Claims
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Biomechanics of Head Injuries

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Did the claimant sustain a head injury in the incident? Would the diagnosed head injury have been prevented if the claimant was using a protective device such as a helmet, seat belt or airbag? Biomechanical engineers frequently answer injury causation and prevention questions like these in personal injury claims.

CAUSATION

To answer head injury mechanism or causation questions, biomechanical engineers compare the forces or accelerations experienced by the head in an incident to those required to cause the diagnosed injury. The incident forces/accelerations are calculated though reconstruction of the event and the forces/accelerations required for the injury are typically determined from published experimental data. If the forces/accelerations in the incident are of the magnitude required for the injury, then the injury is likely consistent with the incident; however, if they are not, then the injury likely is not consistent with the incident.

This type of analysis can be useful when injuries like concussion or mild traumatic brain injury (MTBI) are being claimed. The terms concussion and MTBI are typically used to describe the same injury and are often used interchangeably. Concussion is difficult for medical doctors to diagnose because objective evidence of the injury can be lacking. Recent media attention on concussion in football and other sports highlights the significant short- and long-term effects these injuries can have as well as the controversies surrounding proper diagnosis and treatment.

When an individual claims an injury such as MTBI, proper use of a biomechanical engineer can be valuable in assessing the validity of the claim. A common case involves a concussion claim following a relatively low speed rear-end collision. In this type of collision, the driver initially moves rearward relative to the forward-moving vehicle. The driver's back compresses the seat cushion and his head rotates rearward until it contacts the head restraint. Following this rearward motion, the driver rebounds forward into the seat belt, but typically avoids head contact with any other structures.

In this case, the peak head acceleration occurs during the head contact with the head restraint. Many experimental tests simulating this type of collision have been conducted using human volunteers, cadavers, and crash test dummies. From these tests, the driver's peak head acceleration exposure is estimated. This value is then compared to published levels that have been associated with concussion. For low speed rear-end collisions, the head restraint padding and compliant seats of most vehicles typically result in low head accelerations with a very low concussion risk.

PREVENTION

Safety equipment such as helmets, seat belts and airbags can mitigate or prevent head injuries when used properly. Biomechanical engineers often answer questions about the use and effectiveness of these safety devices.

Helmets

Helmets for motorcycling, bicycling, and other activities are designed to mitigate and prevent brain, skull and superficial head injuries. Brain injuries and skull fractures are prevented as the helmet attenuates the head acceleration and distributes the impact force to a larger region of the head. This is achieved primarily through compression and cracking of the helmet's energy absorbing liner (Figure 1). Superficial head injuries such as lacerations and abrasions are prevented in the regions of the head that are covered by the helmet.

While most certified helmets are made up of the same general components, not all helmets provide the same level of protection. Full-faced helmets cover a larger area of the head than shorty or beanie helmets, and therefore may protect a larger area of the head from lacerations and abrasions. They will also protect against skull/brain injuries for impacts over a larger area of the head, though often not the entire area covered by the helmet.

Furthermore, just because a helmet has a sticker indicating that it is certified to a specific standard (e.g. DOT and/or Snell for motorcycle helmets and CPSC for bicycle helmets) does not mean that it actually meets the requirements of that standard. Fake labels are readily available and are even sold on some online auction sites. In addition, random testing of DOT motorcycle helmets conducted from 2000-2008 shows that 44% of the DOT labeled helmets tested actually failed some aspect of the standard.

Helmet impact testing illustrates the significant difference in performance between different helmets, particularly those that are not certified. A common question we answer is whether or not a "better" helmet would have mitigated or prevented a diagnosed head injury. The presence of an adequate energy absorbing liner (typically at least 1" thick) is generally associated with a "good" helmet. Testing of

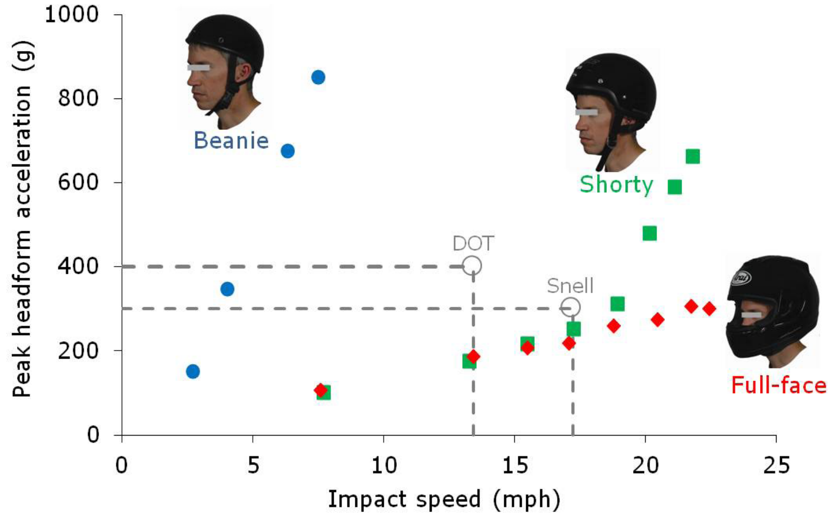

Figure 2. Motorcycle helmet performance at various impact speeds (data from DeMarco et al., 2010). The dashed lines indicate the impact performance requirements of the DOT and Snell standards

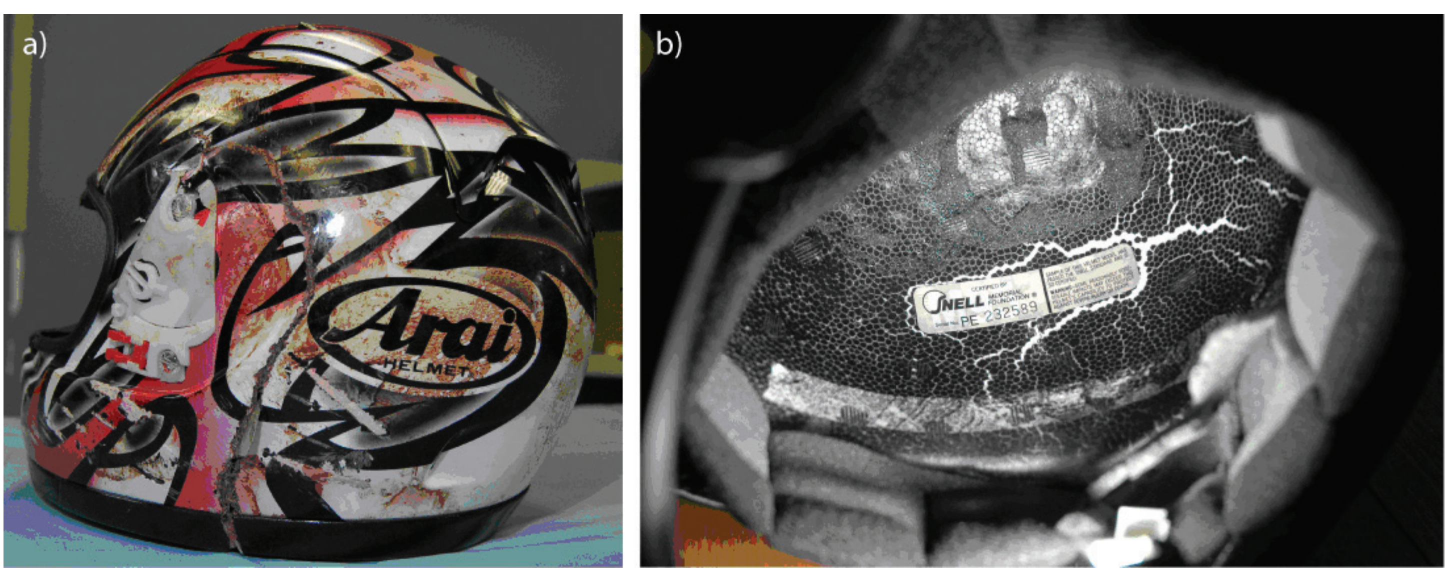

Figure 1. Typical motorcycle helmet (a) exterior and (b) interior damage following an impact.

non-certified beanie helmets (Figure 2) clearly shows their inferior performance relative to DOT certified shorty and full-face helmets.

Seat belts and airbags

When used properly, seat belts and airbags can also mitigate or prevent head injuries. Seat belts are designed to limit and control occupant motion within the vehicle during an impact or rollover. Seat belts are most effective in frontal impacts, where they can limit the forward motion of occupants and prevent or minimize body contacts with vehicle interior structures. Eliminating head contact in an incident substantially reduces or prevents head injury risk.

A variety of airbags exist in today's automobiles and include frontal airbags, side airbags, curtain airbags, and knee bolster airbags. Each of these airbags is designed to prevent specific injuries for a specific direction or type of impact (e.g. frontal, side, rollover). Seat belts and airbags perform best when used together and with "normally" seated occupants. The effectiveness of these safety devices can be challenged by occupants that are "out of position," i.e., sleeping. In "out of position" cases, when the airbag deploys it can inadvertently strike the occupant as it is deploying. Since airbags deploy at a very high speed, this type of interaction can result in large head accelerations and severe injuries.

Typically, the largest head injury-risk reduction with vehicle safety equipment use occurs in cases where an unbelted occupant strikes his head on a window frame (or some other stiff interior vehicle structure). Head contact with stiff structures can result in large peak head accelerations over a very short period of time. Under the same conditions with a seat belt, the head motion is controlled and head contact (if it occurs at all) is against a relatively soft fully deployed airbag (Figure 3) or head restraint. Head contacts with these softer structures typically result in lower peak head accelerations that occur over a longer period of time and are generally less injurious.

Figure 3. Chalk transfer from face of crash test dummy onto a deployed airbag during a frontal impact (source: www-nrd.nhtsa.dot.gov).

SUMMARY

Personal injury claims involving severe head injuries can be substantial. In these claims, biomechanical engineers are frequently used to investigate issues of injury causation and prevention. By analyzing the mechanics of the head impact in the incident biomechanical engineers can show or refute injury causation. They can also evaluate the effectiveness of protective equipment or devices that could or should have been used.

REFERENCE

DeMarco AL, Chimich DD, Gardiner JC, Nightingale RW, Siegmund GP (2010). The impact response of motorcycle helmets at different impact severities. *Accident Analysis and Prevention* 42: 1778-1784.

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