Investigation of Rear Seat Occupant Safety During High-Speed Frontal Crashes Using GHBMC M50-O

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Introduction

Why rear seats?

- Front seats have become much safer than the rear seats for certain occupants and specific crash types.
- While adults make up only 19% of rear seat occupants in frontal crashes, they make up 48% of fatalities.
- Rear-seated occupants are still at risk of injury or death.
- The rise of autonomous driving systems (ADS) could increase rear-seat occupancy and injury risks.

The Objective

- Investigate the safety performance of current vehicle rear seats using FE human body models.
- Evaluate the performance of rear-seat models of various vehicles during frontal New Car Assessment Program (NCAP) crash pulses, assess submarining, and compare with PMHS test data.

Methodology

- The FE seat models (Table 1) of four selected vehicles, created based on geometric data reconstructed from three-dimensional (3D) digitizer scans, were utilized in frontal crash simulations using PMHS sled test pulse: NCAP85 (ΔV = 56 kph).
- Seat foam material parameters were extracted from individual seat testing [1].

Table 1. Vehicle FE Model Information used for HBM based impact simulations [3].

Seat	Seat-bottom angle (°)	Seat stiffness (N/mm)	Seatbelt Restraint Type
A	17	10	Conventional
B	19	12	Pretensioner/load limiter
C	13	10	Pretensioner/load limiter
D	11	7	Conventional

Simulation process

Simulation Setup for sled test using GHBMC M50-O:

- Pelvis angle 29° compared to original angle of 53°, hence spine rotated about middle of lower vertebrae (Fig 1).
- GHBMC-O Male 50th percentile was positioned using PMHS FARO arm data. Gravity settling on seat-back and seat-bottom.

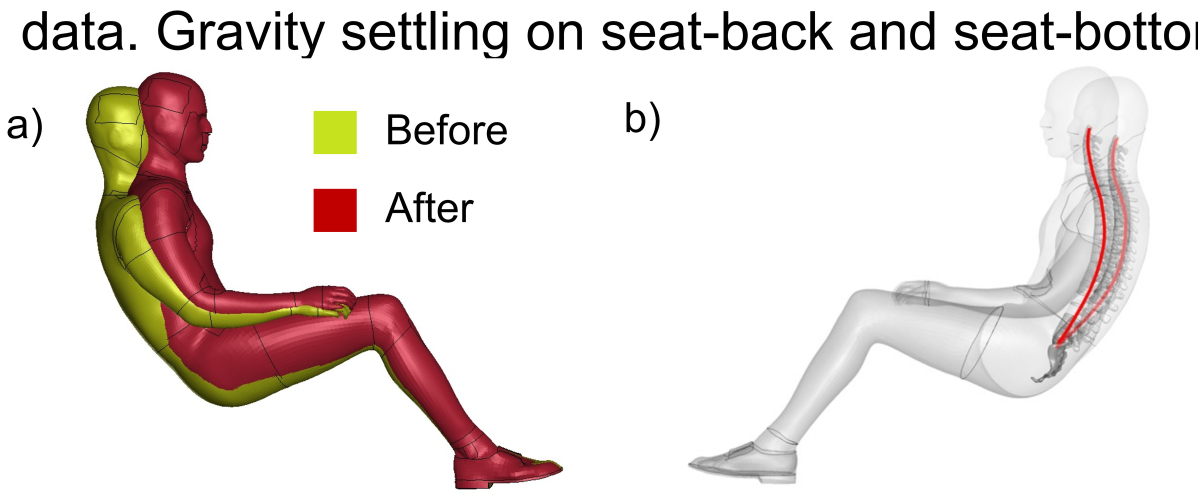
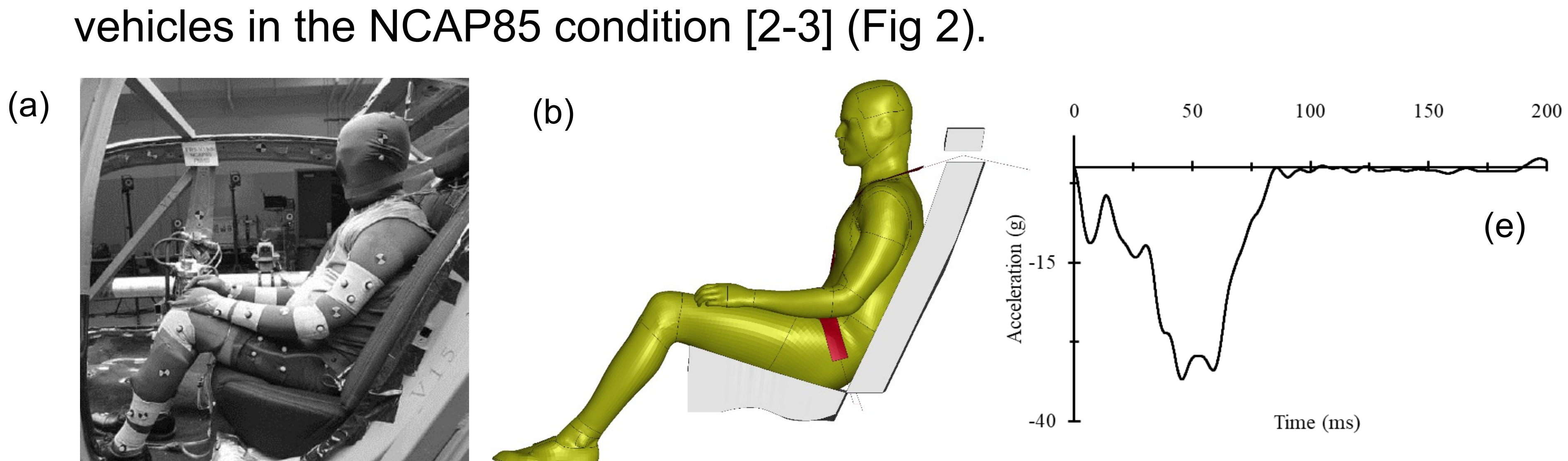


Fig 1. a) Spine simulation to straighten the back and make it parallel to the seat b) Spine curvature before and after in the GHBMC-M50.

- Matching PMHS tests, crash simulations were conducted on four of the vehicles in the NCAP85 condition [2-3] (Fig 2).



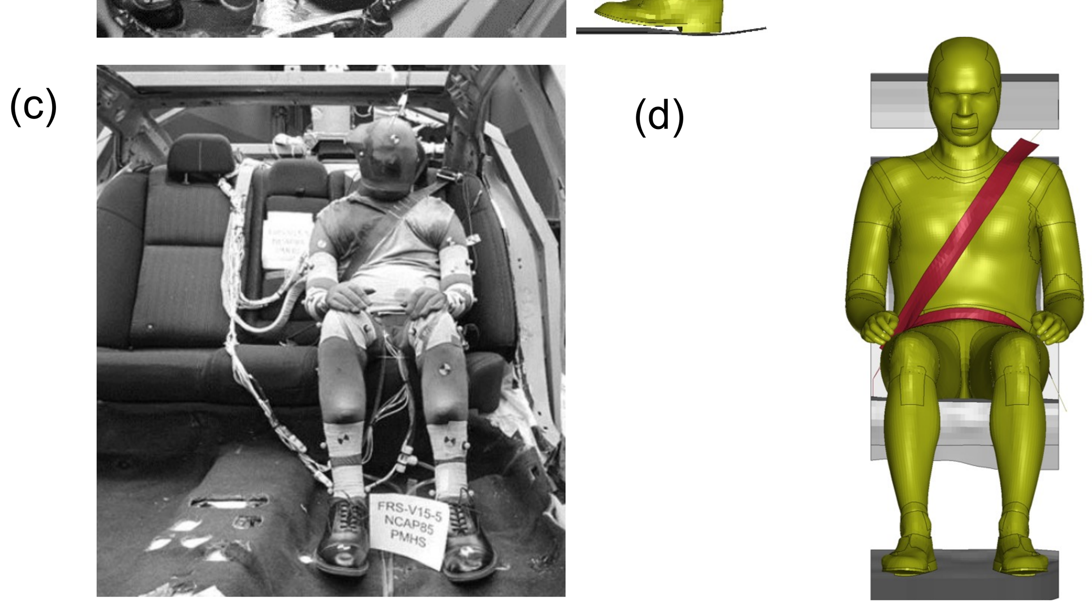


Fig 2. Final pre-impact positioning in (e.g., vehicle rear seat A): mid-sized male PMHS (a) side view, (c) front view; GHBMC M50-O FE model (c) side view, (d) front view. Knee-to-knee and hip-to-hip distance adjusted to ~225 mm. e) Rear seat A crash pulse used in FE simulations derived from PMHS sled tests [3].

Results

NCAP85 crash results using GHBMC-O Male 50th Percentile

Non-submarining case

- With Seat-C, NCAP85 sled test produced no submaring (Fig 3) but a pelvis fracture was observed in both the PMHS test and CAE simulations around 90 ms as depicted by pelvis acceleration spike (Fig 3c).
- This PMHS stayed on the seat bottom and lower pelvis excursion was observed compared to other cases.

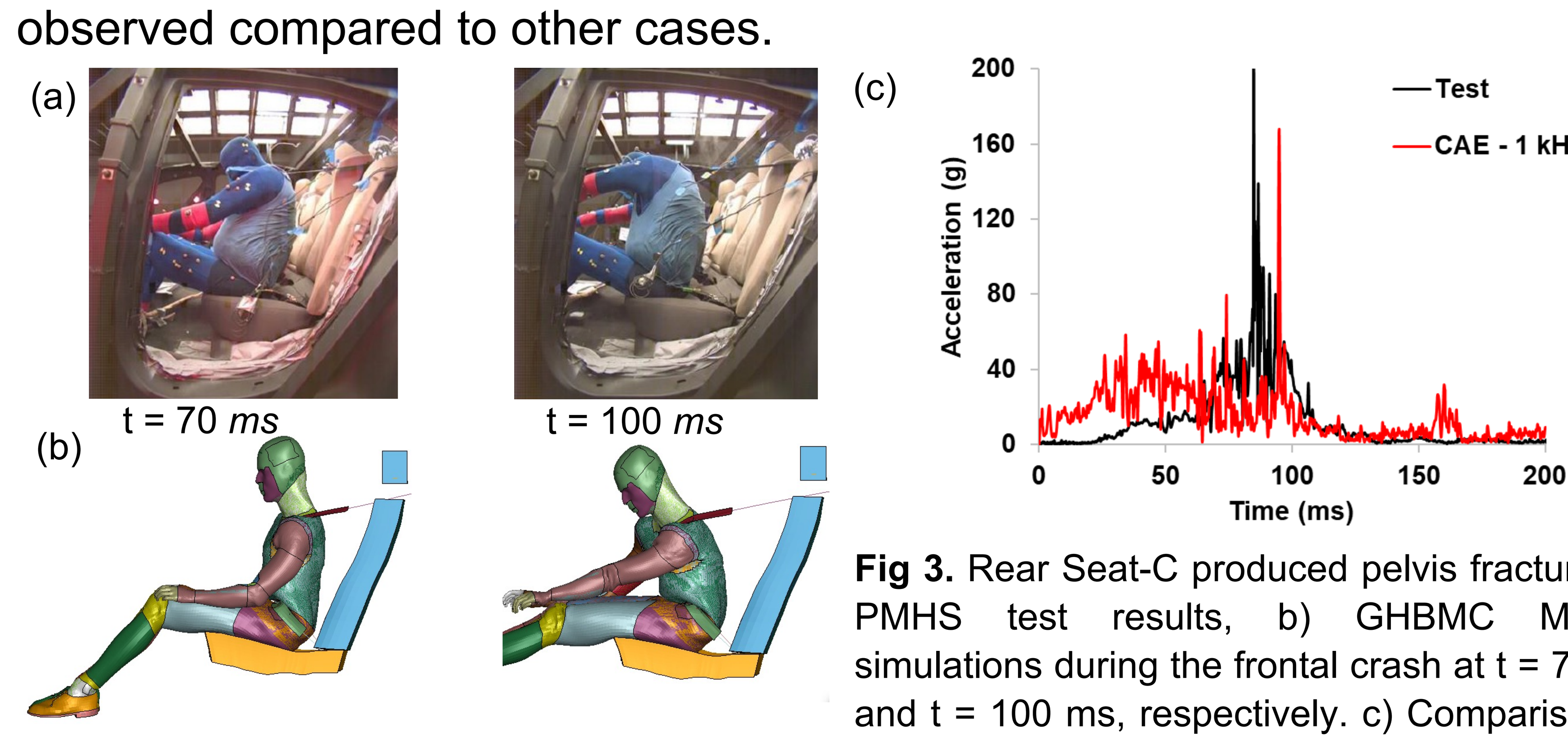
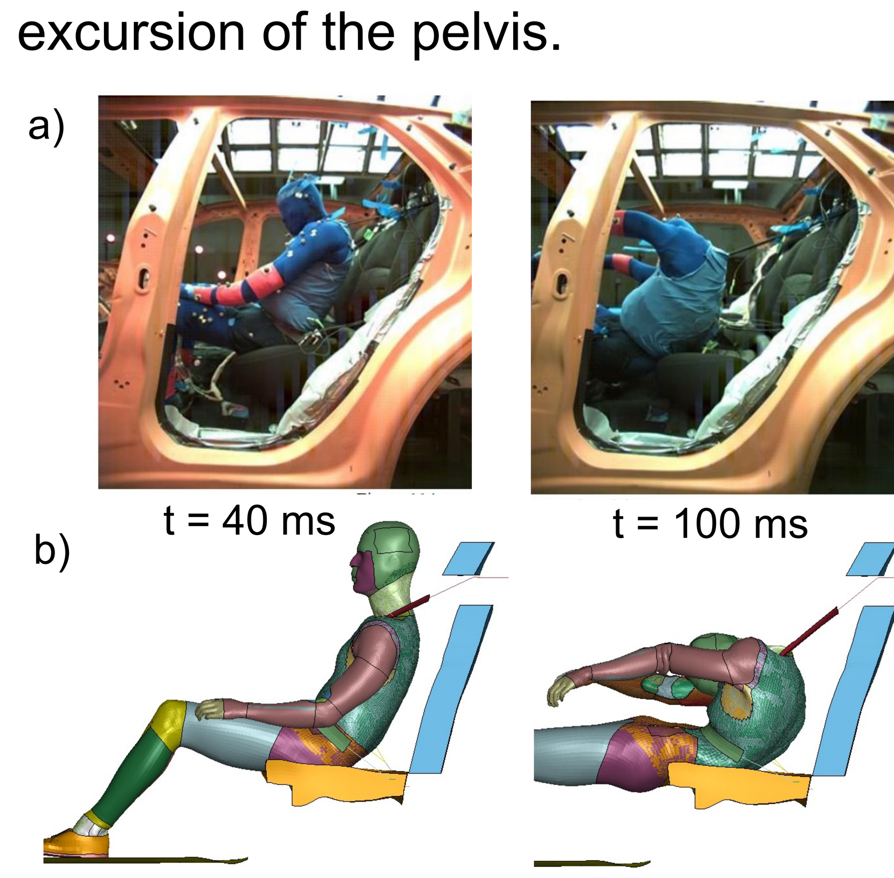


Fig 3. Rear Seat-C produced pelvis fracture. a) PMHS test results, b) GHBMC M50-O simulations during the frontal crash at t = 70 ms and t = 100 ms, respectively. c) Comparison of test vs CAE pelvis acceleration.

Submarining case

- With Seat-D, NCAP85 sled test produced severe submarining (Fig 4).
- This PMHS came completely off of the seat bottom before the lumbar spine slammed against the anterior edge of the seat. CAE results showed reasonable agreement with the test data.
- The occurrence of submarining was identified and assessed for severity by symmetry of lap belt slip, degree of abdominal loading, and forward excursion of the pelvis.



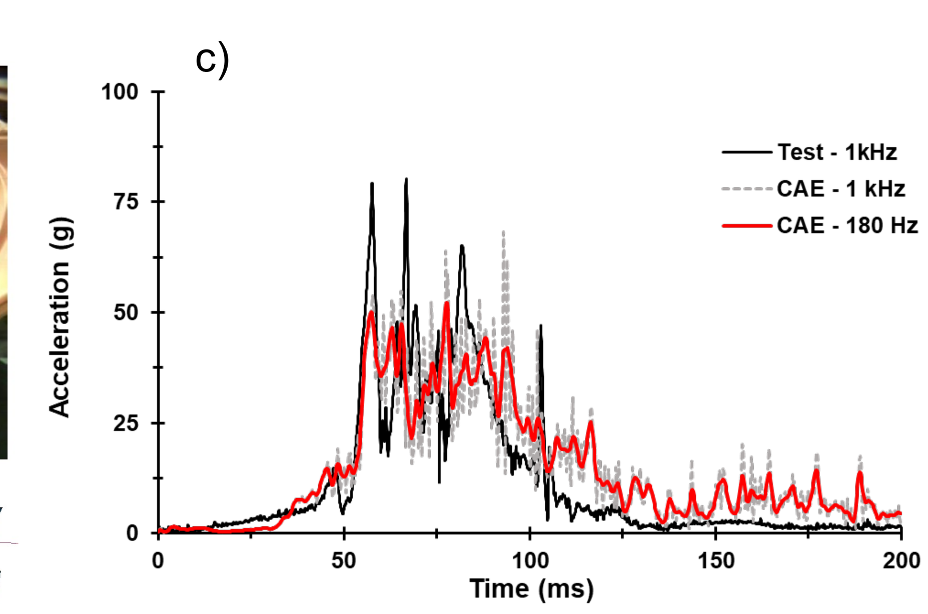


Figure 4. a) Rear Seat-D PMHS test results, b) GHBMC M50-O simulations during the frontal crash at t = 40 ms and t = 100 ms, respectively. c) Shows the comparison of Test and CAE pelvis acceleration.

Table 2. Submaring results from the PMHS tests and HBM based FE simulations.

Vehicle	Restraint type	Vehicle Type	Submarining Test	Submarining CAE
Seat A	Conventional	Sedan	None	None
Seat B	Advanced	CUV	Moderate	Moderate
Seat C	Advanced	Sedan	None	None
Seat D	Conventional	CUV	Severe	Severe

Conclusions

- Numerically investigated and evaluated rear seats in terms of occupant safety during a frontal crash.
- The results of the simulations with PMHS sled test frontal-impact pulses showed reasonable agreement with test data (Table 2).
- Restraint type was not indicative of whether or not the GHBMC or PMHS would submarine as many other factors in the rear seat environments of these vehicles likely contribute.
- This study found that advanced restraint systems and steep seat pan angles have the potential to reduce the risks of occupant injuries.

References

[1] Meng et al., "Numerical Investigation of the Performance of Current Vehicle Rear Seats Using Finite Element Analysis," SAE Int. J. Trans. Safety, 2022.

[2] Bianco et al., "Evaluation and comparison of thoracic injury risk for the Hybrid III and THOR 50th-percentile male anthropomorphic test devices in the rear seat during frontal impacts". SAE International Journal of Transportation Safety, 2022.

[3] "Submarining and abdominal injuries for rear-seated mid-size males during frontal crashes". PhD dissertation, Allison J. Guettler, 2023.