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# Injury Biomechanics – Sports and Recreation

Injury, in the context of the musculoskeletal biomechanics, is defined as the damage sustained by tissues of the body in response to forces applied through physical trauma. Injury causation is a central issue in many personal injury claims. In sports and recreation events, injury causation can be related to many different issues including exercise equipment, safety equipment, player contact, playing surface, internal muscle forces, skeletal anatomy and individual tolerance.

In this article we will discuss the issue of injury causation in the courtroom. We will describe the science of injury biomechanics and its application in assessing the causation of an injury. We will focus on the biomechanical issues most commonly associated with sports and recreation and will conclude with a few examples demonstrating injury biomechanics analyses in sports activities.

## Injury Causation in the Courtroom

To succeed in a personal injury claim, the plaintiff must prove that the forces applied to the plaintiff by the defendant's action (or inaction) caused or materially contributed to their injury. Conversely, the defendant can show that either the forces were inappropriate or insufficient to cause the plaintiff's injury or that the forces from another unrelated event or activity better explain the injuries. For this type of assessment, experts qualified to analyze injury causation, that is injury biomechanists, are required.

In the past, accident reconstruction engineers and medical doctors have offered opinions regarding injury causation, although reconstruction engineers typically lack formal training in anatomy, physiology or injury mechanics, and medical doctors often have no formal training in engineering mechanics, failure analysis or tissue tolerance (Figure 1). Thus, in rendering opinions about injury

causation, both reconstruction engineers and medical doctors stray outside their areas of expertise.

Courts increasingly recognize the specialized knowledge needed to link the applied forces to the claimed injury. In British Columbia, reconstruction engineers have been admonished for opining about injury<sup>1-4</sup> and medical doctors have also been admonished for offering biomechanical opinions outside their area of qualification.<sup>5-6</sup> In Alberta, biomechanics is not only a distinct area of expertise, but biomechanical evidence—due to its perceived complexity—is often used under the Jury Act to prevent cases from being heard by juries. In the United States, many jurisdictions draw clear distinctions between the three professions and opinions regarding injury causation are routinely given by injury biomechanists.

Injury biomechanists have formal training in both engineering mechanics and tissue injury (Figure 1). Usually injury biomechanists have undergraduate engineering degrees with graduate degrees (Masters or PhD) in biomechanics, kinesiology, or biomechanical/biomedical engineering with a focus on injury. Some biomechanists have medical degrees combined with degrees in engineering or biomechanics. Whatever the combination of degrees, an injury biomechanist should have formal training in applying engineering principles to the failure of biological tissue. Additionally, just as you would expect an engineer analyzing bridge failures to have tested concrete and steel, you should also expect an injury biomechanist to have tested biological tissues.

From an engineering perspective, an injury biomechanist's training includes; an understanding of how different parts of the human body react—and interact—to external forces; how stresses and strains develop in tissues during an impact; the failure mechanisms and tolerances of different

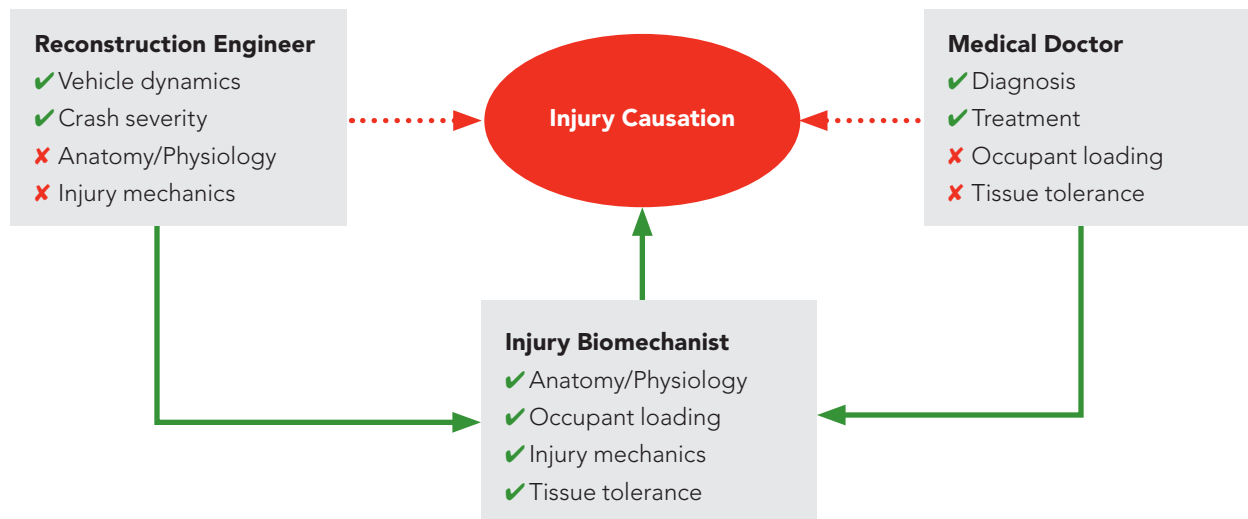


Figure 1. Typical areas in which training is (✓) and is not (✗) received. The dotted red arrows show injury causation being incompletely addressed by engineers and doctors. The solid green arrows show the appropriate use of an injury biomechanist.

types of tissues and: the wide variability in the mechanical properties of biological tissue. From a medical perspective, an injury biomechanist's training includes; an understanding of medical diagnoses; the relevant anatomy and physiology; the different injury classification schemes; and the neuromusculature and reflexes that can exacerbate or attenuate externally applied loads. This combination of engineering and medical knowledge is needed to properly understand the biomechanics of injury.

### Injury Biomechanics Analysis

Injury biomechanics analyses examine the causal relationship between a specific event and a specific set of diagnosed injuries. A summary of the diagnosed injuries is obtained from the medical records and reports and is assumed to be accurate for the analysis. In the case of sporting and recreational injuries, information regarding the forces applied in the event and their severity is often interpreted from witness statements, photographs, and video.

The biomechanical analysis itself consists of two main steps: mechanism and magnitude. To assess injury mechanism, the direction and location of the forces applied to the body are first determined for each event in question. This information is then compared to the direction and location of

the forces required to cause each injury. If the direction and location of the required and applied forces do not match, then a mechanism for the diagnosed injury does not exist and the injury was not caused by the event in question. If, however, the direction and location of the applied and required forces do match, then a mechanism for the diagnosed injury exists and the analysis proceeds to the second step.

To perform the second step of the biomechanical analysis, the magnitude of the force applied to or through the injured area is calculated for each event in question. The magnitude of the applied force is called the exposure. The magnitude of the force required to cause each injury is called the tolerance and is drawn from scientific studies published in the peer-reviewed literature. If the exposure is greater than or equal to the tolerance, then the injury is consistent with the event. Alternatively, if the exposure is less than the tolerance, then the injury is not related to the event in question.

In sporting and recreation files, contrary to motor vehicle cases, the mechanism and magnitude steps are not normally performed to simply assess the consistency between the event and the injury. The mechanism step is often used to assess which of a given series of events, motions or impacts during the sporting

activity is most consistent with the types of forces needed to cause injury. This pinpoints the circumstances by which the injury occurred and allows the investigation to focus on the appropriate product/facility issue responsible for the injury from a biomechanical perspective. Magnitude analyses in sport and recreation events are more often performed to assess the effect of safety equipment on the forces generated in specific parts of the body. In this way, the analysis often focuses on product performance and equipment effectiveness and can be used to demonstrate the biomechanical effect of safety product "failure"/misuse/non-use on injury causation.

Although the mechanism and magnitude analyses are relatively simple in theory, there are numerous factors that can complicate an injury biomechanics analysis. First, the medical diagnosis is sometimes unclear, particularly for soft-tissue injuries where the specific tissue injury responsible for the plaintiff's symptoms is often not identified. Second, the forces applied to the occupant may be difficult to calculate, either because of the nature of the event or the lack of scientific data. Third, the tolerance values for some diagnosed injuries or conditions and the tolerance values for individuals with some pre-existing conditions are not known. And finally, there is

considerable variation in the tolerance values for some injuries. Thus the quality of the diagnosis, the state of the science for a specific injury, and the known details of the specific circumstances of the injurious event play a large role in the quality of the answer an injury biomechanist can provide regarding injury causation.

### Examples of Biomechanics in Action

Biomechanical analyses are typically useful if it is unclear whether an injury is related to an event, or if the severity of an injury seems inconsistent with the exposure. As mentioned above, this type of analysis is most typically applied in motor vehicle cases where causation is the prime concern. In sporting and recreational activities, the analyses are useful to answer questions about the effect of a defective product or a missing or unused piece of safety equipment on the causation of the injury. Questions on whether the injury is more consistent with misuse of the product can also be answered. A few examples of sporting and recreational cases that benefit from a biomechanical analysis are given below:

A helmeted bicyclist participating in a road race struck an unpadding lamp standard and sustained a fatal neck injury. A biomechanical analysis showed that for the speed at which the bicyclist struck the lamp standard, the neck loads were sufficient to cause the fracture even if the lamp standard had been padded. It was further shown that padding can increase the potential for pocketing or trapping the head, which increases rather than reduces the likelihood of neck injury.

A man playing squash sustained an Achilles tendon rupture allegedly due to jamming his foot in a small separation between the floor boards on the squash court. A biomechanical analysis showed that the most common mechanism is a forceful push-off with the foot during running or changing directions in combination with a large contraction of gastrocnemius and soleus muscles. The described jamming of the foot in the floor gap does not represent an injury mechanism for Achilles tendon rupture.

A female rider of a vertical trampoline at an amusement park dislocated her knee and sustained severe ligamentous damage as a result of a hyperextension injury. Biomechanical analysis demonstrated that the body posture and forces applied to the knees of a rider on the vertical trampoline were different and increased the risk of knee hyperextension compared to a typical trampoline. Also the free rotating harness used on the vertical trampoline increased the risk for single leg loading and off-axis loading which also increased the risk of injury on this apparatus.

An indoor lacrosse player was cross-checked near the goal line and thrown into the boards head first, resulting in a cervical spine fracture and permanent quadriplegia. The game was being played on artificial turf laid directly over an ice surface and the turf was wet in the vicinity of the incident. Our analysis showed that the reduced friction of the wet artificial turf did not affect the player's ability to regain his balance after being checked and was therefore not a factor in producing the catastrophic neck injury.

A little league baseball player sustained an ankle fracture from sliding into second base. At the time of the incident, the base was a fixed type rather than a "break-away" base which is designed to release after a threshold level of force is applied. A biomechanical analysis revealed that the ankle fracture would likely have been prevented had a break-away base been used at the time of the incident.

A motorcyclist wearing a "beanie" helmet sustained a concussion when he fell to the ground after being sideswiped. Biomechanical analysis demonstrated that use of a standard approved helmet would have allowed head accelerations in excess of proposed concussion tolerances and thus would not have prevented his injury.

### Summary

Injury causation analyses are based on a comparison of the forces applied to the body, i.e., the exposure, and the forces required to cause the injury, i.e., the

tolerance. Injury biomechanists have the formal training in both engineering mechanics and tissue injury needed to make this comparison and to conclude whether there is a causal relationship between the diagnosed injuries and the event alleged to have caused those injuries. Injuries caused during sport or recreational activities can also be analyzed to assess the use and effectiveness of safety equipment (helmets, padding, etc.) and determine whether arena facilities or product failure contributed to the injuries.

### References

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*Alyssa DeMarco is a member of MEA's injury Biomechanics group. She frequently conducts biomechanical analyses of injury producing events such as automobile collisions. Case analyses involve assessment of the injury mechanics, the loads applied to the body, and investigation into the relationship between the applied loads and the injury. She is also the lead investigator of a helmet impact study at MEA and regularly inspects and assesses the effectiveness of motorcycle and bicycle helmets.*



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