Forensic Biomechanics

by Daniel J. Schneck

Thanks to the movies and television, the term "forensic medicine" is fairly well understood to mean the science that involves applying medical knowledge to answer certain questions of civil and criminal law—like time of death, cause of death, and so on. What, then, is "forensic biomechanics"? This term is relatively new to the legal industry, but gaining in popularity as the general field of biomechanics grows and matures. Stated simply, forensic biomechanics applies biomechanical knowledge to answer certain questions of civil and criminal law—but what do we mean by "biomechanical knowledge," and what questions can this knowledge answer in the courtroom? Let's see.

To begin with, we note that mechanics is the science that deals with how "things" *react* (in space and time) to being "loaded." For purposes of analysis, "things" are classified as being solid, fluid (all liquids and gases), or some combination of both, i.e., *viscoelastic*; by "loaded," we mean subjected to external force-couple systems that act to: 1) *push* on these things (compress and/or translate them, i.e., physically move them from one point to another); 2) *pull* on them (tension/translation); 3) *twist* them (torsion/rotation-in-place); 4) *shear* them (shave/rub/slide); 5) *curl* them (bending/rotation); and/or 6) otherwise subject them to external disturbances that result in some type of *reaction*. The reaction can range from passive resistance (static deformation) to dynamic movement (kinematics/kinetics), and both might occur with or without the thing failing—i.e., ripping, tearing, breaking, fracturing, or otherwise becoming impaired as it yields to the external disturbance.

Biomechanics, then, involves the application of the science of mechanics to biological things, including the human body. Among numerous diverse activities, biomechanical engineers deal with subjects such as the body's response to a subgravity environment; vehicular impacts; work- and sports-related stresses and strains; environmental insults (extremes of temperature, pressure, acceleration, deceleration, vibration, etc.); combat conditions; and other issues, some of which have legal implications, hence, *forensic biomechanics*. How does this work? Let's assume, for example, that a forensic biomechanical engineer is called upon as an expert witness to testify as to the likelihood that there is a biomechanical basis for an alleged work-related injury. What is his or her approach to making that determination?

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Well, to begin with, the forensic biomechanical engineer is provided with the medical records that track the diagnosis and treatment of the particular affliction under investigation. Typically, such records are subjective—more art than science—and medical opinions resulting from them are purely speculative and conjectural. (I could write reams on *that* topic!) But let's assume, for the moment, that the diagnosis is correct (although the *cause* of the affliction is still in question), and that the treatment follows logically therefrom. Working backwards from these medical records, the forensic biomechanical engineer should be able to define the exact mechanism of tissue failure consistent with this diagnosis and treatment. By "mechanism of tissue failure," I mean, "Was the failure typical of that which would result from compression loading, or tensile loading, or shear, bending, twisting, etc.?" Each of these failure mechanisms has associated with it specifically observable types of tissue damage and well-defined characteristics that yield clues as to what happened and when. The forensic biomechanical engineer is trained to know what clues to look for in order to determine the mechanism of tissue failure and its approximate age.

With respect to the latter, the next question is: "Does the tissue damage appear to have resulted from progressive, chronic degeneration, or is it consistent with an acute, one-time traumatic event?" Again, diagnostic evidence should provide the clues as to what happened. Whichever appears to be the case (i.e., chronic versus acute), "Do the diagnostic records substantiate the presence of *confirming* evidence in the form of *additional expected findings*?" For example, if a spinal disc is *presumed* to have been ruptured as a result of a one-time, traumatic event, there should be diagnostic evidence of concomitant cracks in the vertebral column (see "Slipped a Disc, Did You?" *Am Lab News* 2004; 36[23]:4–6). Alternatively, if the disc failure is presumed to have resulted from progressive degeneration, there should be diagnostic evidence of age-related clues, such as tissue desiccation (drying out), osteophyte formation (bony outgrowths), spurring, calcification, tissue discoloration (due to vascular issues), and so on (ibid.).

If one can show self-consistency between the clinical management of the patient and the presumed (biomechanical) mechanism of tissue failure, the next step is to define from what *source of loading* such a mechanism of failure would likely result. In other words, "What type of biomechanical loading would result in that type of tissue damage, at that time, in that anatomical location—loading which, to this point in the analysis, has to be *assumed* to have existed in order to maintain the self-consistency of the reasoning?" Moreover, based on the biomechanical engineer's understanding of the envelope of human performance characteristics, it follows that, in order for such loading to have resulted in such tissue failure, the loading *must have* exceeded that individual's ability to tolerate it without consequence. In other words, if the tissue failed as diagnosed, due to the biomechanical failure mechanism consistent with that diagnosis—which failure mechanism resulted from a corresponding type of known biomechanical loading—then *that* loading must have exceeded the ability of *that* patient's body to tolerate it without consequence. So the next obvious question is: Did it?

At this point, the forensic biomechanical engineer turns from a review of the medical records to an analysis of the biomechanical loading to which the plaintiff was actually exposed in the alleged work-related, injury-causing incident itself. Keep in mind that in the United States, innocence is presumed unless guilt is proven "beyond a reasonable doubt" in criminal cases, "with a preponderance of the evidence" in civil cases. Moreover, the burden of proof supposedly rests squarely on the shoulders of the accuser, not the defendant. Thus, one would hope and expect that it should be incumbent on said accuser to show that the biomechanical loading to which the plaintiff was exposed at work did, indeed, exceed that which the tissue in question could be expected to reasonably tolerate without consequence—and, hence, that the actual injuries are self-consistent with the presumed work-related cause of such injuries. Going one step further, that proof should be arrived at not by qualitative suggestion, or by the unconfirmed opinions of the patient's treating physicians, but by rigorously *quantifying* the operationally defined loading to which plaintiff was actually subjected in the incident in question! In other words, when is biomechanical loading excessive? How high is "high"? How awkward is "awkward"? And, to a reasonable degree of scientific certainty, did the *actual* biomechanical loading, quantified for the *actual* incident itself, match the *assumed* loading, as determined by the clinical/biomechanical mechanism-of-injury considerations discussed above? While the biomechanical literature has not yet completely defined the outer limits of what loading the "normal" human organism can tolerate without consequence, the body of knowledge related to what we *do* know the human organism can tolerate, so far, without damage, is rather extensive, so it's not like the forensic biomechanical engineer has no guidelines and criteria to go by in determining potential failure mechanisms and consequences thereof (i.e., "causes" of injury).

Plaintiffs often circumvent the above rigorous analysis by alleging that "it's a moot point," because the body in question was not normal, for whatever reasons, at the time of the alleged injury-causing incident. But if that is truly the case, then again, it should be incumbent upon the accuser to quantify that degree of abnormality, and to define, precisely, the extent to which it compromised the tissue in question, thereby narrowing its operating window, putting the individual at greater risk of injury. Of course, this never happens. In fact:

1. Rarely does the plaintiff present any objective, quantified evidence of actual work-related biomechanical loading exposure. Quite to the contrary, treating physicians *never* quantify the biomechanics of the incident involved, and ergonomists do so only by "arm-waving" estimates and a reliance on what they call "known risk factors for injury" (whatever *those* are... see "Beware of Medical (and Scientific) Fads," *Am Biotech Lab* 2005; 23[1]:4–6). In one case that comes vividly to mind, I remember the treating physician who was rendering an "expert opinion" as to the cause of his patient's injury, openly admitting that, "I have no knowledge of plaintiff's actual work activities, but from what he described, it sounds like these activities could have caused his injury." This qualifies as "a preponderance of the evidence"?
2. Treating clinicians almost never know what condition the plaintiff was in *prior* to the incident in question. Indeed, even the "history" that they take leaves a

great deal to be desired, so they have no reference points, baseline values, or established criteria against which to base their opinions.

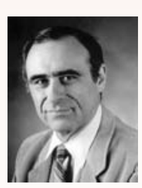
3. Treating physicians, as illustrated by the testimony alluded to above, rely almost exclusively on the plaintiff's own version of what happened, and what he or she thinks caused his or her affliction (not tainted, of course, by any ulterior, litigation-related motives!). Then they back up their patient's version with unsubstantiated "expert" testimony as to causation, with the result that, in actuality, it is *guilt* that winds up being presumed unless the *defendant* can prove his or her innocence—by much higher standards than those to which plaintiff is held! The system, my friends, is broken.

In defense of the medical establishment, let me add quickly that clinicians are concerned more with diagnosis and treatment than with causation. Thus, they tend to justify their opinions in a rather cavalier fashion—not by hard, objective, quantified evidence on which to base a conclusion "to a reasonable degree of *scientific* certainty," but by soft, subjective, qualitative conjecturing that goes something like this: "Look, patient *says* he (or she) was fine prior to the incident in question, and I have not really dug deep enough or hard enough to assume otherwise, so I arbitrarily take his (or her) word for it. Now he (or she) presents with these symptoms, is obviously hurting, and I don't have the time to dig deeper into the issues of causation … my job is to treat the patient. Therefore, to a reasonable degree of *medical* certainty, it seems 'obvious' to conclude that. . ." As far as the treating physicians are concerned, that is all the reasoning and proof they need, and ergonomists don't really shed much light on the *real* issues, either, which emphasizes the need for objective, forensic biomechanical engineering!

The trouble, of course, with the now-famous *post hoc, ergo propter hoc* ("after this, therefore, as a result of this") type of reasoning is that it represents a common scientific trap—a fallacy in thinking that what immediately preceded an event, and the circumstantial evidence associated with it, must also be intimately related to its cause. The scientific literature (and, I might add, hundreds of detective novels) is replete with hard evidence to the contrary—evidence that what often *appears* to be the *cause* of an event—because of its spatial or temporal proximity to that event—is subsequently determined not to be the cause at all. In fact, such quick and superficial assessments and diagnoses of health-related issues are all too often downright wrong! (see *Ultra-Prevention*, written by Drs. Mark Hyman and Mark Liponis, New York: Scribner Publishers, 2003).

One of the problems with the above line of reasoning is that it often overlooks confounding variables (see *Am Lab* 2003; 35[16]:4–8) that are more intimately related to what actually happened than is the circumstantial evidence that is being accused of being the culprit. Thus, to get at the *real* cause, one must move *beyond* the initial assumptions—dig deeper—perform rigorous forensic biomechanical analyses, look for inconsistencies in reasoning, non sequiturs (conclusions that do not follow directly from the reasoning that led up to them), circular reasoning (conclusions inherently assumed in the very reasoning that leads up to these same conclusions), and so on.

Physicians are busy people—they see many patients a day, have little time to spend with any one patient, and really do not *care* about causation issues: Again, their primary role is to diagnose and treat. Causation, in the case of presumed work-related musculoskeletal issues, is of less concern to them; they are readily willing to simply take the patient's word for what happened and what caused it. If the patient's description *seems* to make sense, the treating physician is perfectly willing to accept it as fact, and *testify* to that fact in a court of law, "to a reasonable degree of medical certainty" (whatever *that* means!). By far, medicine is more art than science, so "to a reasonable degree of medical certainty" is a far cry from "to a reasonable degree of *scientific* certainty." The difference between *scientific* certainty and *medical* certainty being, respectively: quantified assurance (*variables* lists) versus qualitative conjecture (*attributes* lists); double-blind, controlled, randomized, rigorous studies versus anecdotal, biased, uncontrolled, circumstantial evidence; logical reasoning to logical conclusions versus purely speculative reasoning to vague assertions; and objective criteria versus ill-defined (or *not* operationally defined), subjective judgments. Our judicial system *must* recognize that the forensic biomechanical engineer—not the treating physician, not an ergonomist, not any other type of "expert"—is the one *most* qualified to render legal opinions as to causation in civil and criminal matters where the cause of a medical affliction clearly involves biomechanical issues!



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