Forensic Engineering Evaluation of Statistical Validity in Low-Speed Vehicle Impact Cases

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ABSTRACT

Forensic testimony regarding the minimal severity or non-probability of personal injury regarding low-speed vehicle accidents is occasionally non-scientific, biased, and often fails to meet scientific standards of statistical probability. While there may be no dispute as to the cause and liability of a vehicle-to-vehicle impact, the defense argument of "no causation for injury" is often based on a technically insupportable interpretation of published technical articles. Said publications, which may contain valid but minimal technically supported evaluations of occupant responses in specific staged vehicle-to-vehicle impacts, are not statistically valid and typically do not support the erroneous conclusions extracted by some experts.

The purpose of this presentation is to (1) present appropriate principles of *inferential statistics* and *probability* as they relate to the analysis of injury-causation, particularly in the analysis of "low-speed" vehicle accidents, (2) review a representative sampling of these articles, and (3) evaluate typical erroneous conclusions. No inference is made herein as to strictly medical evaluations. The principles presented within this article are strictly based on critical elements of "inferential statistics" and "probability", of which the principles are endorsed and peer-reviewed through academia. The content of this article is not intended to replace a detailed study of statistics and probability but to present in a clear and brief manner, scientific elements the forensic expert may encounter when evaluating contentious scientific testimony.

Keywords

Forensic Engineering, low-speed impacts, statistics; descriptive statistics, inferential statistics, probability, random sampling, bias, outliers, sample population

INTRODUCTION

Scenario: A fairly common "low-speed" two-vehicle impact occurs when a stopped ("target") vehicle is struck in the rear by the driver of an approaching ("bullet") vehicle. (Note the terms "target" and "bullet" are not intended to suggest any derogatory bias but are terms often used to effectively describe a vehicle struck by an approaching vehicle.) Vehicle A may be stopped at a traffic signal awaiting the proper time to proceed when it is struck in the rear by the front bumper of vehicle B, of which the driver may have been distracted, inattentive, or simply unable to stop for some reason. Within days, the driver of vehicle A begins to claim some neck or back pain or

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discomfort (albeit perhaps from a pre-existing condition). Said driver eventually contacts his or her attorney and litigation begins against the driver of vehicle B for physical injuries sustained in the collision.

The defense response is often provided by a "biomechanist" (i.e., one claiming expertise regarding the limits of physical tolerance levels in humans), who claims the change in velocity or "Delta V" was so low that, based on supporting articles, injury could not occur or at least was unlikely. [Author's note: The term"Delta V" is incorrect since V, indicating velocity, is a vector quantity and infers both speed and direction whereas S or "speed" is a scalar quantity only. A great deal of "biomechanical" analyses of low-speed impacts do not analyze angular displacement; therefore, the correct term would be "Delta S." However, the commonly-used term "Delta V" will be continued throughout this presentation.]

The defense expert often lists supporting documents, many of which represent studies of human or anthropomorphic (i.e., human-appearing test dummies) test subjects and, on occasion, cadavers. The essential and numerous problems with these presentations is that the publications relied upon most often do not portray the conclusions experts appear to extract from technical publications in support of their conclusions. In addition, the test subjects are considerably few in number, are not random (a critical element of sampling), and are generally biased in many ways.

The term, "low-speed impact" is generally reserved for impacts of less than 10 miles per hour (MPH) differential between a stopped or slower moving target vehicle and the striking bullet vehicle. It has been my experience that a Defense expert will typically offer testimony regarding this typical impact scenario, with statements similar to, "Because the Delta-V was less than X MPH, no injury could occur." Notwithstanding the Plaintiff's medical examiner's evaluation of injury and related causation, the Defense expert, in an attempt to support his analysis, may offer in support, numerous publications, often referencing the Society of Automotive Engineers (SAE) or similar sources, which he/she believes support the Defense expert's conclusions. Three such SAE articles are presented herein to present the referenced defense fallacies.

A Forensic Engineer's evaluation of such testimony should evaluate the basis for erroneous conclusions based largely on an improper or mis-guided evaluation of SAE or similar articles. The following commentary will offer a representation of often fallacious evaluations and explain why the supporting articles are not based on scientific principles of statistical validity.

PRINCIPLES OF STATISTICS AND PROBABILITY

The basic term *statistics* is generally understood to mean the science of collecting, analyzing, and interpreting data for a particular purpose. From that term, two key branches of statistics emerge. *Descriptive statistics* is used to summarize and describe a collection of data without predicting a future outcome. As an example, the height of a collective group of seventh grade male students may be collected and tabulated. On the other hand, *inferential statistics* is used to predict events based on an evaluation of previously collected data. Example: A university-bound student's educational success may be predicted (i.e., inferred) by the student's college entrance exam scores based on the historical data of a much larger sample population. *Probability* can then be an extension of inferential statistics and addresses the likelihood a certain event will occur. The subjects of this presentation are the fields of *inferential* statistics and *probability*.

Critical Elements of Sampling

Random Sampling

With regard to the subject of inferential statistics within this presentation, a *random sampling* of subjects representing the intended population should first be acquired and eventually evaluated in order to predict or infer an outcome for the entire subject population. It is critical for the chosen sample population to be truly random, meaning each member of the sample population has an equal chance of being chosen. A proper random sample is basically a collection of a subset of individuals from within a population in order to estimate characteristics of the entire population. In the course of this presentation, a study of human response to low-speed vehicle impacts must include a sample of all persons expected to ride in automobiles.

Bias

In addition to randomness, all samples must avoid any *bias*. Bias can occur when the sample chosen has a certain agenda or pre-conceived motion or idea of the study's intent. [As in the example of descriptive statistics in a previous paragraph, a sampling of seventh grade male basketball players is only a descriptive analysis and would result in a significant bias for any evaluation of average height for students in other grades.] We shall soon see that often employees from a testing firm are chosen as test subjects for staged vehicle impacts. In that event, a potential bias exists in that such subjects may be aware of the objectives of the employer and would typically have an inherent desire to conform to the employer's objectives. Also, the testing entity is often supported financially by special-interest groups with an agenda for an analysis favorable to their best interests. When told of the process of a pending staged impact, a test subject seated in a target vehicle is prepared and aware of a staged impact to some degree resulting in another bias. Finally, an inherent bias exists in vehicle-to-vehicle staged impacts when vehicles are modified for purposes of repeated tests, video taping, and applied instrumentation.

Sample Size

In order to make an acceptable inference on the intended population, the sample population must be of sufficient size to counteract any "*outliers*" (i.e., extremes within the sample population) and to accurately represent all persons in the larger population. If the purpose of statistical testing is to collect information applicable to all possible vehicle occupants in the United States, (as of this writing, approx. 320 million people), a relatively large sample population would be required. The size of a sample is generally dependent on two elements, (1) the size of the population being studied and (2) the degree of confidence (i.e, 85% confidence level, 90%, 95%, etc.). The defense (e.g., biomechanist) argument generally appears to insinuate the same outcome (at a 100% confidence level) without acknowledging the wide disparity of individuals. In other words, it does not appear to matter to many defense experts if the plaintiff is, for example, an 80 pound, 80 year old great-grandmother or a 300 + pound 25 year-old football lineman. Essentially, the sample size must be sufficient to include all persons within the entire population being studied.

Subsets

As referenced in the prior paragraphs, the sample population must represent all persons within the entire population being represented. That includes subsets or groups with particular characteristics such as age, general health, alertness and other criterial unique to a reasonable occupant of a struck vehicle. In the course of this study, I have suggested the subset of age be considered from 0 to 80 years in subset groups of 10 years,.from birth to 10 years (terminating at the birth date resulting in 10 complete years), then beginning the 11th year of life through the 20th birthday, and continuing until one reaches 80 years of age, resulting in 8 groups of 10 years each. Sex is another subset consisting of two groups, male and female.

For purposes of this explanation, I have only considered the following basic subsets (Fig. 1):

SUBSETS		
Group Description	**Details**	**No. of Groups**
Age	0 - 80 years in groups of 10 years	8
Sex	Male/Female	2
General Health	Poor, Avg., Fit	3
Alertness	Distracted, Alert, Keenly observant	3
Weight	Underweight, Avg., Overweight	3
	Total Groups	**19**

Figure 1

A total of 19 groups does not sound too overwhelming; however, when considering a collective croup of subsets, each combination of groups must be included. For example, in each age group of 8, there are both male and female. Therefore in just these first two groups there are a combination of 16 possible **single** subjects (8 X 2 = 16). When all 5 basic groups are considered, the total of individual **single** subjects increases to 432 (8 X 2 X 3 X 3 X 3 = 432). Since a single person does not constitute an accurate sample, assume a minimum of 100 individuals in each subset group are evaluated. The total of sample subjects then becomes 43,200 (432 X 100 = 43,200)!

Summary of Sample Population

Simply stated, a sample population must be randomly chosen, ideally without bias, of sufficient size, and include all subsets. In the example of subsets presented in the previous section, I suggest if one intends to evaluate and infer vehicle occupant response for the entire population of the United States alone (presently at approximately 320 million people), a sample population of 43, 200 persons may be difficult to obtain but should be considered an absolute and minimum basic number of persons sampled in order to satisfy scientific and statistical significance.

Probability

Probability answers the question, "How probable is the outcome?" Probability is dependant on the number of potential results. For example, if one roles a single die (a singular form of dice), a single"number" (represented by dots or "pips") (1 - 6) has an equal chance of appearing. However, when a second die is added, two identical numbers have a combined 1 in 36 chance of appearing. The rule of probability essentially states that the outcome of multiple events is the result of multiplying together, or the product of each singular event. In the case of two dice being thrown, there is a 1/6 chance of a select number (say, "one") on each dice. Therefore, "snake eyes" (two "ones"), (or any other similar pair of numbers) have a 1/6 X 1/6 = 1/36 chance of appearing in any single "roll" of a pair of dice.

As that principle applies to vehicle occupant response, if we assume each of the referenced minimum 43,200 test subjects has an equal and accurate chance of being evaluated in the subject two-vehicle accident, the probability is 43,200/320,000,000 or about a one-hundredth of one percent chance of representing the entire population.

SAMPLE SAE ARTICLES

The Society of Automotive Engineers (SAE) publishes articles on various subject including evaluated occupant response in staged vehicle to vehicle impacts, of which many of the articles relate to low-speed impacts. While the articles often contain valid information, some experts erroneously extract information which is often not contained with the reports and typically does not meet the strict standards of statistical reliability.

The following often-referenced articles are only a few of the publication which have been relied upon by biomechnaical experts in the analysis of low-speed rear impacts:

SAE 930889*, Analysis of Human Test Subject Kinematic Responses to Low Velocity Rear End Impacts,* McConnel, Whitman E., et al.

SAE 952724, *Human Head and Neck Kinematics After Low Velocity Rear-End Impacts - Understanding "Whiplash",* McConnel, Whitman E., et al.

SAE 962432, *Human Subject Kinematics and Electomyographic Activity During Low Speed Rear Impacts,* Szabo, Thomas J., Welcher, Judson B.

Note the following brief summary of these articles (Fig. 2):

SAE DATA			
SAE Art.	**No. Test Subjects**	**No. Vehicles Tested**	**Total No. of Tests**
930889	4	4	10
952724	8	3	14
962432	5	2	10

Figure 2

Commentary

SAE 930889: In this article, four healthy males test subjects, ranging in age from 45 to 56, were fitted with instrumentation including "biteblock(s)" and accelerometers, seated in one of four test basically unmodified vehicles (except for the removal of driver-side doors to facilitate photography), a 1986 Dodge 600 convertible, a 1984 Buick Regal Limited coupe, a 1984 Ford Club Wagon van, and a 1984 GMC 1500 pickup truck, some of which the rear end of target vehicles were raised to align with the bullet vehicle's front bumper. No reference was given as to the source of the test individuals.

SAE 952724: Three test vehicles were selected, consisting of a "bullet" 1984 GMC C-1500 pickup truck, and two "target vehicle, a 1986 Dodge 600 Convertible and a 1984 Buick Regal Limited Coupe. [Author's note: One may detect the notable similarity in test vehicles utilized by the same authors of SAE Art. 930889.] In this study, the front bumper of the bullet vehicle was removed and replaced with a steel reinforced and wood-faced structure while the two target vehicles were modified with steel braces. Eight test subjects were chosen among the employees of the testing facility.

SAE 962432: Two Volvo test vehicles, a (target) 1976 Volvo 242 and a (bullet) 1977 Volvo 244 comprised the test vehicles. The only modification was the removal of the driver's door to facilitate high-speed video taping. Of the five test subjects, (one female and four males, ages 22 - 54 years), all were reportedly in good health except that three of the individuals reported various degrees of prior injuries. Ten tests were performed.

ANALYSIS

In each of the referenced articles, no outright reference was made as to the probability of injury as may be applied to the overall population. One could only surmise for example, that an inference of injury could possibly and remotely be made but only if a female of the same age, physical and general description of the female test subject in SAE 962432, who happened to be in the driver's seat of a 1976 Volvo 242, which was struck in the rear by a 1977 Volvo 244, under approximately the same conditions as experienced in the referenced tests. Similarly, the same basic premise could be made for all referenced tests.

In all tests, the number of test subjects was grossly inadequate to make any scientifically valid statistical conclusion. Bias occurred when the chosen test subjects were aware of a pending impact to the rear of their test vehicles. While efforts are often made to suppress any knowledge of the exact timing of impact (by providing blindfolds, music, etc.), one could surmise that preemptive tension would likely be a significant factor thus creating a bias. Bias also occurs when some, if not all test subjects are chosen among the testing facility staff thereby negating the primary and essential element of randomness. In addition, no attempt was apparently made to include all reasonable subsets or groups.

The test vehicles are also subject to statistical error. The driver doors of target vehicles were typically removed in order to facilitate photography which likely have altered the structural aspects of the vehicle body. Often vehicles were provided with stiff braces which allowed for repeat tests. In some tests, the front and rear bumpers were replaced again, to allow for repeat tests since an impact may alter the energy absorbing qualities of vehicle bumpers.

CONCLUSION

The objective of this analysis is not to degrade SAE or its publications or similar articles since it is believed the respective publications offer a generally fair and objective analysis especially with regard to the limitations of the few human test subjects. It is, however, my objective to expose generally Defense arguments regarding causation when a reliance on the referenced articles is erroneously endorsed.

Statistical analysis requires a well-defined and strictly controlled test environment, of which the referenced and similar articles are limited in design for the purpose of evaluating the potential of injury in low-speed vehicle impacts. Due in part to the insinuation that the entire US population of nearly 320 million people can be evaluated by a minimum of often less than ten test subjects, such testimony is not worthy of credible scientific consideration and expert testimony.