Comparison of the THOR-AV-5F ATD and 5th Percentile Female Volunteer Responses during Low-Speed Frontal and Frontal-Oblique Sled Tests

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Introduction

The THOR-AV-5F anthropomorphic test device (ATD) was designed to represent small females in autonomous vehicles, which are equipped with crash avoidance technologies like autonomous emergency braking. As these technologies become more prevalent, it is necessary to study occupant responses during pre-crash braking events. The low severity and long duration of these events provide sufficient time for muscle activation to affect occupant response. Unfortunately, this effect is not captured in post-mortem human subject test data typically used to validate ATDs. Performing matched low-speed volunteer and ATD tests can provide insight into the validity of using ATDs during low-severity events. Therefore, the objective of this study was to quantify the response of the THOR-AV-5F during low-speed frontal and frontal-oblique sled tests, and compare to relaxed and braced small female volunteer responses.

Methods

Six 5th percentile female volunteers experienced low-speed sled tests on two days using a rigid test-buck. On a given day, volunteers experienced either frontal (0°) or frontal-oblique (330°) tests at two pulse severities (1g and 2.5g), with two muscle conditions per pulse severity (relaxed and braced). Three matched THOR-AV-5F tests were performed for each test condition.

Reaction forces were measured using multi-axis load cells at each interface, including the left and right foot pedals, steering column, seat pan, and seat back. Head CG, neck (C7/T1), and sternum (x-direction only) accelerations were also measured. Average peak resultant forces and accelerations were compared between the THOR-AV-5F and relaxed and braced volunteers for each test condition.

Results

In the frontal orientation, the THOR-AV-5F had higher forces compared to relaxed volunteers for the foot pedals and seat back at both pulses and seat pan at 2.5g (ΔTHOR-Relaxed = 26125N), but lower forces for the column at 1g ($\Delta_{THOR\text{-}Relaxed}$ = -45N). Forces were similar between the THOR-AV-5F and relaxed volunteers for the seat pan at 1g and column at 2.5g ($\Delta_{THOR\text{-}Relaxed}$ = -11 to -3N).

In the frontal-oblique orientation, the THOR-AV-5F and relaxed volunteers had similar forces for all interfaces at 1g ($\Delta_{THOR\text{-}Relaxed}$ = -8 to 10N), except for the seat back ($\Delta_{THOR\text{-}Relaxed}$ = -129N). However, at 2.5g the THOR-AV-5F had higher forces for all interfaces ($\Delta_{THOR\text{-}Relaxed}$ = 23-466 N).

Compared to braced volunteers, the THOR-AV-5F had lower forces for all interfaces across all test conditions ($\Delta_{THOR\text{-}Braced}$ = -609 to -25N), except for the seat back at 2.5g in both orientations (ΔTHOR-Braced = 258-270N).

Across all test conditions, the THOR-AV-5F's head, neck, and sternum accelerations had minimal differences compared to relaxed volunteers ($\Delta_{THOR\text{-}Relaxed}$ = -0.4 to 0.5g), and greater differences compared to braced volunteers ($\Delta_{THOR\text{-}Braced}$ = -1.6 to 1.1g).

Conclusions

A range of differences in reaction forces was observed between the THOR-AV-5F and relaxed volunteers in the frontal orientation. The THOR-AV-5F generally had lower forces than braced volunteers for all test conditions and higher forces than relaxed volunteers in the frontal-oblique 2.5g condition. The

THOR-AV-5F forces were generally most similar to relaxed volunteers in the frontal-oblique 1g condition. The THOR-AV-5F head, neck, and sternum accelerations were more similar to relaxed volunteers than braced volunteers.