# Hybrid III Small Female Neck Interaction with a Driver Airbag: Preliminary Observations

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## INTRODUCTION

The Hybrid III 5th-percentile female (HIII-05F) anthropomorphic test device (ATD) has been used to represent the small female occupant in New Car Assessment Program (NCAP) and Federal Motor Vehicle Safety Standards (FMVSS) 208 tests since the 1990s [1]. Upper neck loads in the HIII-05F are currently used to predict neck injury for small females in frontal collisions. In a recent series of sled tests, large compressive loads occurred in the upper neck of the HIII-05F during 30-kph tests, but did not occur during 56-kph tests, or in any tests using the THOR 5th-percentile female ATD (THOR-05F). One 30-kph HIII-05F test, which was characterized by early airbag deployment (EAB), also did not have large compressive loads occur in the upper neck. These results suggest that interaction with the airbag greatly affects the neck injury predicted by the HIII-05F at lower speeds, an under-researched category of motor vehicle collision safety. Therefore, the objective of this analysis was to investigate the interaction between the HIII-05F and the airbag and analyze how neck response can be affected by differences in deployment timing.

## METHODS

Frontal sled tests were conducted using a custom test buck designed to represent a 7th-generation Toyota Camry driver seat environment. The test buck used Camry parts, including a 3-point seat belt (pretensioner and 4kN load limiter), steering wheel, dual-stage airbag, steering column, seat bottom, D-ring adjuster, and buckle (Figure 1). The Camry seatback was modified to allow lines of sight to the ATD spine. The knee bolster was simulated using 65-psi rigid polyurethane foam [2]. Two pulses were used, a 56-kph NCAP pulse, and a scaled-down 30-kph pulse [3]. Eight tests were conducted using the HIII-05F: 4 tests at 30 kph, and 4 tests at 56 kph. Six tests were conducted using the THOR-05F: 3 tests at 30 kph, and 3 tests at 56 kph (Figure 2).

For the 30-kph tests, the 1st stage of the airbag was fired 10 ms after the start of sled motion and the 2nd stage was fired at 40 ms. Both stages were fired at 10ms for the 56-kph tests. For one of the four 30-kph HIII-05F tests, the 2nd stage of the airbag was fired at the same time as the 56-kph tests (i.e., 10ms), which was 30 ms earlier than the other 30-kph tests (referred to as the early airbag test, or EAB).

High-speed videos (Vision Research, Phantom V-9, Wayne, NJ) were recorded at 1,000 fps. Sensor data was recorded at 20,000 Hz. Loads and moments in the upper neck were transferred to the occipital condyle (OC) joint. For the THOR-05F, this was done using the methods outlined by Wang [4].

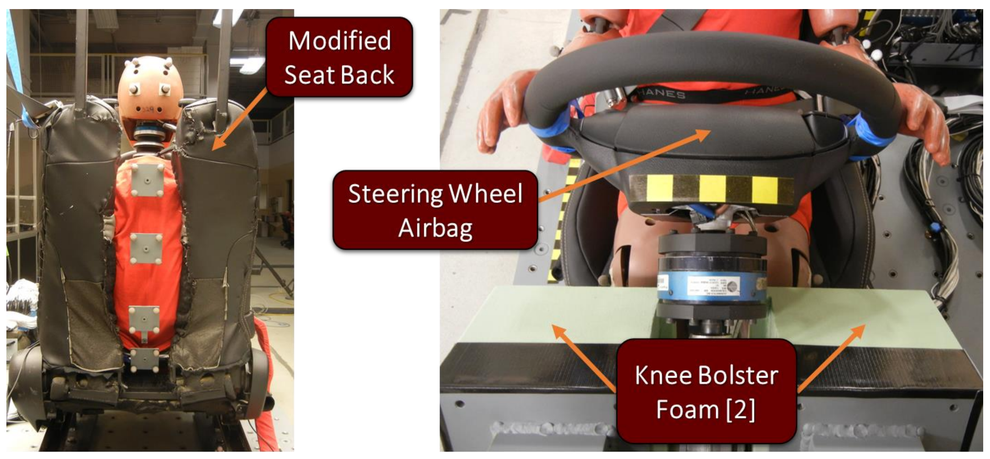


**Figure 1. Camry test buck with modified seat back**

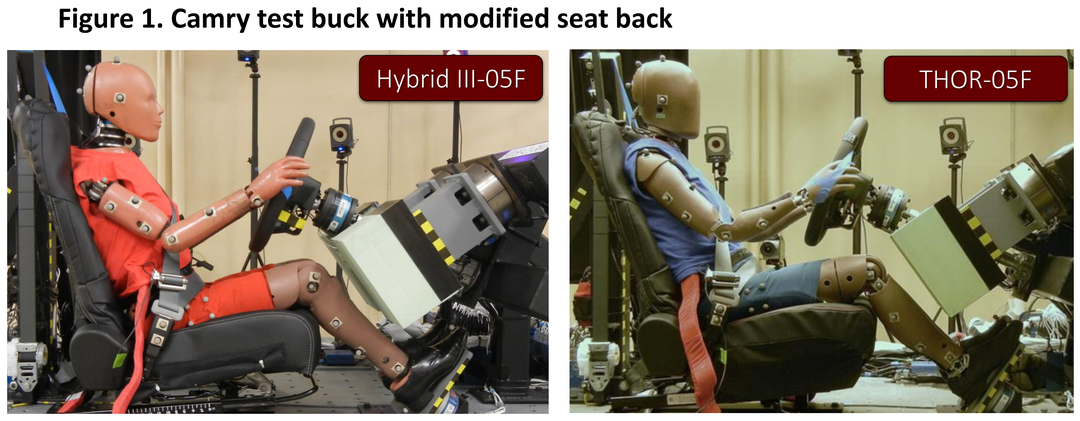


**Figure 2. ATD initial positions**

## CONCLUSIONS

Different upper neck loads were likely caused by different head-airbag interaction. Compression in the upper neck was greater in the 30-kph HIII-05F tests when the 2nd stage of the airbag was fired at 40ms compared to when it was fired at 10ms. This indicates a need to further study how airbag interaction affects neck response. Neck injury risk predicted by the HIII-05F was much greater in the 30-kph tests than the 56-kph tests, which reinforces the need for more crashworthiness research at lower speeds. Future work will include small female PMHS tests which will allow for biofidelity and injury risk analysis.

## REFERENCES AND ACKNOWLEDGMENT

[1] NHTSA. (1995). Anthropomorphic Test Dummy; Occupant Crash Protection (Docket No. 74–14; Notice 96). *Federal Register, 60*(126), 34213-34224.
[2] Albert, D. L., Beeman, S. M., McNally, C., and Kemper, A. R. (2016), "Evaluation of Rigid Polyurethane Foam as a Surrogate Material for Knee Bolsters and Knee Bolster Airbags in Full Scale Frontal Sled Tests," Traffic Injury Prevention 17, no. 1: 205-208.
[3] Janovicz, D., and Fischer, B., "Final Report of New Car Assessment Program Frontal Impact Testing of 2012 Toyota Camry LE 4-dr sedan," USDOT Document no. NCAP-MGA-2012-027, 2011.
[4] Wang, Z. J., "THOR Neck Moment Calculation at Atlanto-Occipital Joint," SAE Technical Paper 2019-01-1037, 2019, doi: 10.4271/2019-01-1037.

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## RESULTS AND DISCUSSION

Differences in head-airbag interaction likely resulted in different forces and moments in the neck. Peak compression in the upper neck in the 30-kph HIII-05F test with early airbag deployment (EAB) was -599 N while the average peak compression in the other HIII-05F 30-kph tests was -4630 N, greatly exceeding the FMVSS 208 limit of -2520 N (Figure 3). For the 30-kph HIII-05F tests, the airbag contacted the HIII-05F face before full inflation (approximately 126 ms), which corresponded to the onset of compressive loading in the upper neck (Figure 7). Further inflation of the airbag forced the chin toward the chest, which is likely associated with the upper neck compressive loading and an associated flexion moment (Figures 3 & 4). This is different from how the airbag interacted with the head in the EAB test, in which the airbag was fully inflated before making substantial contact with the face of the HIII-05F (116 ms, Figure 7). Similar head-airbag interaction was observed in the THOR-05F tests and the 56-kph HIII-05F tests. These results suggest that HIII-05F upper neck loads are sensitive to airbag deployment timing which indicates a need to further study how airbag interaction affects neck response.

Despite being a higher speed test, the average peak compression in the 56-kph HIII-05F tests was smaller than the average load in the 30-kph HIII-05F tests (-976 N). Again, the difference appears to be associated with different airbag interaction, similar to the EAB test. This difference reinforces the need for more crashworthiness research at lower speeds.

The axial forces in the lower neck were similar between tests (Figure 5). This is especially notable between the 30-kph HIII-05F tests and the EAB HIII-05F test. This result suggests that airbag deployment timing has a greater effect on the upper neck loads than the lower neck loads. Lower neck moments were similar in shape, but different in magnitude. The flexion moment in the HIII-05F EAB test was greater than the HIII-05F 30-kph tests, and more similar to the HIII-05F 56-kph tests (Figure 6). As the airbag was less inflated later in the test, the head was allowed to pitch forward more in the EAB and 56-kph tests than the 30-kph tests, which may have increased the flexion moment in the neck (Figure 7).

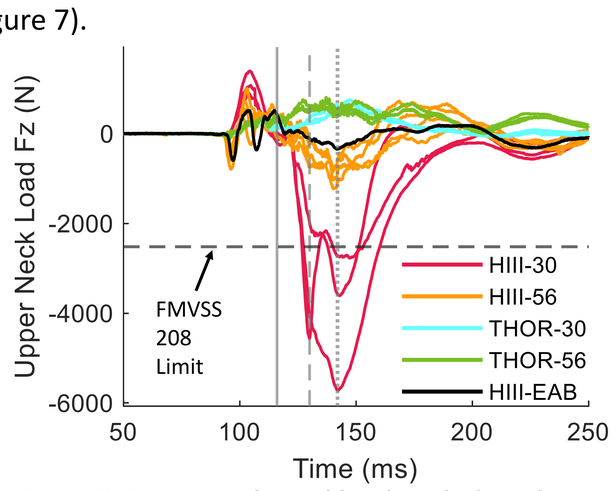


**Figure 3. Upper neck axial load, including the early airbag HIII 30-kph test (EAB)**

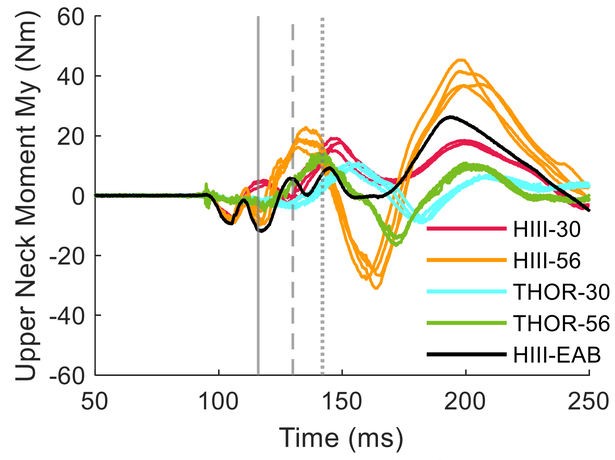


**Figure 4. Upper neck moment (My), including the early airbag HIII 30-kph test (EAB)**

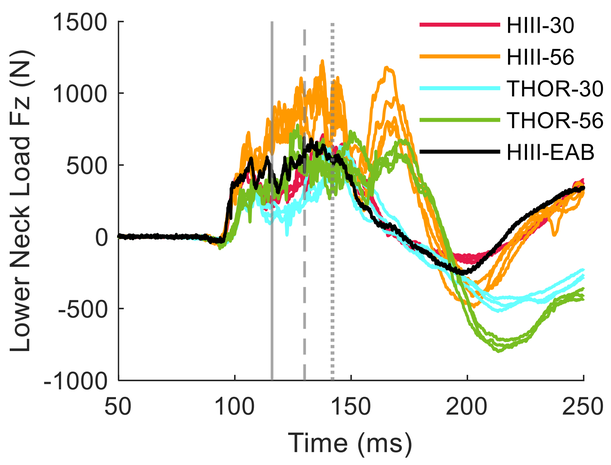


**Figure 5. Lower neck axial load, including the early airbag HIII 30-kph test (EAB)**

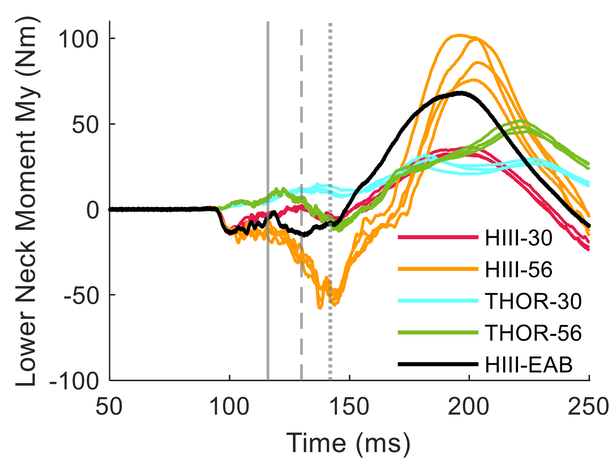


**Figure 6. Lower neck moment (My), including the early airbag HIII 30-kph test (EAB)**

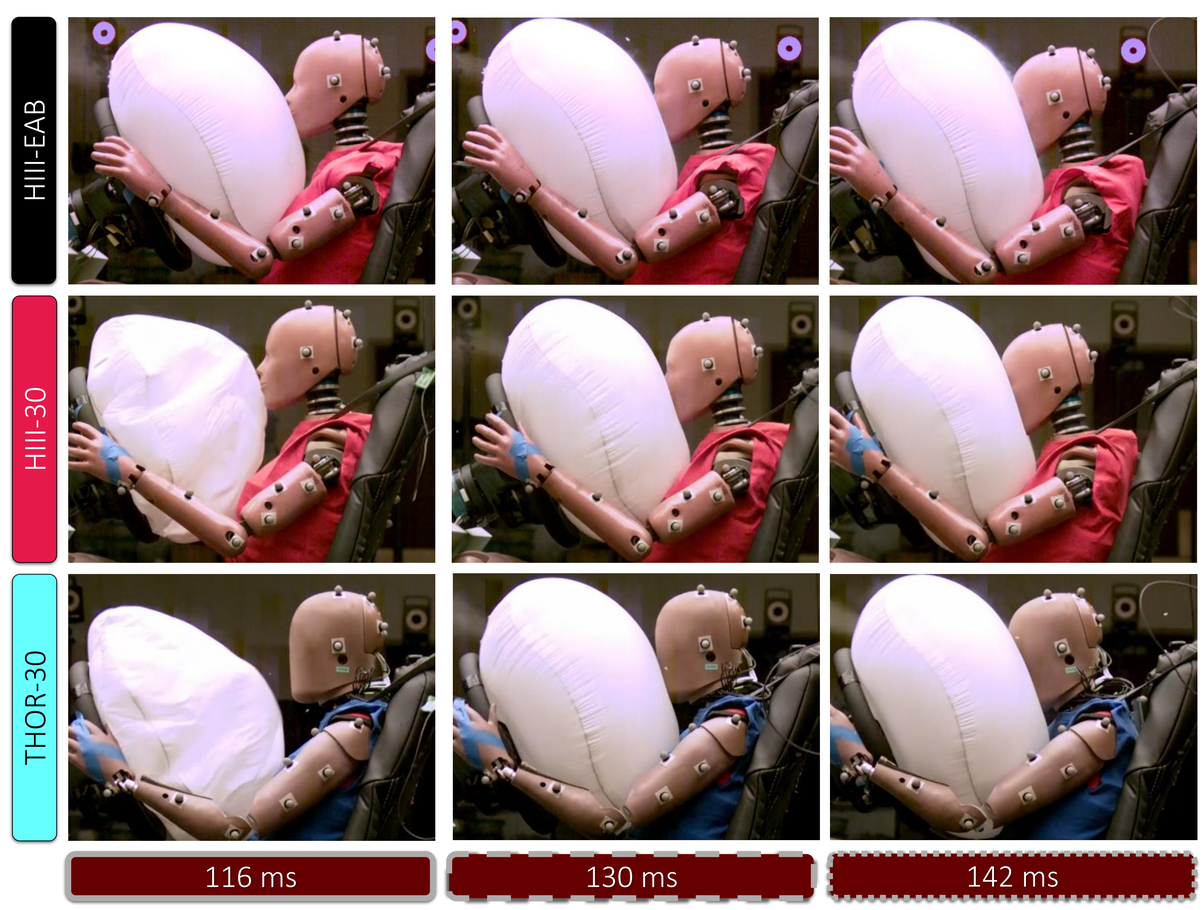


**Figure 7. High-speed video frames at the time of full inflation in the EAB test (116 ms) in the 30 kph tests (130 ms) and at the approximate time of peak compression in the HIII upper neck (142 ms).**