C34 Evaluation of Head Protection Provided by Sports Helmets

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After attending this presentation, attendees will have a greater understanding of sports helmet safety, with the ability to identify helmet designs and materials that can reduce risk of brain injury and concussions in helmeted head impacts.

This presentation will impact the forensic science community by demonstrating the use of a helmet drop test method with a biofidelic head form that can be used to compare helmets to meet different testing standards.

In this study various helmets were subjected to identical drop tests onto a hard flat surface and the resulting head accelerations were analyzed and compared. More than fifteen different helmets of various designs were tested. Helmets used for ice hockey, snowboarding, bicycle riding, skateboarding, football, and motorcycle riding were tested. These helmets are designed to different standards that vary according to sport and country.

Comparison of impact attenuation under the same identical hard surface impact conditions with a confirmed biofidelic head form provided a unique opportunity to evaluate the head protection in potentially serious to fatal head impacts.

Testing Method: The sports helmets were attached to an instrumented head form. The head form utilized was from 50^{th} percentile of a standard instrumented Anthropomorphic Test Dummy (ATD) with a calibrated triaxial accelerometer mounted internally. The helmeted heads were dropped onto a hard flat asphalt surface from a height of 60 inches. The free-fall drops resulted in impact speeds of approximately 12mph. Each helmet was impacted on the top, back, right, and left sides in four separate drop tests. Each test was recorded on high-speed video (1000 frames per second) and real time video. Orthogonal ATD head accelerations versus time were recorded as specified in SAE J211, *Instrumentation for Impact Test*. Resultant head acceleration traces and Head Injury Criteria (HIC) values were compared and analyzed.

Results and Comparison: Due to the common impact velocity, the area under the acceleration curves were comparable and not a significant factor. However, peak head acceleration values and trace shapes exhibited considerable differences. The response differences are analyzed and interpreted.

For comparison, the accelerations and resultants were normalized with respect to helmet weight because the weight of the helmet influences the head acceleration. Helmet characteristics associated with the best impact attenuation were identified.

Since all head injury criteria are related in some way to head acceleration magnitude, helmets that reduce or minimize head acceleration provide better protection. Helmets with thin, soft, or non-existent liners provided the least protection. For example, a novelty type motorcycle helmet exhibited the worst performance, reducing the resultant head acceleration in a top side impact by only about 3% from a comparable bare head impact (487g). These novelty helmets are not safety certified, and although the rider wearing this helmet could circumvent helmet laws in various states, he or she would not be protected from injury in an accident. By comparison, a similarly shaped open face DOT-rated motorcycle helmet reduced the head acceleration by 50%. This reduction was the result of the Styrofoam-type liner's ability to dissipate the energy from the impact.

An even better performing helmet was the ski/snowboarder helmet, which reduced the head acceleration by 64%. Ridges in the shape of the shell deformed and helped absorb energy. However, such ridges would not be acceptable in a motorcycle helmet that needs a low friction, continuously slick hard surface. The best helmet tested was a newly designed hockey helmet that reduced the resultant head acceleration by 66%. This helmet has a liner made of hollow plastic cylinders placed adjacent to one another. The walls of the cylinders deform in the impact. This helmet performed better than an earlier designed hockey helmet with a firm foam liner that reduced head acceleration 60%. Head acceleration pulse shapes are flatter and elongated in all tests where energy is dissipated by the liners.

Conclusions: Based on the testing performed, protection varies widely from one helmet to another. All helmets provide some skull protection. Brain injury prevention requires impact attenuation. The impact attenuation provided is directly related to the liner material properties. Inadequate to non-existent liners, as in novelty helmets, provide little to no brain protection. Some sports helmets with contoured deformable shells can also help dissipate the impact energy. Most impressive is the superior protection provided by the new liner designs that utilize deformable plastic cylinders.

Head Protection, Sports Helmets, Helmet Drop Testing