D3 Motorcycle Helmet Translational and Rotational Head Injury Risk Measures Using H-III Head Impact Tests

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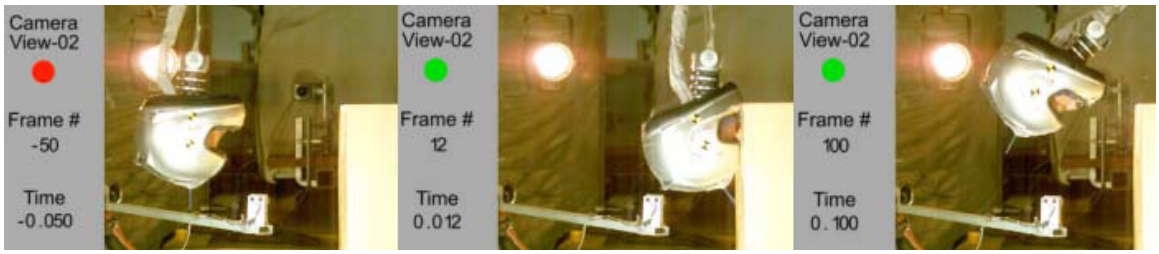
After attending this presentation, attendees will understand an experimental pendulum impact test method, using H-III biofidelic surrogate head and neck components, for measuring impact and rotational head injury risks of motorcycle helmet safety performance.

This presentation will impact the forensic science community by illustrating how this test method provides a means for efficiently evaluating helmet safety and injury risks related to both translational and rotational head/brain injury mechanisms by utilizing a human-responding H-III head and neck with a multidimensional pendulum impact device that also allows for full-face helmet safety evaluation not tested in current European and United States helmet certification standards.

Concussion and severe head injuries sustained by helmeted motorcycle riders are often related to both direct translational contact impact and brain rotational shearing mechanisms. Research by Hodgson (1975), Gennarelli, (1982), and Ryan (1994), among others, have addressed biomechanical injury risk levels of direct impact and rotational effects on humans.1-3 More recent studies by O'Riordain (2003) and Antona-Makoshi et al. (2013) have also studied brain injury risk as functions of both direct impact and rotational effects.[4-5] Unfortunately, current helmet certification standards do not test with Human Responding (HR) head forms nor do these criteria measure multi-directional impact conditions necessary to evaluate both direct contact impact and rotational effects. Also, the current helmet certification impact test devices do not enable measures of "full-face" head impact modes.

In this study, a 3D pendulum impact device, with an HR Hybrid-III head form and neck, is used to study multi-axial direct contact impact and head rotational effects on helmet safety. The H-III head is instrumented with a tri-axial accelerometer and multi-axial angular motion recording devices that allow measures of the Head Injury Criteria (HIC) and angular velocity versus angular acceleration levels for the helmeted head form when subjected to various impact conditions including full-face frontal loads. The test impact speeds and energy levels are comparable to current helmet certification test criteria. The figure below shows a sequence of photo clips taken from one of the pendulum impact tests of this study that involved a "full-face" 110 Joule (J) impact to a helmet when impacted at 25kph. The photos show, from left to right, film clips at: 50ms before impact; 12ms into the impact; and, 100ms after impact. The peak acceleration was 145 G's at 11.4ms, and the 15ms calculated HIC was 758. The head pitch-rotation rate was 19.8r/s at 10ms and the angular acceleration was 11,210r/s/s at 11.5ms.



In addition to the above 25kph test, another full-frontal impact test was conducted on the same model helmet but at an impact speed of 28.4kph to examine helmet safety performance at a higher 150J impact energy level. In this test, the peak resultant acceleration was 266 G's at 4.6ms, and the 15ms calculated HIC was 2009. The test HIC levels of 758 and 2009 both violate the NHTSA recommended head injury limit of 700 and indicate danger of a severe head injury. The head pitch-rotation rate in this second impact test was 28.9r/s at 4.9ms and the angular acceleration reached 13,776r/s/s at 4.1ms. The measured acceleration-time data from the above two tests were at the upper tolerance level for Acute Sub-Dural Hematoma (ASDH) and Sub-Arachnoid Hematoma (SAH) as predicted by Auer et al. (2001) based on head injury reconstructions from 25 fatal pedestrian accidents.[6] With regard to Diffuse Axonal Injury (DAI) effects, the rotational acceleration measures for the first test were indicative of a classical concussion level as defined by Gennarelli. The much higher rotational acceleration measures for the second test were indicative of a "mild" DAI level as defined by the Gennarelli reference.

Finally, the above ASDH, SAH, and DAI injury risk findings derived from the direct contact impact and rotational measures obtained from the two full-frontal impact tests on the helmet model shown in the figure above were consistent with the medical record descriptions related to severe brain injuries sustained by a motorcycle rider wearing the same model helmet in an actual accident. Damage to the accident helmet indicated primary impact to the chin bar and forehead full-frontal region of the helmet, like the region tested on the exemplar helmets. The correlation of the tests with the actual accident injuries suggests that the pendulum impact apparatus, with the human responding H-III head form and H-III neck, provide a reasonable method for assessment of overall helmet safety performance as related to both direct contact impact and rotational acceleration forces in all modes of impact, including full-frontal, and improves on current helmet certification test limitations.

References:

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Head Injury, Helmet Testing, Impact Analysis