D11 Biomechanical, Mechanical, and Epidemiologic Characteristics of Low-Speed Rear-Impact Collisions

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The goal of this presentation is to provide a reliable description of the mechanical, biomechanical, and injury-risk characteristics of minimal and no-damage rear-impact collisions based on an analysis of epidemiologic data.

This presentation will impact the forensic science community by demonstrating a validated methodology for investigating and describing the dynamic vehicle and occupant characteristics of minimal and no-damage bumper-to-bumper, rear-impact collisions as well as the injury risk associated with such collisions.

Bumper-to-bumper, rear-impact collisions are unique events that can result in substantial occupant forces while leaving little physical evidence of the collision. Highly elastic bumper components protect the vehicle from visible damage in ≤10mph (16km/h) closing speed and ≤8mph (13km/h) delta V collisions. Precise reconstruction of the delta V of the target vehicle is challenging, as a 3mph delta V crash can leave the same degree and pattern of physical evidence as a 7mph delta V crash (little to none); however, the energy of the latter collision is more than four times greater than the former. Absent multiple full-scale reenactments of the collision, commonly employed reconstruction methods, such as a Mass, Energy, and Restitution (MER) or conservation of momentum calculation, are error-prone because of the speculative basis of some of the critical input variables (closing speed, coefficient of restitution, etc.).

Regardless of the shortcomings, such reconstructions are common in litigation involving minimal damage collisions. This practice is in part due to the fact that it is not uncommon to see claims for injuries in such collisions that are significant, including claims of spinal disk derangement resulting in surgery. The most common purpose of the reconstruction is to estimate vehicle forces, given in terms of acceleration (g). Vehicle acceleration is often used for an inference regarding occupant forces, which are often used to estimate the injury risk of the collision. The relationship between the vehicle delta V and acceleration is based on an assumption regarding the duration of the crash pulse. The method of estimating the occupant acceleration is often unspecified, and typically estimated as equal to two or more times the average vehicle acceleration. The estimate of injury risk from the delta V is most commonly based on the lack of significant injury reported in full-scale human volunteer crash testing and the estimate of injury risk from assumed occupant acceleration is based on comparisons with reported accelerations of daily activities and other non-injurious events.

There are available data sources for estimating all of the above-mentioned parameters of rear-impact collisions, thus eliminating the speculation inherent in the approach described above. Several researchers have examined and described vehicle dynamics associated with low-speed rear-impact collisions via information collected contemporaneously by data event recorders in the vehicles and matched the vehicle information to injury outcome and duration.[1,2] Other researchers have described the results of volunteer crash testing such that the range of occupant acceleration at a specific delta V can be estimated.[3] The purpose of the present investigation is to describe the range of vehicle and occupant dynamic and injury response to a range of rear-impact-related delta Vs associated with minimal and no-damage collisions (3-7mph delta V (5-11km/h)), based on an analysis of previously published observational data. The statistical methods used for the continuous variable outcomes were regression utilizing a general linear model and for dichotomous outcomes binomial logistic regression (JMP®, Version 11).

Delta V (mph, (km/h))	Peak vehicle accel. (g)	Peak occupant head acc. (g)	Crash pulse duration (msec)	Any injury %	Injury >6 months %	Cervical disk injury %
3 (4.8)	6.1 (5.5, 6.7)	4.4 (3.5, 5.9)	55.8 (52.0, 59.6)	24.4 (14.8, 37.4)	1.9 (0.5, 6.8)	1.6 (0.3, 7.3)
4 (6.4)	6.7 (6.2, 7.2)	5.4 (4.5, 7.0)	61.3 (57.9, 64.7)	29.3 (19.6, 41.5)	2.5 (0.7, 8.2)	1.9 (0.5, 7.9)
5 (8.0)	7.2 (6.8, 7.7)	7.2 (6.0, 9.1)	66.7 (63.6, 69.8)	34.9 (25.0, 46.4)	3.5 (1.2, 9.8)	2.5 (0.7, 8.6)
6 (9.6)	7.8 (7.4, 8.2)	10.6 (7.9, 15.9)	79.2 (62.2, 75.2)	40.9 (30.4, 52.3)	4.7 (1.8, 11.8)	3.0 (0.9, 9.3)
7 (11.2)	8.3 (7.9, 8.7)	13 (10, 20)	77.6 (74.6, 80.6)	47.2 (35.5, 59.1)	6.4 (2.7, 14.2)	3.7 (1.3, 10.3)

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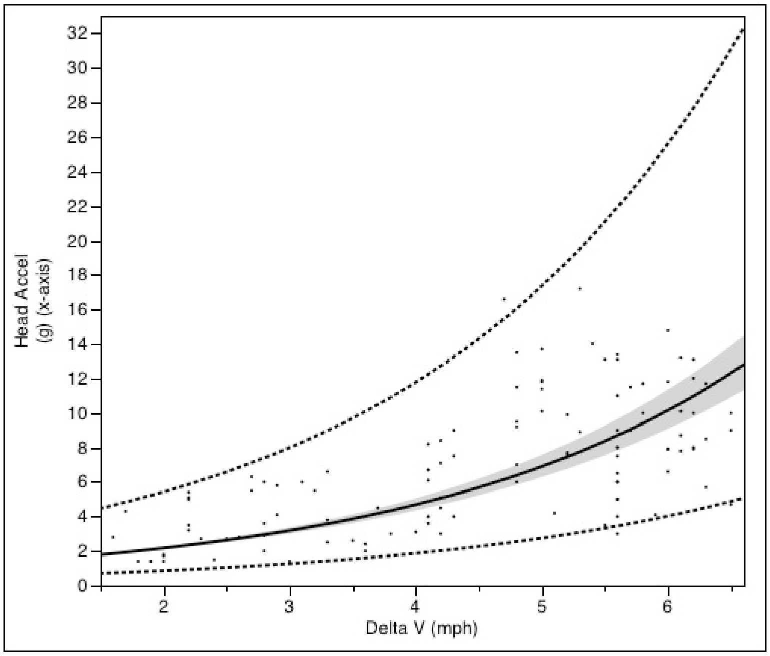
The above table depicts the results of the analysis of event data recorder-reported findings and the associated medically observed outcomes in 114 occupants exposed to rear-impact collisions. The reported vehicle accelerations were based on a 3g recording threshold, which may have affected the speed change calculation. The risk of cervical disk injury is based on the classification of an injury as a "WAD III," which includes findings of neurologic involvement. Peak head acceleration is based on the results of 93 volunteer crash tests. The values for occupant acceleration at 7mph delta V are estimated due to excessive variance. The values in brackets are the 95% confidence interval for the point estimate.



The above graph demonstrates the curvilinear relationship between vehicle delta V and peak head acceleration in 93 human volunteer crash tests. The shaded section is the 95% confidence interval, and the dotted line is the predictive interval depicting the likely range of accelerations in the general population.

This presentation will demonstrate the mechanical, biomechanical, and injury risk characteristics of minimal and no-damage rear-impact collisions.

References:

1. Krafft M, Kullgren A, Ydenius A. Influence of Crash Pulse Characteristics on Whiplash Associated Disorders in Rear Impacts — Crash Recording in Real Life Crashes. *Traffic Inj Prev* 2002;3(2):141-9.
2. Ono K, Ejima S, Yamazaki K, et al. Evaluation Criteria for the Reduction of Minor Neck Injuries during Rear-end Impacts Based on Human Volunteer Experiments and Accident Reconstruction Using Human FE Model Simulations. *International Research Counsel on the Biomechanics of Impact*. York, UK. September, 2009.
3. Nordhoff L, Freeman MD, Siegmund GP. Human Subject Crash Testing: Innovations and Advances. *Society of Automotive Engineers*, Detroit MI 2007

Rear-Impact Collision, Crash Reconstruction, Biomechanics