**Whiplash Injuries**

**Acceleration Curve**

*Human Volunteer tests*

<table>
<thead>
<tr>
<th>Time (msec)</th>
<th>Acceleration (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-100</td>
<td>Head, Torso, Car</td>
</tr>
<tr>
<td>100-250</td>
<td>Torso, Car</td>
</tr>
<tr>
<td>250-400</td>
<td>Torso, Car</td>
</tr>
<tr>
<td>400-600</td>
<td>Torso, Car</td>
</tr>
</tbody>
</table>

*Note: Some researchers have measured peak acceleration to the head of more than 10 g in similar crashes.*

**Phase 1 (0-100 msec)**
- Car acceleration
- Release of brake pedal pressure.
- Slack in shoulder harness.
- Torso descends.
- Elastic recoil of seat back.
- Brakes reapplied.
- Abrupt shoulder harness restraint aggravates neck flexion.
- Car stops.

**Phase 2 (100-250 msec)**
- Car pitches up.
- Car pitches down.
- Temporary bumper deformation.
- Head moves abruptly rearward.
- Car stops.

**Phase 3 (250-400 msec)**
- Cars separate.
- Torso descends.
- Brakes reapplied.
- Abrupt shoulder harness restraint aggravates neck flexion.
- Car stops.

**Phase 4 (400-600 msec)**
- No apparent structural damage to car.

**Rear impact**

**Stationary marker**

**Front impact**

- Vertical motion of torso and straightening of spine allow vertical rise of 3.5 inches.
- Head snaps into full extension, extends over head restraint and collapses it.
- Restraint acts as a fulcrum.
- TMJ injury is possible with high compression in joint.

- The head begins in its forward motion.
- The torso descends in the seat.
- Seat back bounce increases occupant velocity to 30-70% more than that of car.
- Slack is taken out of shoulder harness.

- Full deceleration of head, neck, and torso; aggravated by shoulder harness.
- High tension and shear forces in spine.
- High brain stem, spinal cord, and nerve root tension.
- Posterior ligamentous complex tension.

- Back and torso load the seat.
- Torso acceleration begins.
- High shear forces develop in neck.
- Spinal curves straighten; spine is compressed.
- High pressure gradients develop in brain; high brain stem shear forces.

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