C32 Comparison of Hybrid III Dummy Neck Stiffness to Actual Human Neck Injury Tolerance for Axial in Rollovers Compression

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The goal of this presentation is to examine the Hybrid III dummy neck stiffness and compares it to the human neck. After attending this presentation, attendees will understand the difference between dummy and human neck response to axial loading and its significance.

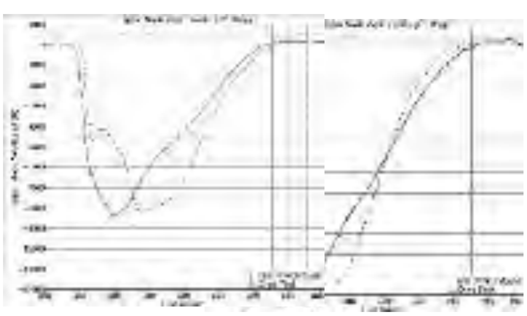
This presentation will impact the forensic science community by showing that a value of at least 10,500 N is an appropriate representation for upper neck axial load in the Hybrid III dummy as a threshold for predicting human cervical spine injury.

Over 10,000 people die annually in the United States from rollover motor vehicle collisions, and more than 16,000 people suffer catastrophic injury. Most of the research on cervical injury potential in rollover accidents has utilized the Hybrid III anthropomorphic test device (ATD), aka, the Hybrid III dummy. This presentation examines the Hybrid III dummy neck stiffness and compares it to the human neck. After attending this presentation, attendees will understand the difference between dummy and human neck response to axial loading and its significance.

Although it is the most advanced ATD currently available, the Hybrid III dummy is not a good surrogate for neck injury investigations during rollover collisions. Inadequacies of the Hybrid III dummy neck have been reported in the literature. The dummy neck geometry is clearly not the same as a human neck. The human neck is articulated with joints while the dummy neck is a non-jointed structure, which leads to dynamic dissimilarity. In fact, the Hybrid III in current use is a scaled- down, cheaper version of the original GM design. The dummy neck is too stiff in the axial direction when compared to the human neck. No one-to-one relationship between the dummy and the human neck with respect to forces experienced and mechanism of injury has been widely accepted. Despite this, extensive use of the Hybrid III dummy in rollover testing has led researchers to infer that the dummy neck response is a close representation to that of a human neck. Some research even uses a dummy axial neck load as low as 2000 N to represent injury potential from roof crush.

In the current study, the MADYMO (MAthmatical DYnamic MOdels) computer simulation program was used to establish a relationship between the dummy and human neck response. A one- directional (translational) joint between the lower neck and upper torso was added to the basic 50th percentile male dummy model to account for the axial compression response of the dummy neck. The axial compression properties were selected from tests on the dummy head- neck system as reported by Herbst (1998) who used loading rates from
4.5 to 17.9 mph.

Dummy drop tests conducted at SAFE in 2005 were used to validate this modified MADYMO dummy model. A 50th percentile Hybrid III male dummy was inverted and placed in a seated position such that the neck was almost vertical (head 7 degrees rearward of vertical). The dummy was then dropped, free fall onto a concrete surface covered with linoleum flooring from heights of 12 inches and 24 inches. The peak upper neck axial load was 8,458 N for the 12-inch drop and 11,344 N for the 24-inch drop. Figure 1 shows good correlation between the MADYMO model and the drop tests.



(a) (b)

Figure 1. Dummy upper neck axial loads from MADYMO model and SAFE drop tests for (a) 12-inch drop and (b) 24-inch drop.

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Because neck tolerance data on living humans is limited, the only verified injury measure is from recreational activities such as diving and football accidents. This research indicates that cervical flexion-compression injuries can occur at head impacts as low as 10.2 feet/sec (approximately 7 mph). The results of research utilizing cadavers are also consistent with this number.

The modified MADYMO model was then utilized to simulate a 20- inch drop height to represent a 7 mph impact velocity. The results from this validated MADYMO model showed that the neck compressive force is approximately 10,500 N. When the dummy torso position was changed to represent a more vertical neck condition (5 degree variation), the loads increased to about 11,500 N. Thus, this study shows a range of compressive neck loads between 10,500 to 11,500 N for a 20-inch drop height, which represents an approximate 7 mph impact velocity.

The drop testing and the MADYMO modeling clearly demonstrate that the Hybrid III dummy neck is much stiffer in the axial direction than the human neck. It should be noted that peak force has not been established as a reliable parameter for assessing catastrophic cervical injury in the human. However, if one does use peak axial load, the human neck is roughly 4,000 N in an inverted drop with an impact speed of 7 mph and the equivalent peak load in a Hybrid III dummy neck under similar loading conditions is over 2.5 times that value. The dummy neck inadequacies, as described above, are responsible for this disparity.

The Hybrid III dummy is routinely used for analyzing the forces and injury potential during rollover accidents with various axial neck loads to predict injury outcome from roof crush. This study shows that a value of at least 10,500 N is an appropriate representation for upper neck axial load in the Hybrid III dummy as a threshold for predicting human cervical spine injury.

Rollover, Hybrid III Neck, MADYMO

