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Biofidelity of THOR 5th Female in Frontal Sled Tests

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ABSTRACT

The goal of this study was to develop biofidelity reference targets from small female post-mortem human subjects (PMHS) and to assess the biofidelity of the THOR-05F in frontal sled tests. Fifteen adult small female PMHS were subjected to frontal impact tests in three conditions. The THOR-05F was tested in the same three conditions. The THOR-05F matched PMHS belt forces and sagittal-plane trajectories well, but differences were observed in lateral motion. The PMHS suffered multiple rib fractures, even at low speeds, which is consistent with general trends from field data.

INTRODUCTION

Recent studies have found that female automotive occupants may be at a higher risk of injury (Bose et al., 2011; Forman et al., 2018) than male occupants. The most frequently employed female crash test dummy, the Hybrid III-5F, was designed to attain biofidelity targets derived by scaling those that had been previously established for the male version, the HIII-50M (Mertz et al., 1989; NHTSA, 1998). Conformity to those targets is assessed primarily by pendulum impacts to various body segments. This may not guarantee a high degree of biofidelity in a vehicle test environment due to the complexity of whole-body motion. This has motivated the design and evaluation of the THOR-05F anthropomorphic test device (ATD), a frontal impact ATD representing a small (nominally 5th-percentile) female occupant. The goal of this study was to develop biofidelity reference targets from small female post-mortem human subjects (PMHS) and to use those targets to assess the biofidelity of the THOR-05F in frontal sled tests.

METHODS

Fifteen adult (48 to 95 years) female post-mortem human subjects (PMHS) of nominally 5th-percentile mass (28 to 60 kg) and stature (149 to 165 cm) and a range of bone quality (osteoporotic, osteopenic, and normal) were subjected to simulated frontal impacts in three conditions (with one test each): ten PMHS at 30 km/h change in velocity (ΔV), three PMHS at 20 km/h ΔV, and two PMHS at 10 km/h ΔV (Figure 1). This ΔV range was expected to bracket injury onset. The test environment was adapted from Shaw et al. (2009) (Figure 2). In all three conditions, a three-point seatbelt with separate shoulder and lap-belt segments was used. The lower extremities were additionally constrained by a rigid knee-bolster initially adjacent to the knees and a footrest with clamps which held the feet. The goal of the test fixture was to isolate thoracic loading of the occupant by the shoulder-belt. In the 30 km/h condition, a 2 kN shoulder-belt force-limiter was used, and in the 20 km/h condition, a 1.3 kN shoulder-belt force-limiter was used. In the 10 km/h condition, no force-limiter was used. The force in the shoulder-belt was measured by a tension gauge. The three-dimensional motions of the head, spine, and pelvis were measured with an optical motion-tracking system as described by Shaw et al. (2009). After the PMHS tests, the THOR-05F was tested three times in each test condition. The three-dimensional motions of the head, spine, and pelvis of the THOR-05F were measured in the same manner as for the PMHS.

ΔV [km/h]	Force Limit [kN]	# PMHS
30	2.0	10
20	1.3	3
10	n/a	2

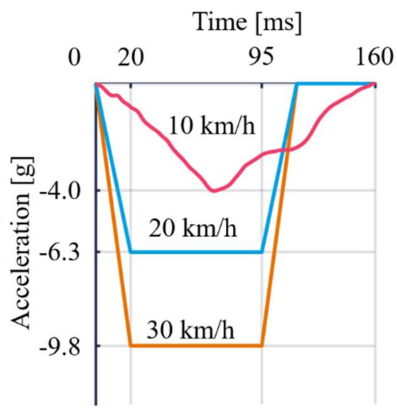

Figure 1. Test matrix and sled acceleration inputs.

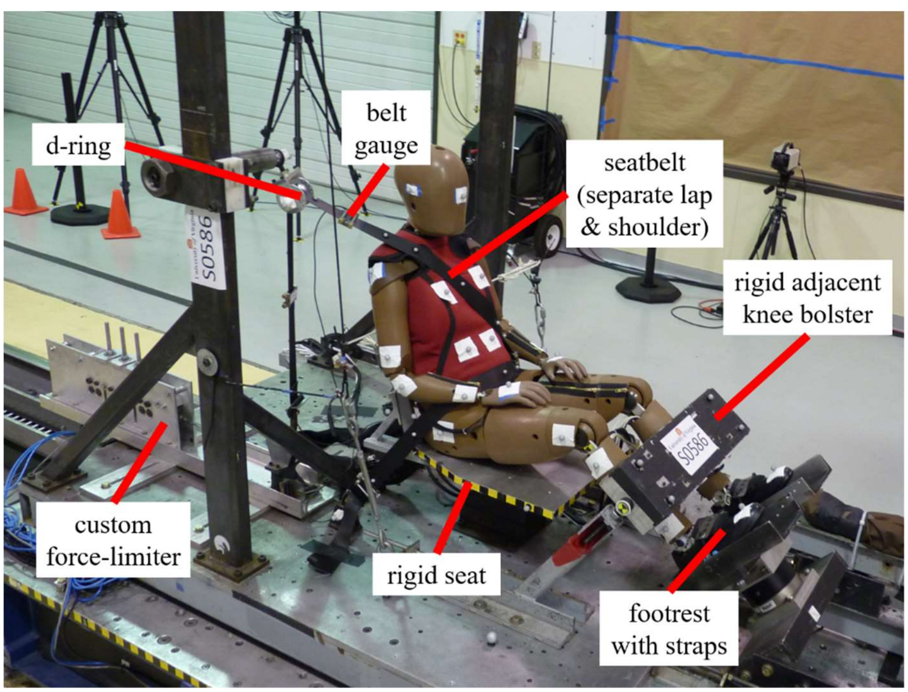

Figure 2. Boundary conditions from the test.

RESULTS

Fifteen small female PMHS were tested in three conditions. The THOR-05F matched PMHS belt forces (Figure 3) and sagittal-plane trajectories (Figure 4) well, but differences were observed in lateral motion (Figure 5). The PMHS suffered multiple rib fractures, even at low speeds (Figure 6), which is consistent with general trends from field data (Forman and McMurry, 2018; Forman et al., 2019).

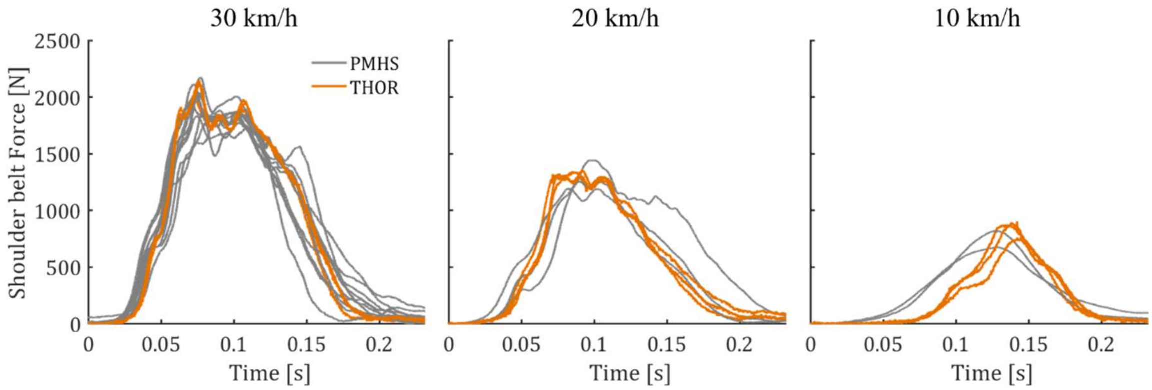

Figure 3. Upper shoulder belt forces.

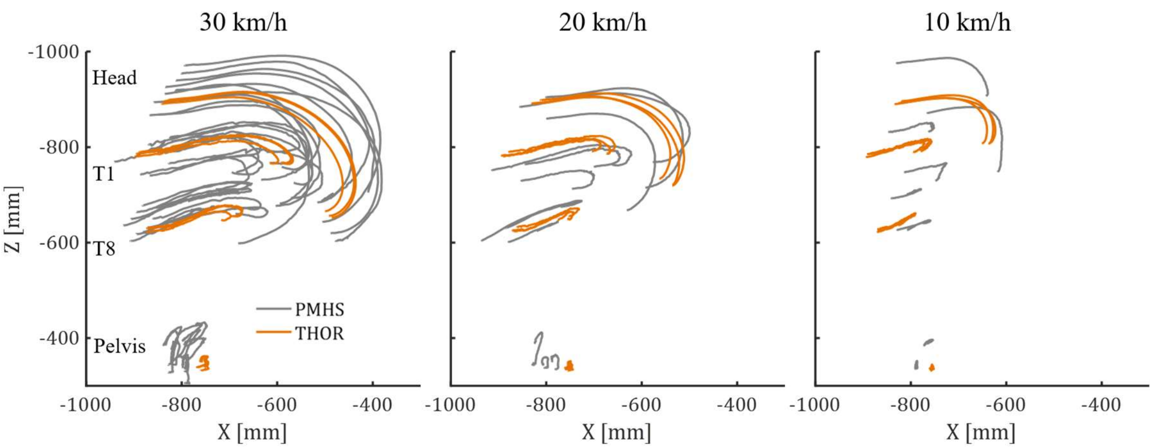

Figure 4. Trajectories of head, spine, and pelvis in the sagittal plane.

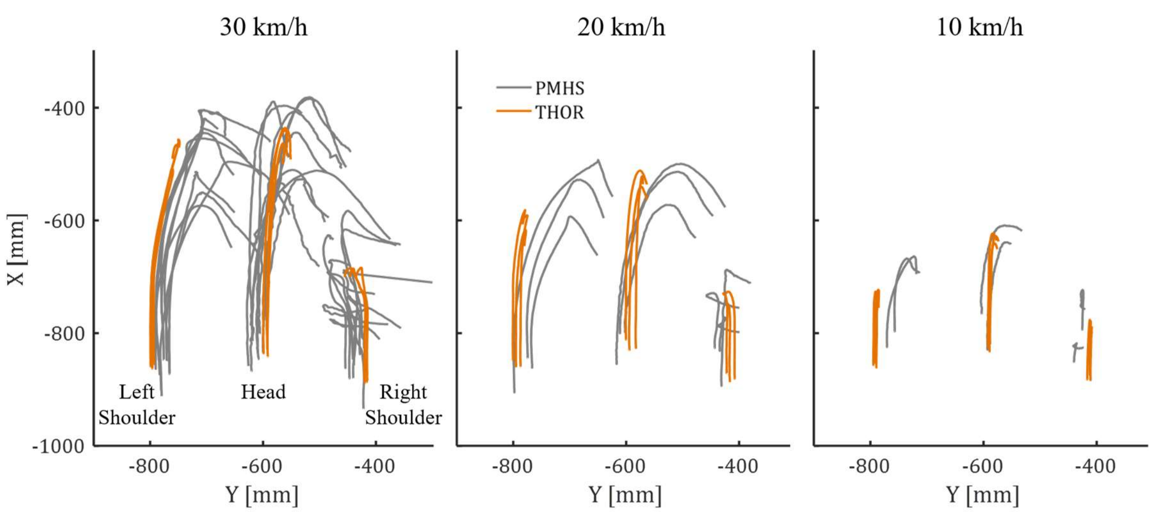

Figure 5. Trajectories of head and shoulders in the horizontal plane.

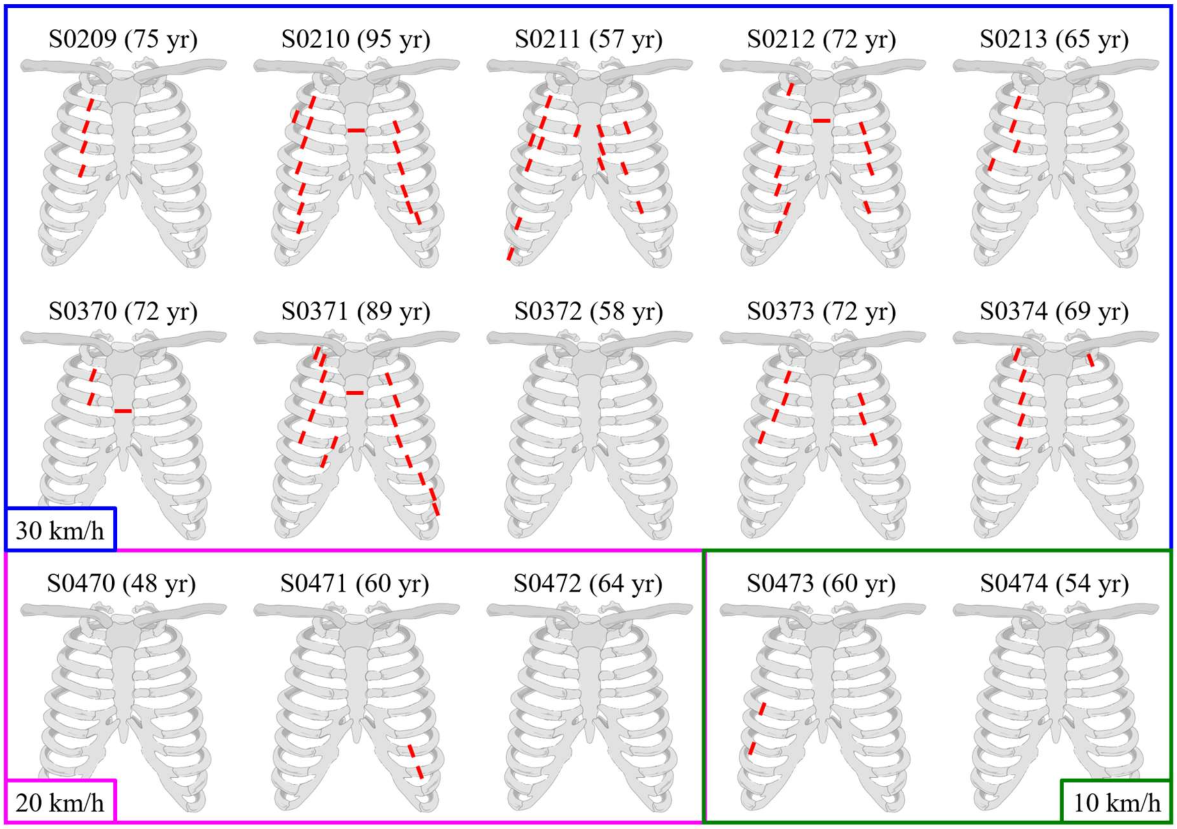

Figure 6. Rib fractures. Top row (S0209-S0213) reproduced from Shaw et al. (2017).

CONCLUSIONS

Fifteen small female PMHS were tested in three conditions. The THOR-05F matched PMHS belt forces and sagittal-plane trajectories well, but differences were observed in lateral motion. The differences in lateral motion imply that the lateral response of the THOR-05F was stiffer than that of the PMHS. The PMHS suffered multiple rib fractures, even at low speeds, which is consistent with general trends from field data.

Future work will include quantitative comparison of THOR-05F and PMHS results. In particular, thoracic deflections will be compared, and the ATD's ability to replicate sensitivity to test condition change (Δ-biofidelity) will be evaluated.

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