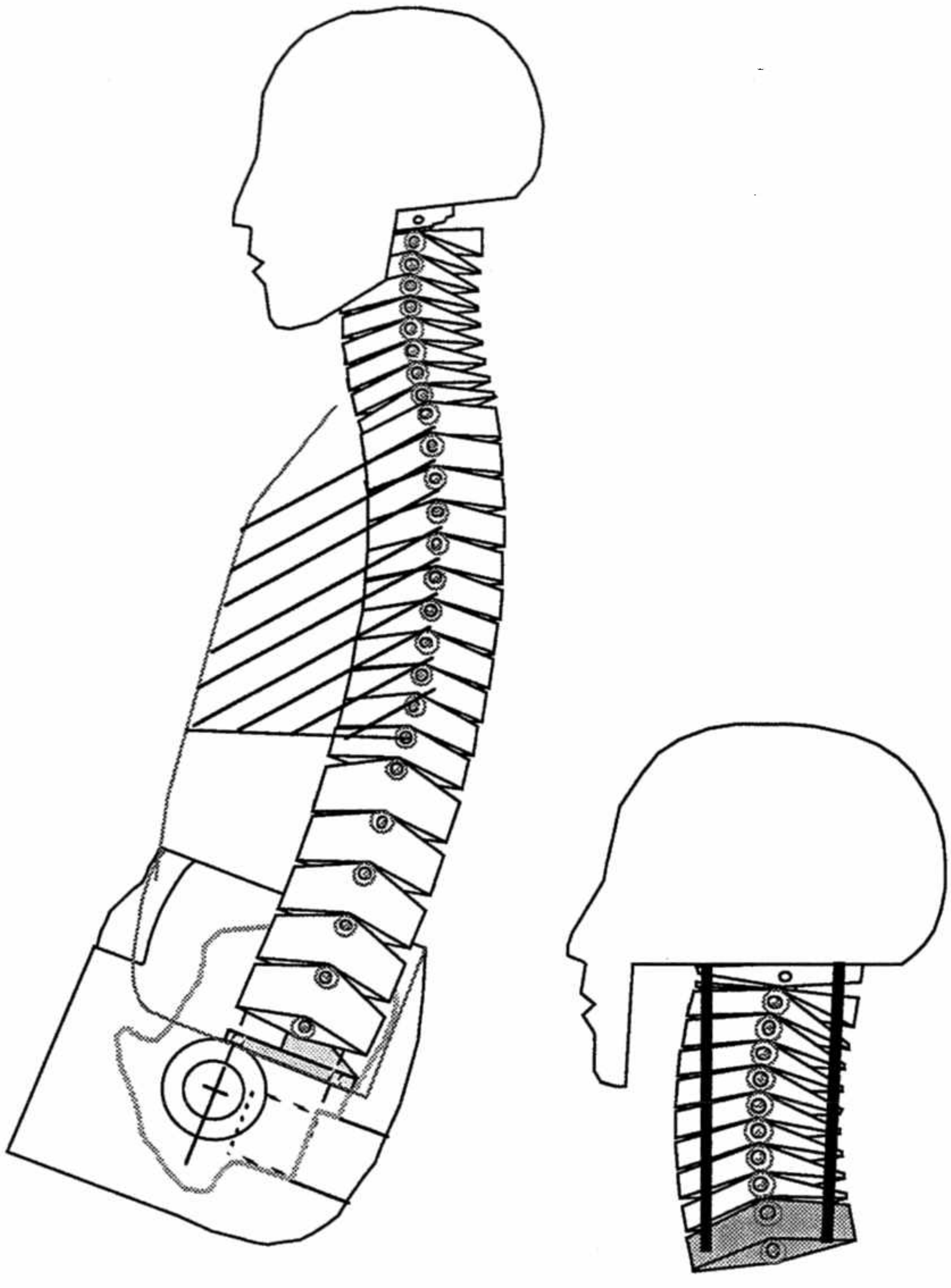
The RID-neck with a Hybrid III head.



Extension angle of the RID-neck in validation tests (Svensson and Lövsund, 1992) and for volunteer tests by Tarriere and Sapin (1969).



The first generation Rear Impact Dummy
developed at Chalmers University

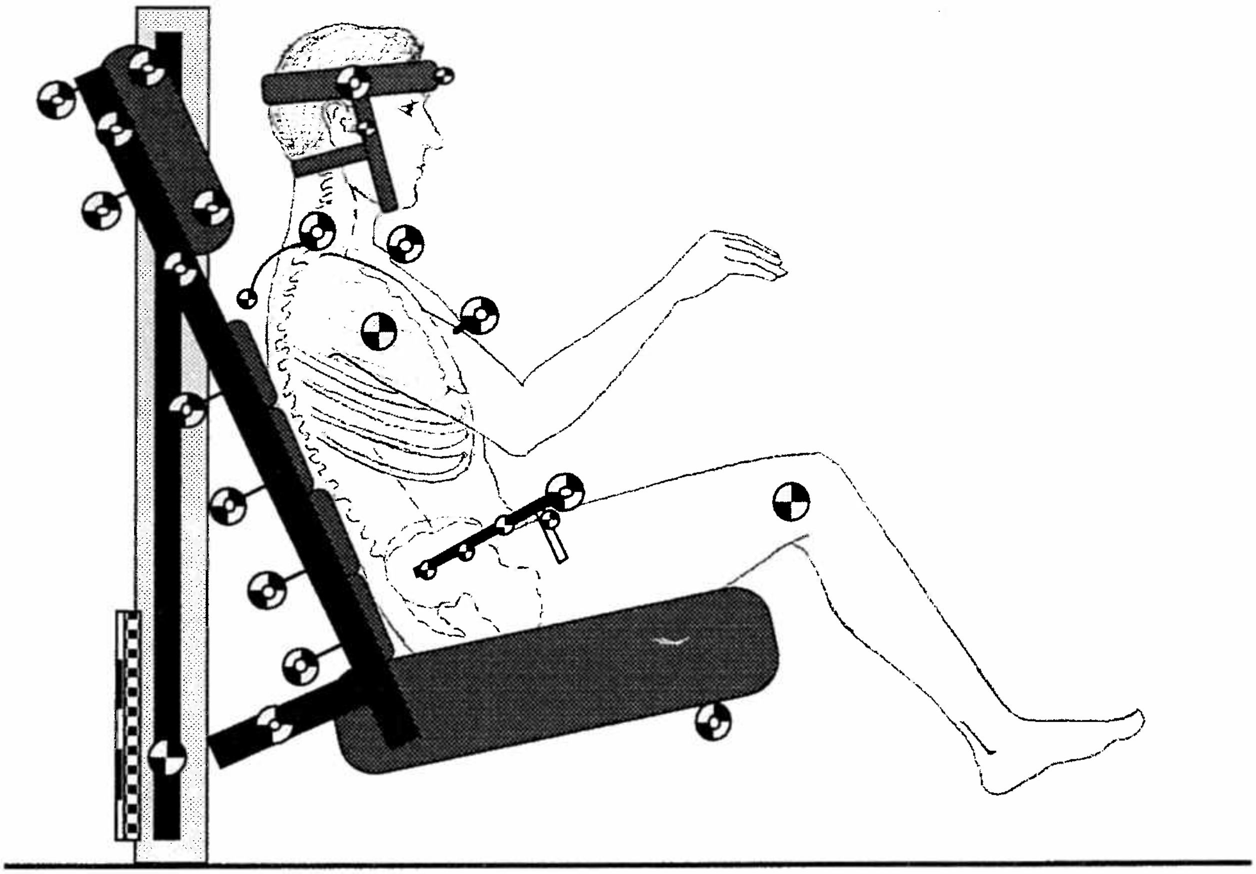


a) b)

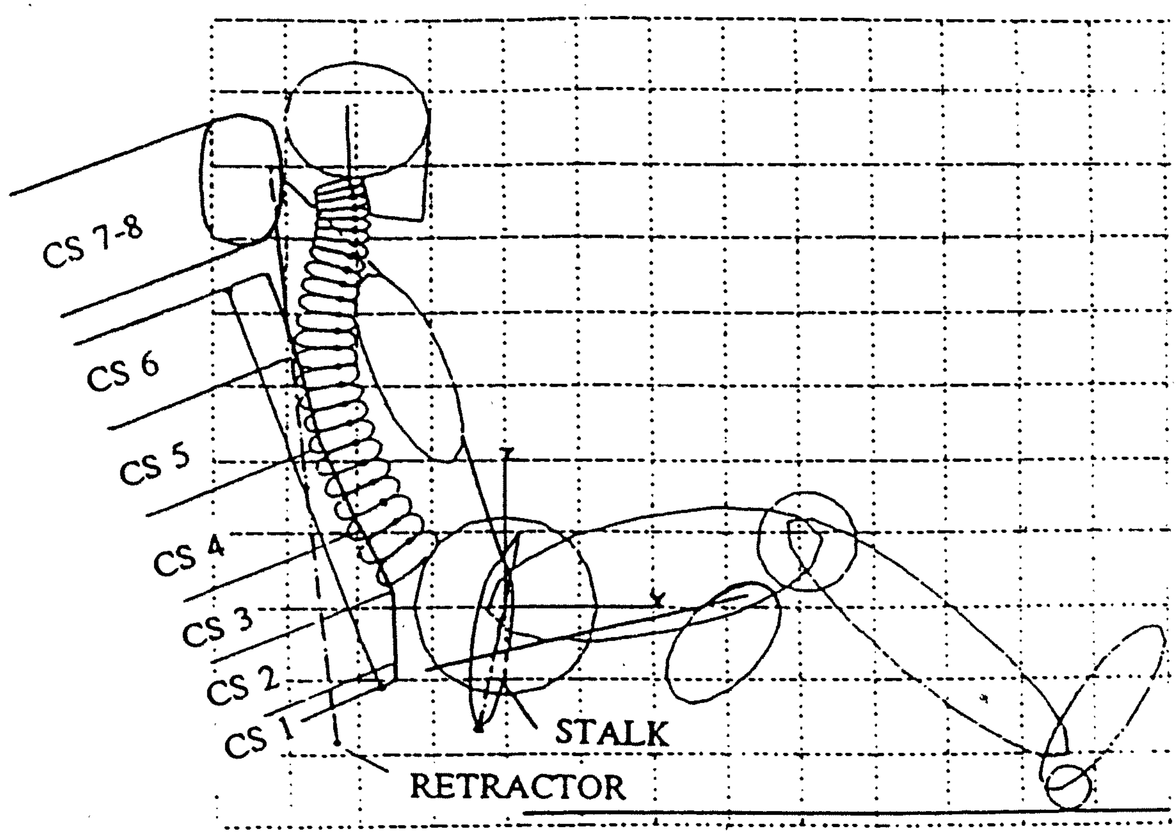
a) Rear Impact Dummy concept with an articulated spine and with a realistic spinal shape. b) Dummy head and neck concept with anterior and posterior muscle substitutes.

Rear end impact volunteer test

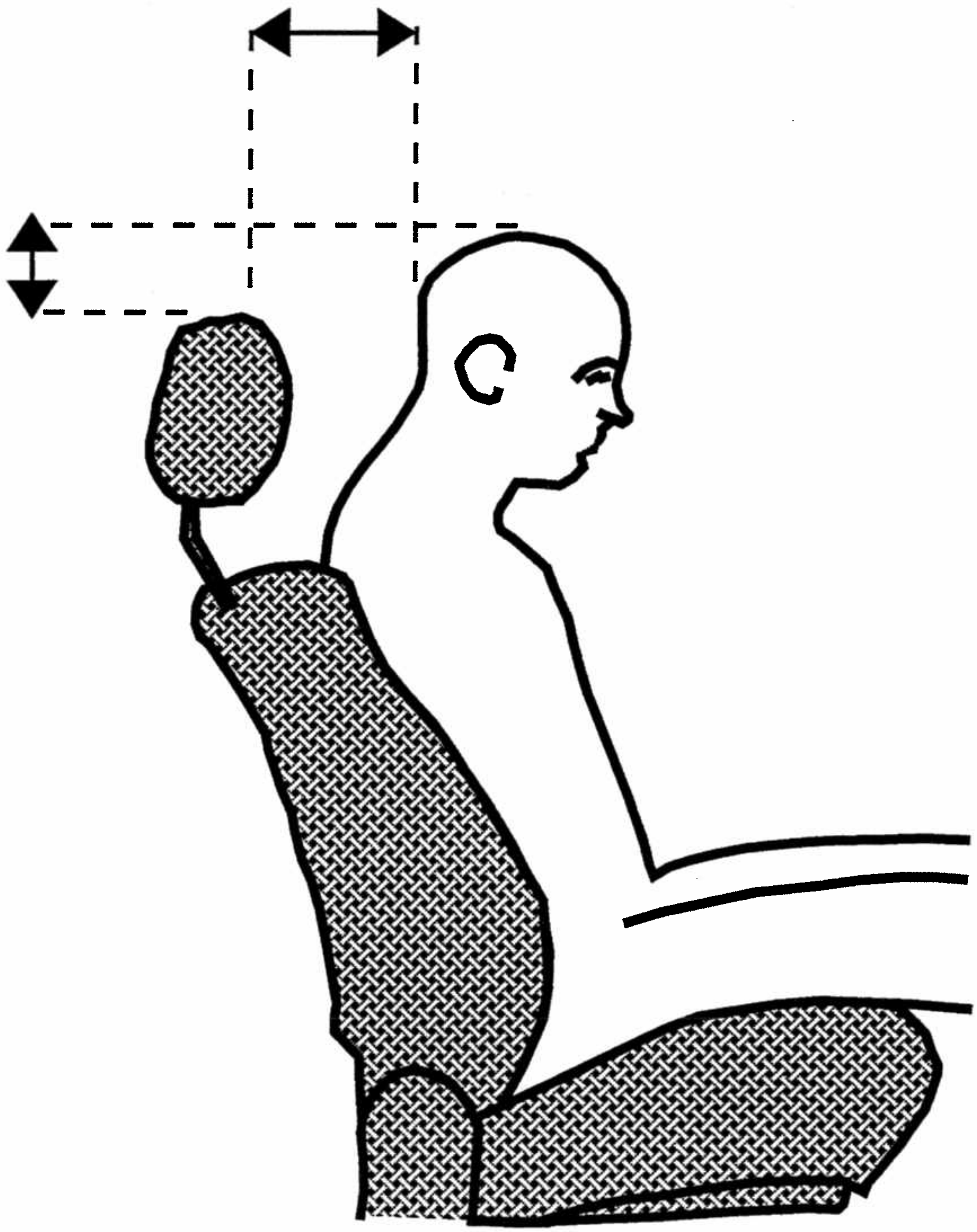
Allianz-Zentrum für Technik, Germany
Chalmers University of Technology, Sweden
Verband der Schadenversicherer, Germany



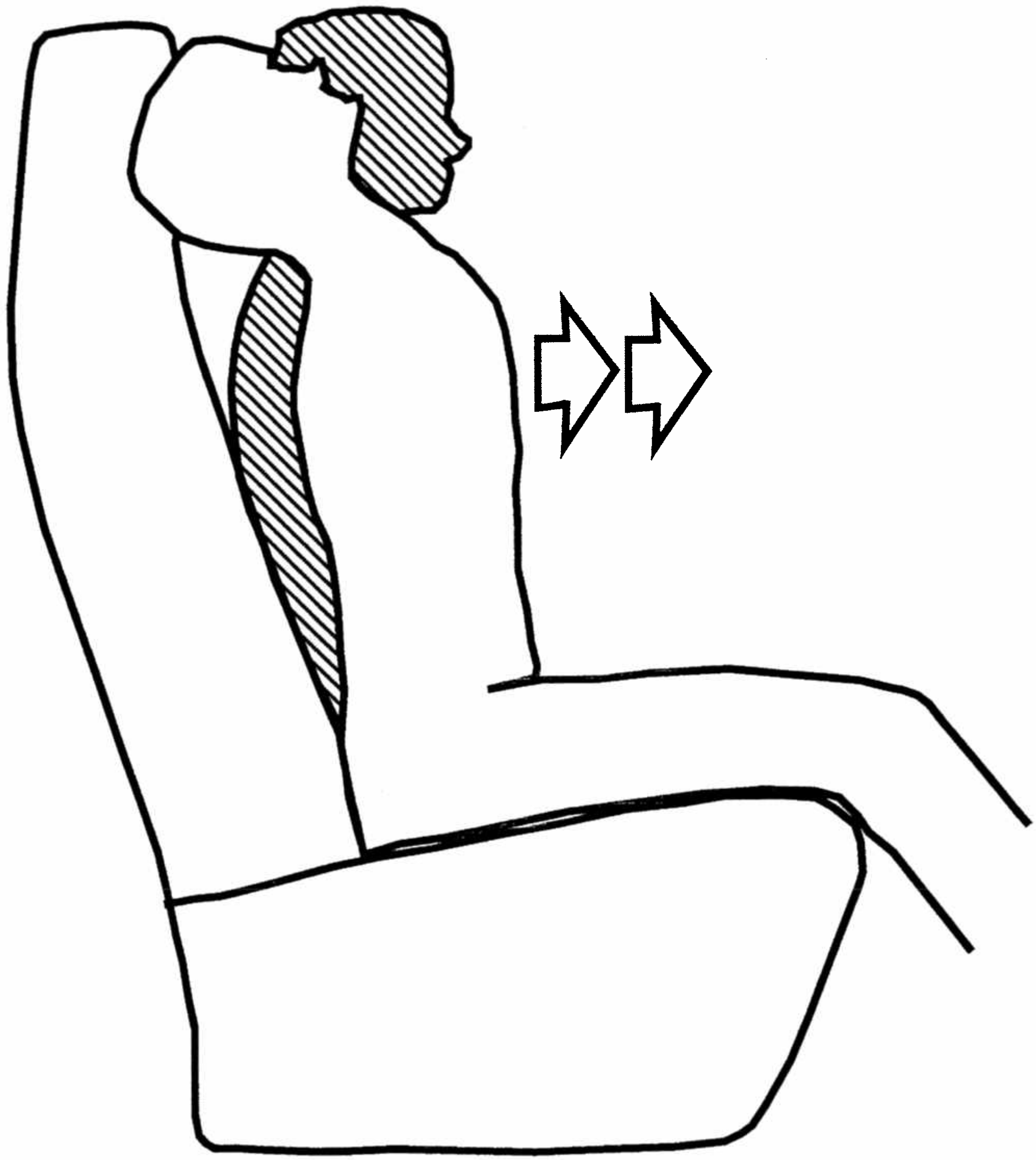
32 tests
ΔV: 4.7 to 7.5 km/h
Acceleration: ≈ 3 g
Parameters: Headrest position
- **Initial muscle tension**
- **Seat-back stiffness distribution**
- **ΔV**



MADYMO 2D rear-end collision model (Jakobsson et al., 1994)

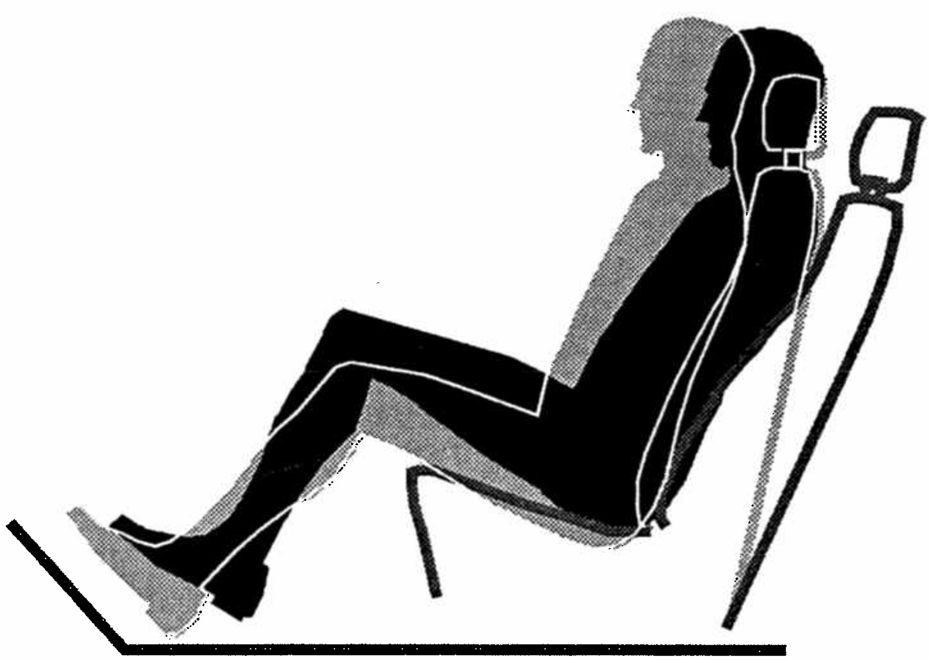


Gap between head and head-restraint,
not the only factor of importance.



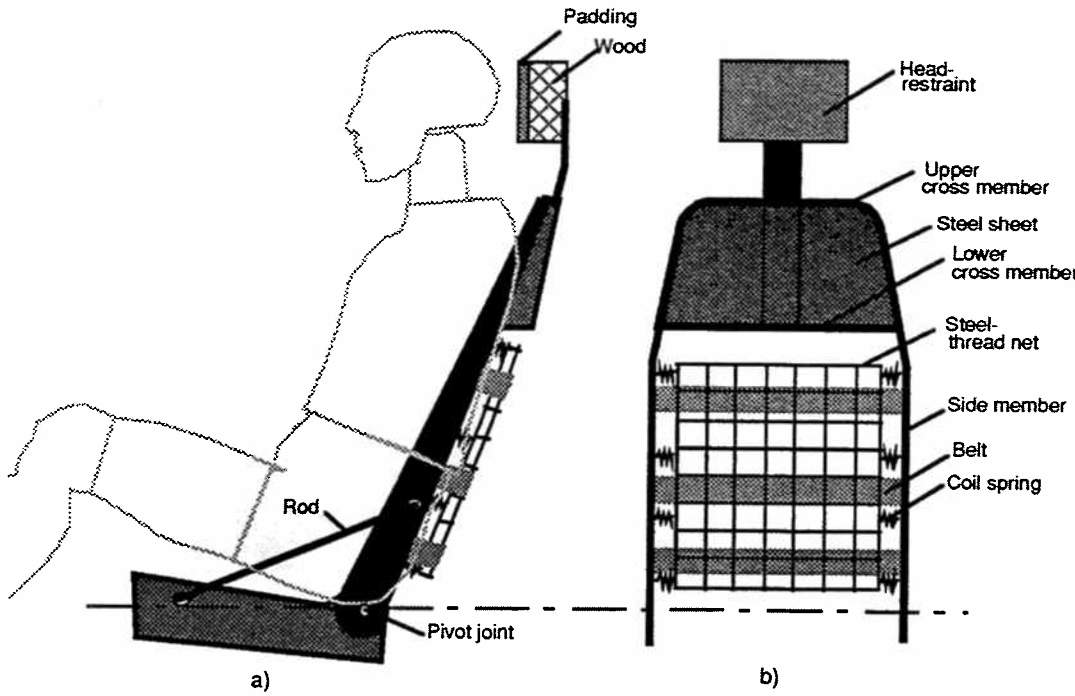
Elastic rebound of seat-back (States et al., 1969)

Standard seat with good stiffness distribution. The torso sinks into the soft surface of the seat-back cushion early in the crash event thus decreasing the distance between the head and the head-restraint before any larger motions between the head and the torso have commenced.

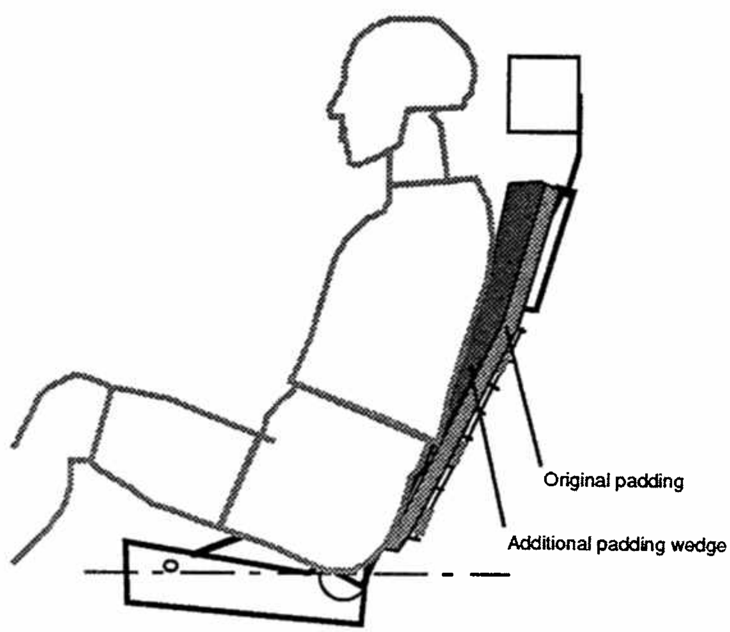


Standard seat with soft recliner or seatback frame. The seat-back frame yields backward at the beginning of the crash event and this in turn distances the head-restraint further away from the head.

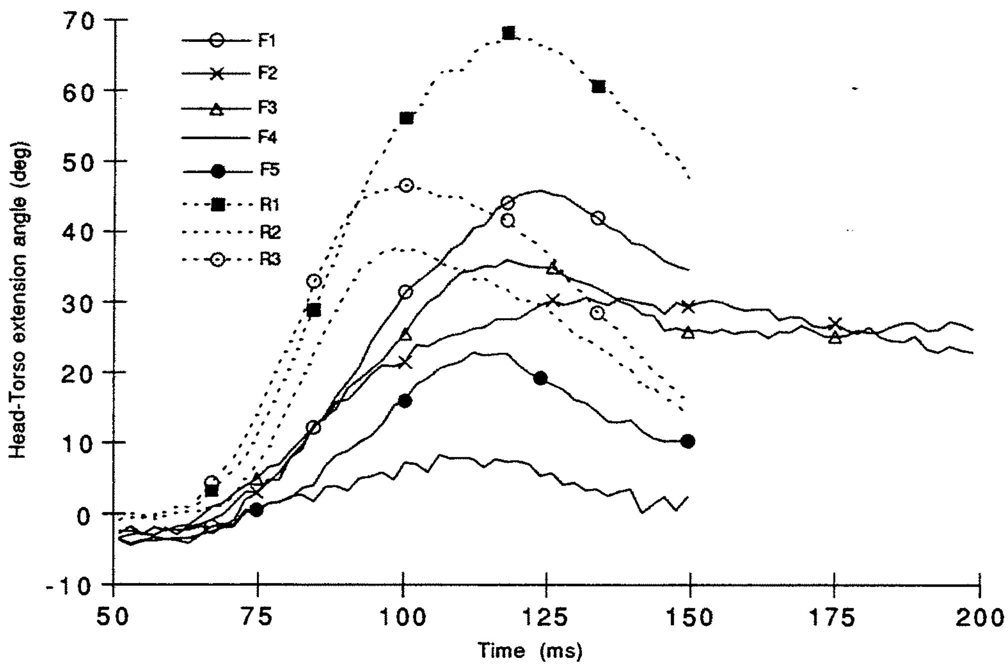
Standard seat with a relatively stiff upper part of the seat-back cushion due to the upper crossbeam of the seat-back frame. Thus it does not allow the upper torso to penetrate very deeply. The lower part of the seat-back cushion is soft and allows deep penetration of the lower torso, and particularly of the pelvis which is loaded by the leg mass. This results in a large angular displacement of the torso relative to the seat-back frame.



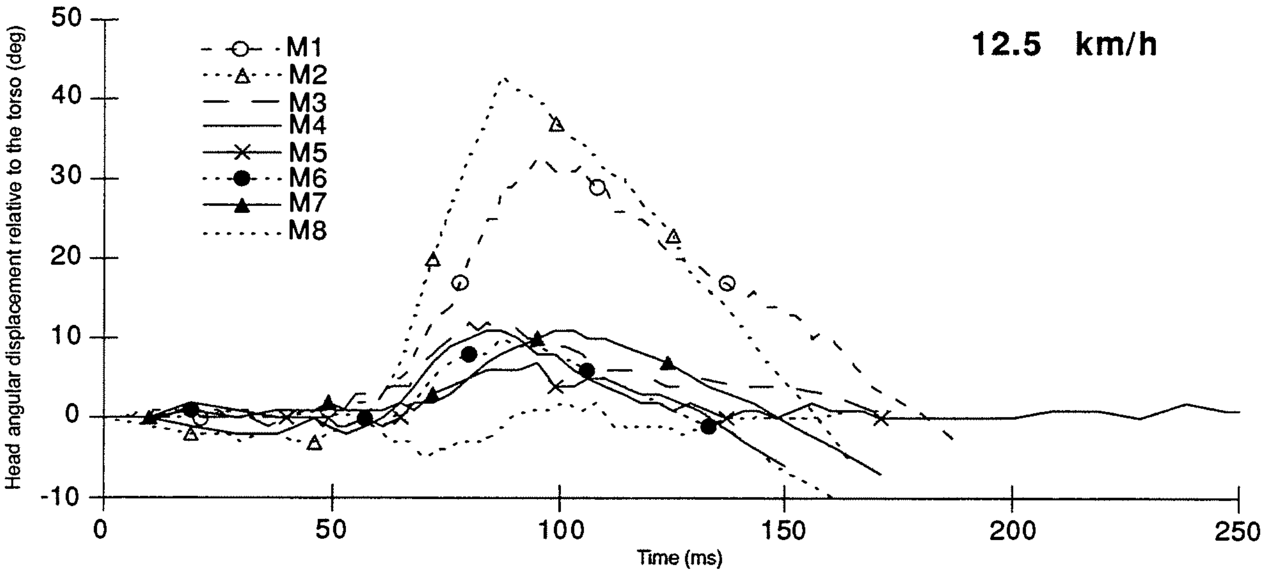
Schematic view of the seat-frame seen from the left side, with the contours of the seated dummy. In some tests a rod was connected between the lower seat-frame and the side member of the seat-back frame. b) A schematic frontal view of the seat-back frame with side members and cross-members. Between the side members, the steel-thread net is attached to the side members by coil-springs, and for some tests three belts were stretched between the side members behind the net.



A schematic cross-section of the seat with dummy contours: The original padding layer, and the additional padding wedge used in two of the modifications, M7 and M8 (Table 2).



Angular displacements between torso and head at 12.5 km/h delta-v in different seat types (Svensson et al., 1993[b]).



Rearward angular displacement of the head relative to the torso for 12.5 km/h delta-v tests with different seat modifications (Svensson et al., 1993[c]).

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