C7 Occupant Kinematics in Low Speed Motor Vehicle Accidents and Evaluation of Common Analogies

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After attending this presentation, attendees will gain an appreciation for a method of physically evaluating the appropriateness of common analo- gies used to describe the magnitude or effect of low speed collisions on the vehicle and its occupants.

The presentation will impact the forensic science community by demonstrating how vehicle and occupant accelerations can be compared, in addition to presenting a number of common analogies will be shown to be appropriate and reasonable, or inappropriate and unreasonable.

Biomechanical engineers commonly use analogies to illustrate the nature or magnitude of low speed collisions and the effect on vehicle occupants. For example, hard braking, backing into a curb, plopping into a seat, and dropping a seat are common analogies for low speed rear-end impacts; rapid side-to-side steering and driving over a rough road are common analogies for side-swipe collisions; and amusement park bumper car collisions are common analogies for rear-end, broadside, and frontal collisions. However, the applicability or fairness of some analogies has been called into question and warrants evaluation.

By using specific examples, a method of objectively evaluating analo- gies by directly comparing the vehicle and/or occupant accelerations meas- ured during low speed collisions to those measured during the corresponding potential analogous events will be demonstrate. The appropriateness or fair- ness of each analogy will be discussed.

Rear-end Collisions: Events that result in the same contact speed between the occupant and seat back should produce similar bodily acce- lerations and forces.

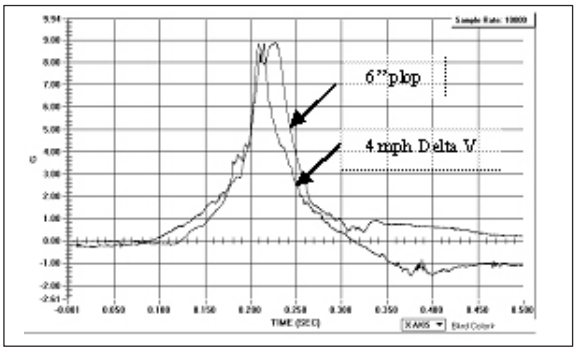

Figure 1: Head accelerations

Indeed, plopping rearward into an automotive seat from a height of 6 inches and 8 inches produced occupant head and upper torso accelerations that compared favorably with those measured in car-to-car impacts producing Delta V's of 4 and 5 mph, respectively. Figure 1 shows the head accelera- tions measured in a 4 mph Delta V impact and a 6 inch plop into the same automotive seat. With comparable occupant accelerations, plopping rearward 6 to 8 inches into an automotive seat can be considered a fair analogy for 4 and 5 mph Delta V rear end impacts.

It has been postulated that dropping an occupant seated in an automo- tive seat with the seat back suspended horizontally 10 inches above the ground would produce a 5 mph contact speed and Delta V and therefore produce occupant forces to a 5 mph Delta V rear-end impact. However, a 10 inch seat drop resulted in two to three times higher thoracic and lumbar accelerations and less than half the head accelerations that those produced in the same seat in a 5 mph Delta V rear-end car-to-car impact. In addition, the occupant rebound characteristic of rear-end impact was absent. Clearly, this analogy can not be considered fair or appropriate.

Previous authors have compared hard braking while backing to Delta V's up to 1.9 mph, when comparing vehicle accelerations, and up to 3.3 mph when comparing occupant accelerations.[1,2] In replicating these tests, head and upper torso accelerations during hard braking while backing at 5 mph were found to be comparable to those produced in a 3.6 mph Delta V car-to- car rear-end impact. Thus, hard braking while backing at low speed would be judged to be analogous to rear-end Delta V's up to 3.6 mph.

It has been theorized that backing a vehicle into a curb at 3 to 5 mph would produce comparable vehicle accelerations and occupant motions in car-to-car impacts with the Delta V. However, vehicles backed into typical curb or parking blocks consistently resulted in the vehicle mounting the curbing with markedly dissimilar vehicle and occupant accelerations when compared to car-to-car impacts. Thus, backing a vehicle into a curb is neither a fair nor appropriate analogy for rear-end impacts in this range.

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Previous authors have reported that amusement park bumper car collisions not only produce similar body motions to rear-end impacts, but the Delta V's and collision durations compare favorably to rear-end impacts with Delta V's as high as 5 to 6.6 mph.[1,3,4,5] As such, amusement park bumper car impacts are judged to be a fair analogy for rear-end impacts with Delta V's up to about 5 to 7 mph.

Similar to the dropping analogy, hopping off a 10 inch step has been equated to a 5 mph Delta V impact. Although similar accelerations are produced, the fact that they are in a different direction coupled with the inherent anisotropic nature of the human body, this analogy can neither be considered fair nor appropriate.

Side-swipe Impacts: The lateral head accelerations of 0.7 g's were measured in side-swipe impacts producing scraping door dents as deep as an inch and fender denting as deep as 3 inches. The amplitude of the lateral shoulder displacement was measured to be an inch. Not surprisingly, side- to-side steering while driving also produced lateral head accelerations of 0.7 g's and lateral shoulder displacements of about an inch. Thus, side-to-side steering is judged to be an appropriate and fair analogy for such side-swipe contact.

Frontal and broadside collisions: Similar to rear-end impacts, pulling forward into curb has been postulated to be comparable to frontal impacts. However, in the highest speed tire to curb contact to date without mounting the curb, a 3.3 mph velocity change was produced. However, the average acceleration was less than 0.23 g's over a 443 msec duration. Clearly, tire- to-curb strikes are neither fair nor appropriate analogies for frontal impacts.

In angled broadsides producing 1.5 to 3 mph Delta V's and door indenting from 2 to 2¾ inches, the lateral head, upper and lower torso accelerations ranged from 0.7 to 1 g. The lateral head, upper and lower torso accelerations measured driving over a rough road was measured to be 1.4, 2.1, and 0.9 g's respectively. Thus, traversing a rough road is a fair analogy for such low speed broadside impacts.

As discussed above, lateral Delta V's as high as 6.6 mph and frontal Delta V's of almost 10 mph can be expected in an amusement park bumper car collisions. With comparable Delta V's and impact duration, frontal and broadside impacts are judged to be comparable to low speed car-to-car impacts with a similar Delta V range.

Head Injury Potential: Head injury criteria or HIC is commonly used to gauge the potential for head injury. Below 50 there is effectively no chance of even the most minor (AIS 1 or 2) head injury.[6] In fact, volunteer studies are routinely conducted in a range that produce HICs below 50 without consequence.

HICs of 1 to 2 have been measured during sneezing and 10 inch hops. HICs of 1 to 22 have been measured in 5 to 14 mph frontal barrier impacts, and HICs as high as 34 were measured in 5 mph rear to barrier impacts, while a pillow blow to the back of the head produced a HIC of 41.

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Low-Speed, Analogies, Biomechanics

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