

Feature Article

*Stephanie Pasquesi, Ph.D., P.E. and Joseph Olberding, Ph.D., P.E.
Explico Inc.*

The Biomechanical Expert: An Important Addition to Cases Involving Questions of Injury

There is often confusion between biomechanical analyses/opinions and medical opinions because both deal with the human body. Medical dictionaries define biomechanics as the science concerned with the actions of forces, internal and external, on the living body. Other dictionaries define biomechanics as the application of the principles and techniques of mechanics to the structure, functions, and capabilities of living organisms. In simplest terms, biomechanics is the field of science that investigates injury mechanisms, potential, and outcomes in relation to forces and motions applied to the human body during dynamic and static loading. Conversely, the word “medical” is defined as relating to the science of medicine, or the treatment of illness and injuries. Medicine is defined as the science or practice of the diagnosis, treatment, and prevention of disease.

Determining the forces and motions acting on an individual during a motor vehicle collision or other incident involving (alleged) injuries, i.e., a biomechanical analysis, is a generally accepted practice. Specifically, the federal government’s National Highway Traffic Safety Administration (NHTSA), an agency whose stated mission is to “Save lives, prevent injuries and reduce economic costs due to road traffic crashes, through education, research, safety standards and enforcement activity,” has the Biomechanics Research Divisions of Human Injury Research and Applied Biomechanics under the Office of Vehicle Safety Research. <https://www.nhtsa.gov/about-nhtsa/nhtsas-core-values>. These groups “conduct cooperative and collaborative research with other organizations around the world to develop knowledge and tools that help mitigate injury and death from motor vehicle crashes.” Five-year research plans published by NHTSA’s Biomechanics Divisions have included a research area of “Injury Causation and Mechanisms Analysis” and explain that, “Understanding injury causation and mechanism from real-world crashes provides significant insight into creating future biomechanics projects.” National Highway Traffic Safety Administration, NHTSA’S BIOMECHANICS RESEARCH PLAN, 2011-2015, DOT HS 811 474, National Highway Traffic Safety Administration (2011). The NHTSA’s Crash Injury Research and Engineering Network (CIREN) program “combines prospective data collection with professional multidisciplinary analysis of medical and engineering evidence to determine injury causation in every crash investigation conducted” with a mission “to improve the prevention, treatment, and rehabilitation of motor vehicle crash injuries to reduce deaths, disabilities, and human and economic costs.” <https://www.nhtsa.gov/research-data/crash-injury-research>.

These examples, from the regulatory perspective alone underline the notion that, in order to prevent injury, one must first understand the mechanisms that cause injury. The opportunity to contribute to the prevention of injuries and fatalities through the application of scientific and engineering principles and research is often the very reason young people decide to enter fields related to biomechanics. To scientists and engineers, biomechanics is hardly a “junk science.”



What is Biomechanics?

At the root of biomechanics is mechanics, a branch of physics concerned with how matter responds to applied forces or motions. In biomechanics, the matter at issue is biological structures and tissues. Injury biomechanics is the science concerned with understanding the magnitude and direction of forces applied to the body that result in a structural failure or injury. The magnitude of force at which injury can be expected is referred to as injury tolerance. One of the many ways biomechanical experts utilize injury tolerances is in the assessment of the likelihood that an injury was sustained during a given event.

What is a Biomechanical Expert?

Biomechanics experts typically have expertise in physics, mechanical engineering, biology, and/or biomedical engineering. Often these individuals have completed advanced degrees, such as an M.S. or Ph.D., in mechanical engineering, bioengineering, biomedical engineering, or related fields. They have specific experience applying their knowledge in the context of biomechanical research studies. A record of scientific publications often exemplifies and supports this experience. Furthermore, biomechanical experts have often completed coursework in physics, dynamics, applied mechanics, anatomy, tissue/injury mechanics, and other related topics. In addition to training, education, experience, and case-specific reliance materials, the biomechanics expert may, depending on the case, call upon the following for bases of opinions: fundamental laws of physics; the principles of dynamics; classical biomechanical and engineering textbooks; published, peer-reviewed, and generally-accepted scientific journal articles; real-world incident data and publicly-available vehicle crash tests; studies of human tissue mechanics and tolerance to forces; and a detailed review of medical records. Some cases may also involve site and evidence (product) inspections, surrogate and exemplar studies, physical testing, and computational simulations (see below).

What Can the Biomechanical Expert Offer?

Biomechanical experts investigate a myriad of questions related to incidents involving injury claims. Utilizing case-specific information and evidence, a biomechanical expert may analyze whether an injury or group of injuries are consistent with the event, and if so, how. Sometimes injuries are used to reconstruct an event or specific elements of an event. A biomechanical expert may also relate diagnoses documented in an individual's medical records to a specific event and analyze whether the type and level of forces required to cause those injuries were present in the event. Specific to product liability, a biomechanical expert may investigate whether alleged defects may have contributed to an individual's injury or injury potential, the effectiveness and performance of safety devices during an incident, how injury risk could—or could not—have been reduced in a given scenario, or other critical aspects of a given product's safety from a biomechanical perspective.

Consulting with a biomechanical expert early on in case assessment can also help in formulating strategies for damages, comparative negligence, settlement, etc., by aiding the attorney in understanding the viability of potential arguments before significant time has been spent and costs incurred. With early engagement, they can also advise on identifying and preserving key pieces of evidence. In addition, like many experts, a biomechanical expert can assist in deposition preparation for witnesses and other experts by providing suggestions for questions that may inform their analysis and the case at large. Especially with regard to opposing experts offering biomechanical opinions, a

biomechanical expert may assist in suggesting questions and topics for deposition and evaluating the opposing expert's opinions and analysis to support preparations for a motion for summary judgment, a motion to exclude, or a *Frye* or *Daubert* hearing.

Biomechanical Versus Medical Analysis

Traditionally, physicians diagnose (i.e., identify) and treat injuries but do not analyze the specific mechanism of an injury to understand its causation. Indeed, physicians often do not have formal training in engineering mechanics and applying mechanics (i.e., forces and motions) to biological tissue. On the other hand, while not qualified to diagnose injuries, biomechanical experts analyze and quantify the forces and motions experienced by the body during a given incident and determine the effect of these forces and motions on the body. In fact, the role of a biomechanical expert may be complementary to that of a physician. The findings and opinions of a biomechanical expert can often provide a link, or lack thereof, between the forces and motions involved in an incident and documented diagnoses of injury alleged to have resulted from the incident.

Forensic Biomechanics and Injury Causation

The Reference Manual on Scientific Evidence is a document written jointly by the National Academies of Science and the Federal Judicial Center to assist judges in understanding the basic tenets of key scientific fields. National Research Council, *Reference Manual on Scientific Evidence* (2d ed. 2000), <https://www.ojp.gov/ncjrs/virtual-library/abstracts/reference-manual-scientific-evidence-second-edition>; National Research Council, *Reference Manual on Scientific Evidence* (3d ed. 2011), <https://doi.org/10.17226/13163>. The manual provides a section dedicated to determining general injury causation, meaning whether the types and magnitudes of forces involved in an event can cause a certain type of injury in general. The manual defines general causation to be a demonstration that the “medical and scientific literature provides evidence that in some circumstances the exposure under consideration can cause the outcome under consideration.” In the context of the typical personal injury case, the “exposure” is the mechanical loading (i.e., forces and motions to the body) associated with the subject incident and the “outcome under consideration” consists of the conditions documented in the medical records.

The Reference Manual on Scientific Evidence also states that, in some situations, “the exposure estimates will be based on methods beyond the scope of medical expertise, such as physical or chemical analyses” During these types of situations, an appropriate area of expertise is required. When determining the mechanical loading experienced by an individual and the mechanisms associated with various injuries, the manual states:

Specifically, one cross-disciplinary domain deals with the study of injury mechanics, which spans the interface between mechanics and biology. The traditional role of the physician is the diagnosis (identification) of injuries and their treatment, and almost never includes a detailed assessment of the physical forces and motions that created injuries during a specific event. The field of biomechanics (alternatively called biomechanical engineering) involves the application of mechanical principles to biological systems, and is well suited to answering questions pertaining to injury mechanics Such an expert would rely on medical records to obtain information regarding clinical diagnoses, and would rely on engineering and physics training to understand the mechanics of the specific event that created the injuries. A practitioner whose experience spans the interface

between mechanics (i.e., engineering) and biology (i.e., science), considered in the context of the facts of a particular case, can be of significant assistance in answering questions pertaining to injury mechanism and causation.

Specifically in Illinois federal districts, case law supports the testimony of biomechanical experts regarding injury mechanics and mechanisms. In *Phillips v. Raymond Corp.*, 364 F. Supp. 2d 730 (N.D. Ill. 2005), the court concluded that a biomechanical engineer's qualifications and experience entitled her to testify about Plaintiff's "injury and related biomechanical issues." In addition, in *McKeon v. City of Morris*, No. 14-CV-2084, 2016 WL 5373068 (N.D. Ill. 2016), the Northern District of Illinois held a biomechanical engineer was qualified to interpret the diagnoses made by Plaintiff's treating physicians in order to opine on the mechanisms of Plaintiff's injuries. In other words, biomechanical experts can speak as to whether and how a plaintiff's injuries—or alleged injuries—are or are not related to the forces and motions they experienced during an incident.

In injury causation cases, the value of a biomechanical expert to a jury lies in their ability to evaluate and explain whether the forces and motions experienced by an individual are consistent with their claimed injuries. While many courts have found biomechanical expert testimony to be admissible, nuance exists in what testimony courts will admit in terms of non-physician causation testimony in personal injury litigation. The distinction between the terms "specific causation" and "general causation" is generally traced back to *Smelser v. Norfolk Southern Railway Company*, 105 F.3d 299 (6th Cir. 1997), which indicated that biomechanical engineers are qualified to: (1) determine the loading experienced by an individual during an event, and (2) opine as to the general types of injuries that could be associated with that loading.

A thorough discussion of general versus specific legal causation is beyond the scope of this article, but both retaining counsel and the prospective or retained biomechanical expert should be aware of potential limits to causation opinions when framing expected testimony. While courts vary substantially on what exactly constitutes specific injury causation, the fundamental tension (figuratively, not mechanically) with biomechanical analyses and opinions is providing enough specificity with respect to the case and reportedly injured person to be helpful to the fact finder, yet sufficiently general so as to not stray outside their qualifications into the specific causation territory. As such, any opinions that resemble injury diagnosis, injury extent, injury permanency, or appropriateness of treatment should, of course, be avoided by the biomechanical expert. The *Smelser* decision noted biomechanical expertise qualification infirmities for specific causation to include needing to rely on a medical doctor to establish an individual's injuries, not being able to account for an individual's particular injury tolerance level, not being able to account for an individual's pre-existing medical conditions, and not reviewing a complete medical history.

So, what are the litigator and biomechanical expert to do? Guided by the above-described framework promoted by the Reference Manual on Scientific Evidence, the first step is to ascertain and characterize the clinically diagnosed medical condition(s) as fully as practicable through detailed review of available medical records and, sometimes, radiological imaging studies and/or injury photographs. Next, in what is typically the most complex and time-consuming step, the biomechanical exposure of the subject incident, that is, the dynamic forces and motions experienced by the individual during the event must be characterized. Ideally, mutually independent redundant approaches should be undertaken. When multiple such techniques yield consistent results, not only is the expert work product better able to withstand vigorous cross examination, but its robustness may also allow the testimony to survive should any single piece of reliance evidence or analysis approach be ruled inadmissible. The third and final step is to assess the causal relationship between the exposure (biomechanical environment) and the outcome (medical conditions). Since the biomechanical expert is uniquely qualified to determine the types and magnitudes of biomechanical loads that generally cause (and don't

cause) certain types of mechanical failure (i.e., structural alteration or damage) of biological tissues, biomechanics is central to determining the validity of claims that allege forces and motions to be the cause of the mechanical failure of biological tissues, i.e., the injury/injuries. A window into these techniques is also provided in the below section. This process constitutes a rigorous, formal, scientific analysis of the criteria that must be met to demonstrate whether or not the biomechanical loading experienced by an individual was consistent with the biomechanical loading generally associated with the alleged condition or injuries. The prudent and effective biomechanical expert will word their causation-related conclusions and opinions carefully to avoid being misconstrued as encroaching on specific medical causation. If time and budget allow, a physician co-expert can cover specific injury causation by incorporating the biomechanical expert's general causation conclusions in their medical opinion. It is often the case that medically diagnosed conditions have two possible causes, namely traumatic or degenerative. In the case that the biomechanical expert determines that the forces and motions experienced are inconsistent with the incident at hand, there are other reasonable explanations for the presence of those diagnosed conditions.

The Biomechanical Analysis Toolkit

The biomechanical expert has a variety of tools available to assist in their evaluations that have been peer-reviewed, validated, and/or are generally accepted in the engineering, scientific, and biomechanical communities. When assessing the loading to a given individual in a specific incident (i.e., reconstructing an incident), the biomechanical expert may utilize studies of similar events described in the peer-reviewed engineering, scientific, and biomechanical literature, calculations based on generally accepted methodologies in the accident reconstruction and biomechanics communities, and/or validated and generally accepted computational modeling approaches. In many instances, studies in the scientific literature have evaluated incidents similar to the incident the expert is evaluating and measured loading to the body via anthropomorphic test devices (e.g., “crash test dummies”), animals, cadavers, and/or live human volunteers. For example, the literature includes many studies of low- to moderate-severity motor vehicle crashes, as well as falls from height, impacts of falling objects onto hard hats, etc. The biomechanical expert may compare what is available in the literature to the precise incident they are evaluating to develop opinions on the loading they may expect the body to experience in the incident they are evaluating. Calculations evaluating elements of the incident and potentially relating them to plaintiff's anthropometry (height, weight, etc.) may also assist in reconstruction and assessing injury potential. Finally, computational modeling approaches often allow the biomechanical expert to simulate a specific incident using a virtual surrogate of the same sex scaled to the same height and weight as an individual involved in the incident. Subject- and incident-specific approaches afforded by computational modeling methodologies can strengthen credibility in reconstructions beyond what calculations and literature comparisons may show, especially if the computational models show results consistent with the more “low-tech” calculations and literature comparisons. This kind of computational simulation imbues biomechanical testimony with specificity in the exposure characterization step of the general causation analysis process.

The biomechanical, engineering, and scientific literature also includes many peer-reviewed studies describing the loading—forces and their direction and rate of application—that results in a specific type of injury. This is often referred to as an injury mechanism and tolerance. By reviewing and summarizing what is known regarding injury mechanisms and tolerances, the biomechanical engineer can then compare the calculated loading and the manner in which the loading was applied to an individual's body during a specific event to a given injury mechanism and/or tolerance to address the likelihood of that injury having occurred during the specific event.

The peer-reviewed biomechanical, engineering, and scientific literature as well as generally accepted computational modeling programs also offer information regarding the type and level of forces experienced by individuals during activities of daily living and other activities generally considered to be non-injurious. While the literature provides information gathered from live human volunteer test subjects of both sexes and a range of ages, heights, and weights, computational modeling programs may allow the expert to use a virtual surrogate subject to account for an individual's sex and scale to an individual's specific height and weight. The computational program can then evaluate the loading to an individual of a given sex, size, and stature performing activities generally considered non-injurious. The generally non-injurious activity loading described in the literature and evaluated by computational modeling programs can then be compared to the loading, as calculated by the biomechanical expert, that a specific individual experienced during a specific event. Not only do these comparisons place the loading that occurs to the body in a given event into a context that is easily understood by a jury, but they can also be helpful in addressing questions of "exacerbation," "aggravation," or "activation" of a pre-existing injury or pathology, especially in relatively low-severity events. While addressing and accounting for individual tolerance levels and pre-existing conditions might otherwise be considered outside the permissible scope of biomechanical expertise, the peer-reviewed biomechanical literature and generally accepted biomechanical techniques pertaining to generally non-injurious everyday activities can provide necessary context for the trier of fact.

Types of Cases where a Biomechanical Expert May Assist

While motor vehicle accidents are perhaps the most common case type for which a biomechanical expert may be utilized, biomechanical experts can also be of assistance in a wide range of cases including premises liability, workplace accidents, recreational accidents, product liability, and criminal cases. Essentially, a biomechanical expert can provide valuable insight into any case involving a question of injuries.

Conclusion

With sound case facts and scientific support, biomechanical expert analysis can be an impactful tool in an attorney's arsenal by bridging the gap between the mechanics of an incident and claimed injuries. When placed into the context of a specific case, tools including peer-reviewed scientific literature, generally accepted calculations, and computational modeling may be utilized in biomechanical analyses to determine the forces and motions experienced by an individual during an event and relate these forces and motions to what is known regarding injury mechanisms and tolerances. These can also be compared to the forces and motions individuals experience during common activities generally considered non-injurious. These analyses are often complementary to the opinions of physicians and other medical professionals in that they relate medical diagnoses to the loading present in a given incident. Beyond issuing biomechanical opinions, the biomechanical expert may also assist the attorney in understanding the viability of potential arguments, identifying key pieces of evidence for preservation, preparing for depositions of witnesses or other experts, and formulating arguments for motions for summary judgment, motions to exclude, or *Frye* or *Daubert* hearings. In summary, biomechanical experts can be valuable members of a legal team in cases involving injury claims.



About the Authors

Dr. Stephanie Pasquesi has a large breadth of experience in translational biomechanics research, applying laboratory studies to clinical observations and applications. She has a background in both bioengineering and mechanical engineering, with expertise in human injury biomechanics and kinematics. Dr. Pasquesi specializes in traumatic brain injury including concussion. At *Explico*, Dr. Pasquesi evaluates injury mechanisms and injury potential in consumer products-related incidents, recreational and motor vehicle accidents, and a variety of other injury scenarios. Dr. Pasquesi additionally evaluates injuries in the context of the design and performance of various products including protective equipment such as helmets and motor vehicle restraints. She also has experience in design and development of medical devices including orthopedic implants and surgical instruments. Dr. Pasquesi holds a BS in Mechanical Engineering from the University of Illinois at Urbana-Champaign and a PhD in Bioengineering from the University of Pennsylvania. Her doctoral research investigated the potential for parasagittal bridging vein rupture due to shaking in infants, employing an integrated approach of animal and pediatric cadaveric tissue mechanical testing, in situ and in vivo animal injury models, anthropomorphic test dummy experiments, and computational finite element modeling to identify possible mechanisms for extra-axial hemorrhage (subdural and subarachnoid hematomas).

Dr. Joseph Olberding is an engineer who assists legal and industrial clients in assessing injury risk and product safety from a biomechanical perspective. He applies mechanics and engineering principles to the human body to answer questions related to how, where, when, or if an injury did or would occur. He analyzes human motion, how forces are applied to the human body, and the forces and mechanisms required to produce specific injuries, with an emphasis on motor vehicle collisions, computational modeling, and pediatric injuries. Dr. Olberding has bachelor's and master's degrees from Tulane University and a Ph.D. from the University of Michigan, all in biomedical engineering.

About the IDC

The Illinois Defense Counsel (IDC) is the premier association of attorneys in Illinois who devote a substantial portion their practice to the representation of business, corporate, insurance, professional and other individual defendants in civil litigation. For more information on the IDC, visit us on the web at www.IDC.law or contact us at PO Box 588, Rochester, IL 62563-0588, 217-498-2649, 800-232-0169, admin@IDC.law.