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THE VEHICLE REAR-END COLLISION

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Abstract

This paper investigates the vehicle rear impact with consequence of this and analyzes the research developed in this domain. In road traffic, especially in urban traffic, there have taken place numerous rear end collisions resulting in serious injuries for the passengers. The numerous studies made lead to today's internationally recognized demand on the car driver's head restraint adjustment for an optimal protection of the neck spinal column (HWS) with regard to rear end collisions.

1. General information

Along with the vehicles number increase, there has been registered an increase in traffic accidents, with more and more victims to be claimed. This fact split the automotive research towards performance increase and passive and active safety.

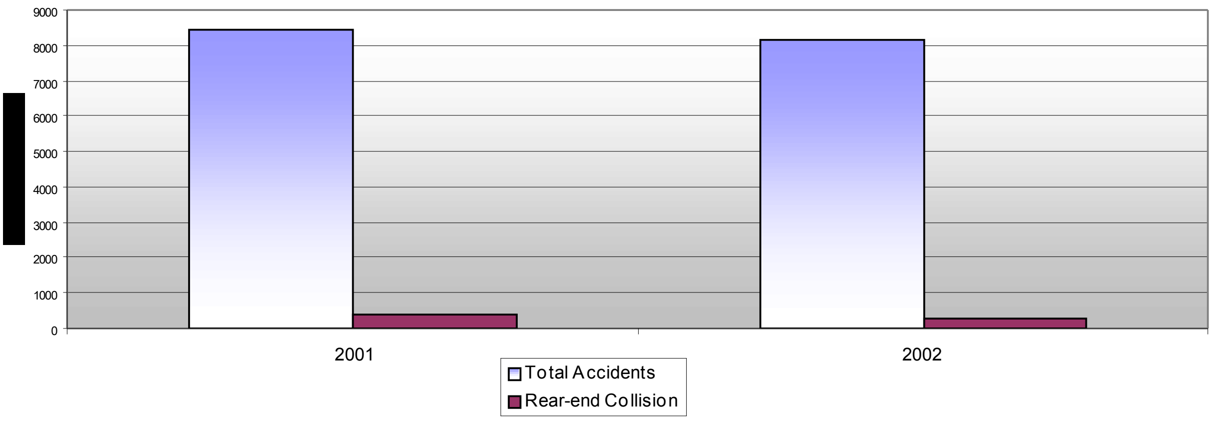


Figure 1. Road Traffic Accidents Statistics for 2000

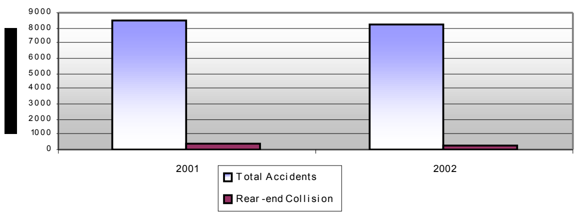


Figure 2. Rear-end collisions for Romania

When analyzing a traffic rear-end collision, we are identifying a three-phased event division:

1. *Pre-collision phase* – the phase prior to the actual traffic collision. It takes place up to the moment of structural contact between the two bodies.

Figure 3. Vehicle speeds prior to impact; ($v_1>v_2$)

2. *Collision phase* – The actual impact phase. As the two bodies are in contact, the cars bodies deform, process that transfers a part of the initial kinetic energy into deformation energy.

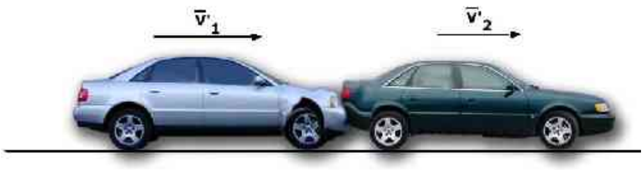


Figure 4. Vehicle speeds during to impact; ($v'_1=v'_2$, t is measured in milliseconds)

3. *Postcollision phase* – from the moment of the two bodies' detachment up to full stop.

Figure 5. Vehicle speeds after impact ($v''_1<v''_2$)

Because the collision takes place in a very short time (measured in milliseconds) impact related relations are to be used:

- first law: total impulse variation for the collision time is equal to the exterior percussions sum: $\mathbf{\Sigma m \cdot v_1 - \Sigma m \cdot v_0 = \Sigma P}$;
- second law: total kinetic momentum variation during a collision is equal to the exterior percussions sum: $\mathbf{\Sigma(r \times m \cdot v_1) - \Sigma(r \times m \cdot v_0) = \Sigma(r \times P)}$, where „r” is the distance from the impulse vector to a point for which the momentum is considered;
- impulse variation law: $\mathbf{m_1 \cdot v_1 + m \cdot v_2 = m_1 \cdot v''_1 + m \cdot v''_2}$.

Thus, it is reckoned that the collision phase is divided into *contraction* and *relaxation*.

2. VEHICLE REAR-END COLLISION RESEARCH

2.1. Impact case study

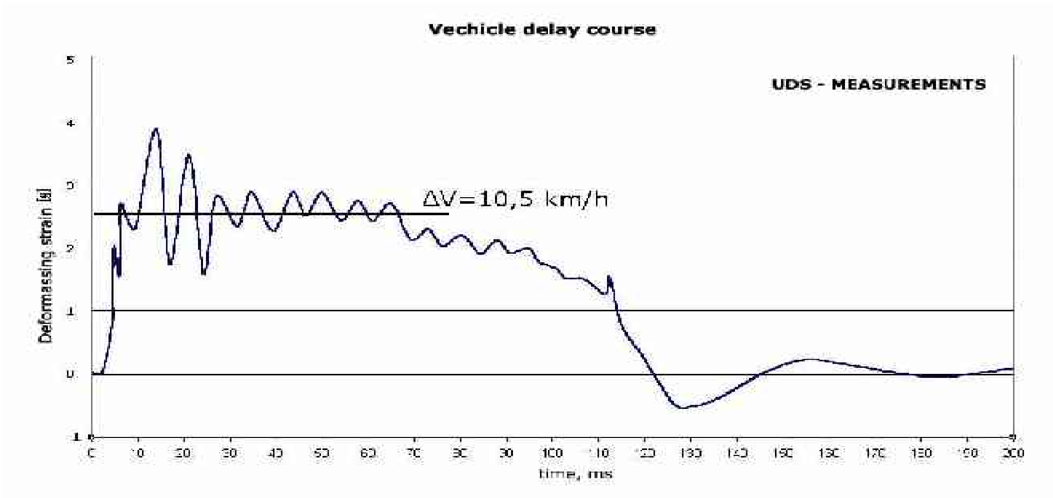


Figure 6. UDS measurements, vehicle delay course

In vehicle collision, v_1 and v_2 are the initial speeds before impact, v''_1 and v''_2 are the resultant speeds, the speed variation rates being Δv_1 and Δv_2. The impact speed determined reached 12-16 km/h, where ΔV_1=7±1.5 km/h. For rear-end collision, the collision direction deviation can be neglected, the “k” factor (0,15-0,35) expressing residual speed.

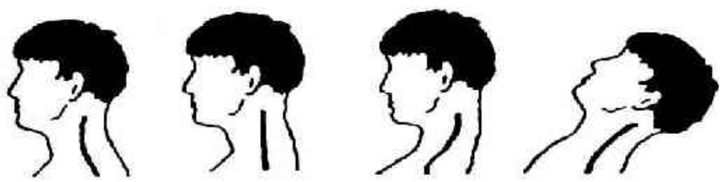


Figure 7. Spinal cord deformation course regarding rear-end collision

Because of the absence of a head restraint, extensions and hyper extensions can appear (fig.7.) for a speed shifting rate of 10,5 km/h. After approximative 15 ms, the acceleration reaches the maximum value. The average acceleration measured on the vehicle body after approximative 120 ms is 2,5 g and/or 25 m/s^2.
The analysis result shows that for the front vehicle it is possible for the acceleration effect to damage the spinal cord when the acceleration change rate caused by the vehicle recoil reaches 13km/h;

Diagram 8 offers the registered physical events during the bio-mechanical operational sequence on which has been figured the Neck Injury Criterion [m^2/s^2]. Thus, the relative speed between head and torso varies between 5 and 7 km/h. For head protection, NIC should not reach 15 m^2s^2. If the vehicle has head restraints, the acceleration point is heightened at head level, the impact reaching the driver/passengers after 50..70 ms.

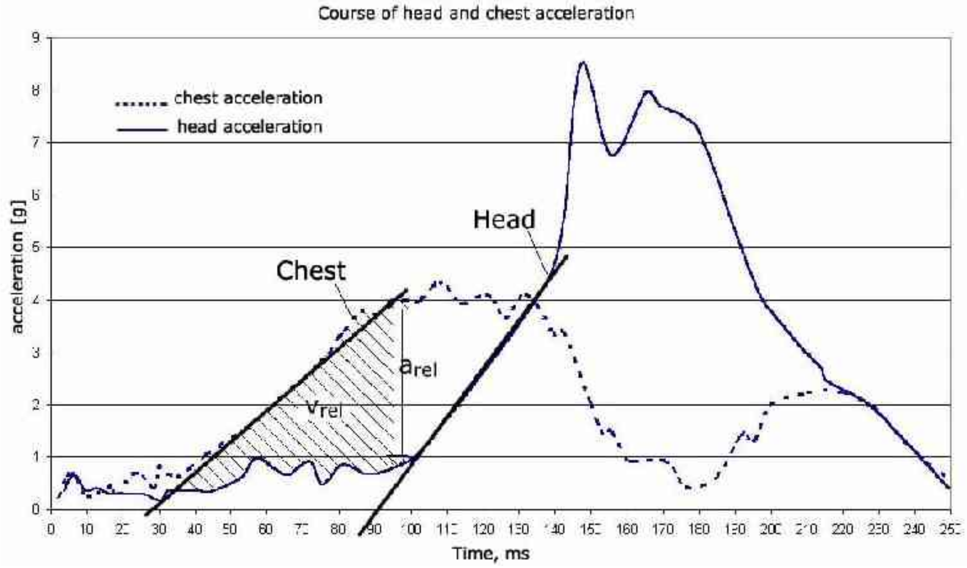


Figure 8. Course of the chest and head acceleration

NIC= a_{rel}•0,2 + v_{rel}^2
a_{rel}: 30 - 35 m/s^2
Δt:60 ms
$v_{rel\ 1}$: 1/2 • 0,06 s • 30 m/s^2
$v_{rel\ 2}$: 1/2 • 0,06 s • 35 m/s^2
NIC_1 = 30 m/s^2 • 0,2 m + 0,8 m^2/s2= 6,8 m^2/s^2
NIC_2 = 35 m/s^2• 0,2 m + 1,1 m^2/s2= 8,1 m^2/s^2

2.1 Biomechanics' neck limits for rear-end collision 3

In case of collisions, neck injuries can occur as a result of its bending because of head inertia, at sudden accelerations/decelerations. Neck bending can occur towards any direction; using medical literature, neck back bending is called *extension*, forward bending is called *flection*, while lateral bending – *lateral flection*. If the cervical region suffers from affections produced by different etio-pathogenic factors, or by clinical demonstrations of the cervicarthrose, then the injury appearance danger is increasing. The known spinal deviations are:Scoliosis, Cyphosis, Lordsis.

The neck part of the spine is formed by seven vertebrae, linked by the intervertebrae disks. With the lower part of its the first two segments (ATLAS if AXIS) of particular morphology and not very prone to the arthrosic degeneration, the cervical rachis comprises 3 articular systems likely to be the seat of osteoarthritis.

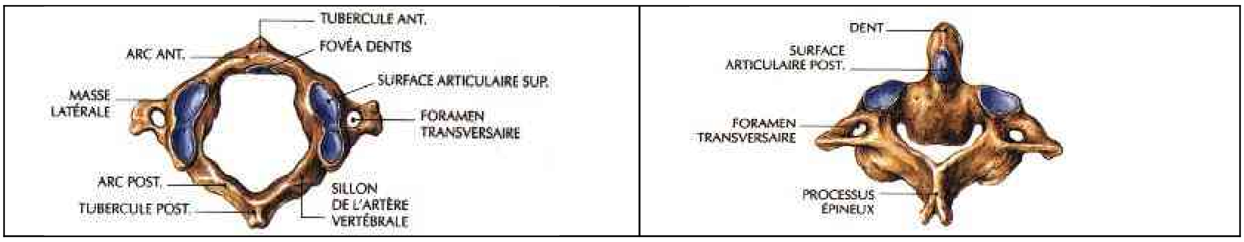


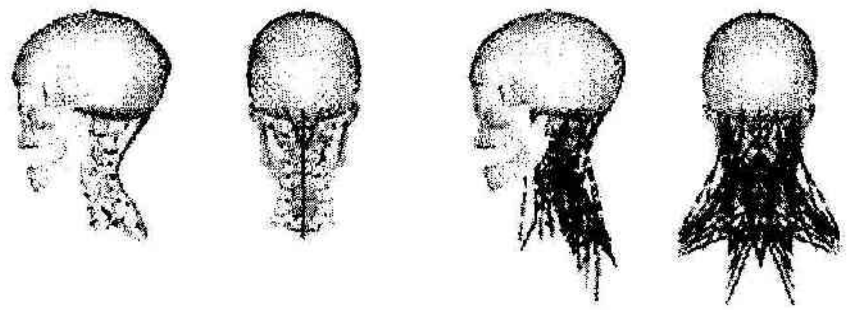
Figura 9. Anatomic configuration Atlas-Axis

Cervical area movements of the spinal cord and of the skull are accomplished by muscle pairs. Dorsal muscles are bigger than the anteriors; as following, the flection resistance will be higher than the extension resistance. This is the reason for which most such neck injuries take place in rear-end collisions, their severity increasing if, during impact, the head is twisted lateraly.

Determination of the head inertia injuries severity and tolerance limits is mostly realized using the following tests:

- static tests, done on volunteers, consisting in applying a force to the head;
- non-traumatic dynamic tests, applied on volunteers;
- dynamic tests, realized on corpses, in conditions favorable to neck trauma, specifying that head muscles cannot overtake and dissipate some of the impact related energy.

New dummy models have been created, possessing a structure closer to real model. The skull and neck vertebrae are being manufactured with rigid materials interconnected with non-linear viscoelastic disks, non-linear viscoelastic ligaments, surface-friction joints and contraction muscle types.



a)	b)

Figura 9. Neck modells: without muscles (a), with muscles (b).

Corpse tests have shown that 190 Nm flection and 57 Nm extension bending moments lead to visible ligaments deterioration, while volunteer tests have resulted in maximal values for pain admission as shown in table below.

Tabele 1. Maximal neck momentum values

Stress type	Bending moment [Nm]	Head-thorax angle [°]	AIS	Notes
Flection	88,2	70	1	Pain, but without injuries
Extension	30,5	68	0	
Lateral flection	45,2	43	0	

During impact, some of the head applied force will be transferred to the thorax by the neck link. The amount of the neck related force will depend on the place/direction of the application of the force upon the head, head inertia and spinal cord configuration for the cervical area, at the impact time. As a result, spinal cord loading will be reduced for a strait neck, when only axial forces apply and increased for a flexed neck, when complex loading would occur. Corpse tests pointed out that, for a strait neck, spinal cord fractures appear when axial forces exceed 4700...6000N and for a flexed neck, 1800...2200N.

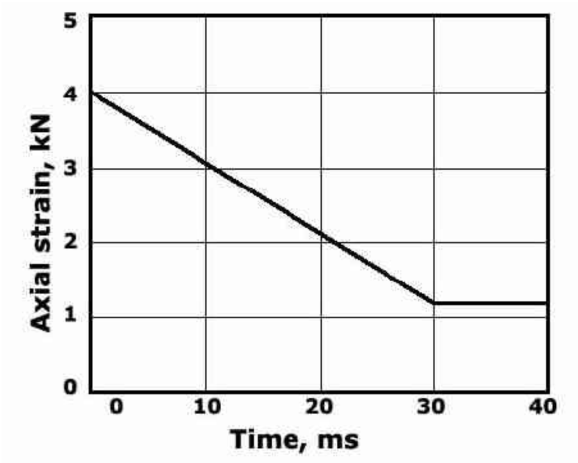


Figure 11. Neck tolerance limits

All axial force-start time combinations found above the delimitation line (fig.11) will lead to major neck trauma with permanent cut-off for some body functions. This can occur even for points found under this line, when a complex neck loading took place during impact.

3. PROCEDURES FOR RATING SEAT/HEAD RESTRAINTS

3.1. Head restraint geometry explained:

The necessary first attribute of an effective head restraint is good geometry. If a head restraint isn't behind and close to the back of an occupant's head, it can't prevent a "whiplash" injury in a rear-end collision. A restraint should be at least as high as the head's center of gravity, or about 9 centimeters below the top of the head. The backset, or distance behind the head, should be as small as possible. Backsets of more than 10 centimeters have been associated with increased symptoms of neck injury in crashes.
Geometric ratings: Geometric ratings are good predictors of how well people will be protected in rear-end crashes -- drivers with restraints rated good are less likely than those with poor restraints to claim neck injuries. Head restraint geometric ratings for hundreds of passenger vehicles are listed by vehicle make and series. Various head/seat combinations are rated (not every available seat option in every series has been measured). The restraints are measured with the angle of the torso at about 25 degrees, a typical seatback angle. Each restraint is classified according to its height and backset into one of four geometric zones -- good, acceptable, marginal, or poor.

The rating for a fixed head restraint is straightforward -- the zone into which its height and backset place it also defines its rating. The rating for a head restraint that adjusts in height and/or backset depends on whether it locks in the adjusted position. If it doesn't lock, its rating is defined by its height and backset in the down and/or rear position. If it does lock, height and backset are measured twice -- in the down position, and in the most favorable adjusted and locked position.

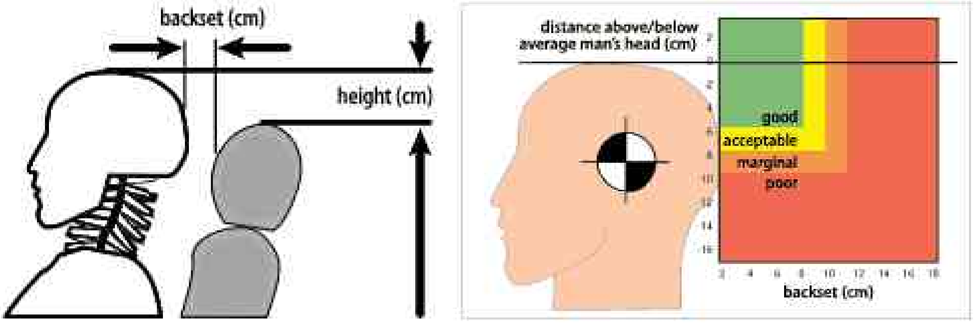


Figure 12. Geometric ratings

The final rating is the better of the two, except that if the rating as adjusted is used, it's downgraded one category because so few motorists adjust their restraints. Many vehicle models have more than one seat option -- if seat differences affect the head restraint rating, more than one rating is shown.

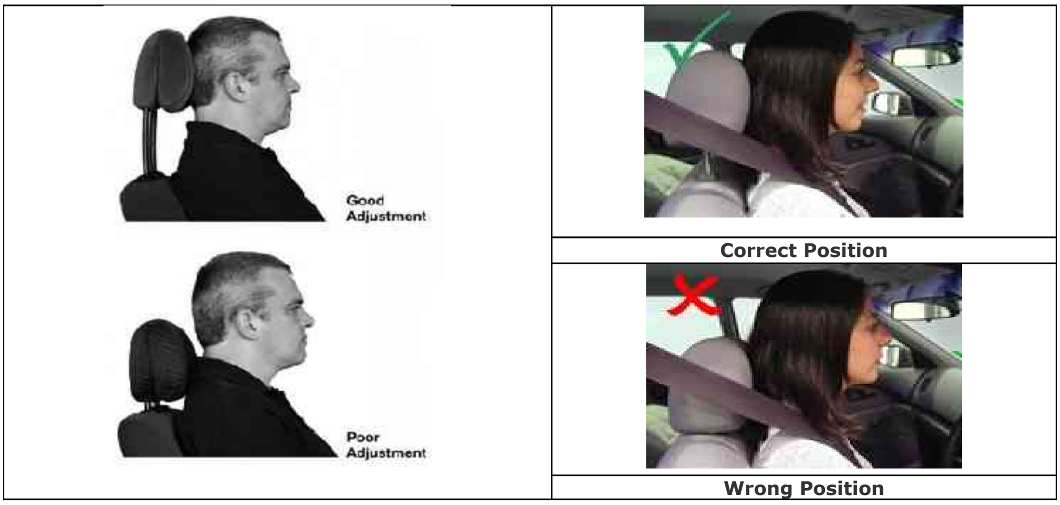


Figure 13. Adequate car seat posture

4. Conclusion

✓ Regarding bio-mechanics, there is not possible for a cervical injury acceleration to appear during impact for values below the delimitation line (fig.11.) for a healthy, uninjured body. For relapsing cases, however, the chance of injury infliction is high even for lower acceleration values.

✓

✓ To offer adequate protection, a head restraint should be as high as the top of the head and as close as possible to the back of the head, touching is best. Although many drivers report initial discomfort with a head restraint so close, especially those with ponytails, it is vitally important that head restraints are positioned sufficiently close to prevent the 'S' shape phenomenon. A properly positioned head restraint is the necessary first step in reducing the relative motion between head and neck, thus reducing injury.

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