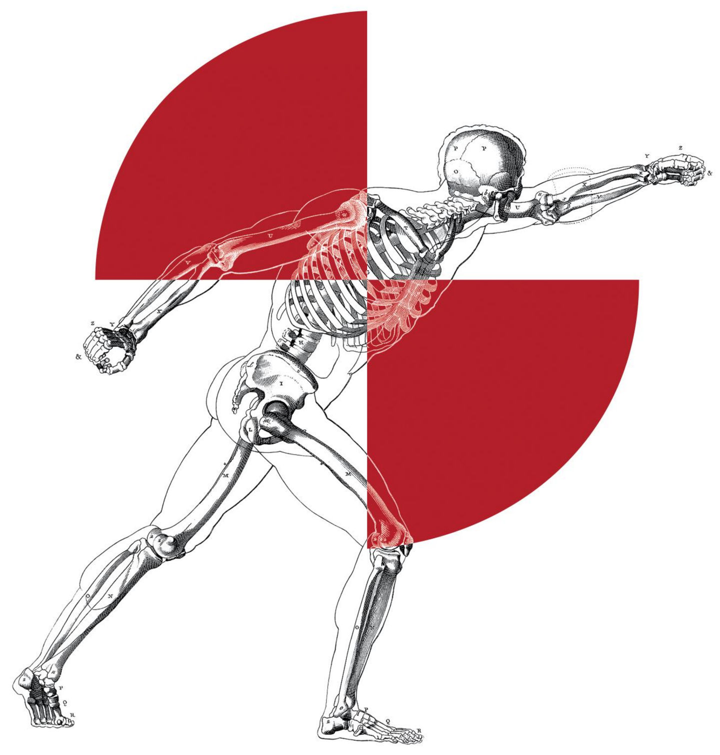

# Preliminary Thoracic Biofidelity Evaluation for GHBMC, THUMS, and VIVA+ Midsize Female HBMs Using Female-Specific Biofidelity Corridors


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## INTRODUCTION

- Thoracic injuries are common for female occupants in frontal crashes [1].
- Midsize (~50th percentile) female Human Body Model (HBM) thoraces have been validated via a simplified frontal impact [2-4] but not compared to female-specific biofidelity corridors from post-mortem human subjects (PMHS).
- **This study generated midsize female PMHS biomechanical response corridors to evaluate thoracic biofidelity of three midsize female HBMs.**

## MATERIALS & METHODS

- Three midsize female PMHS (Table 1) were subjected to 4.3 m/s frontal impacts at mid-sternum by a cylindrical impactor (mass: 14 kg, diameter: 15.2 cm) using a previous test setup [5,6].
- Experiments were replicated using midsize female HBMs and a rigid impactor model (Table 1, Figure 1).

***Table 1:*** *PMHS and HBM information*

| Subject | Elements [millions] | Stature [cm] | Mass [kg] | Chest Depth [mm] |
|---|---|---|---|---|
| GHBMC F50-O v6.0.3 | 2.8 | 162 | 64 | 203 |
| THUMS AF50 v7.1 | 2.6 | 162 | 61 | 204 |
| VIVA+ 50F v1.1.1 | 0.8 | 162 | 62 | 226 |
| PMHS AVG ± SD | - | 169 ± 2 | 69 ± 7 | 258 ± 13 |

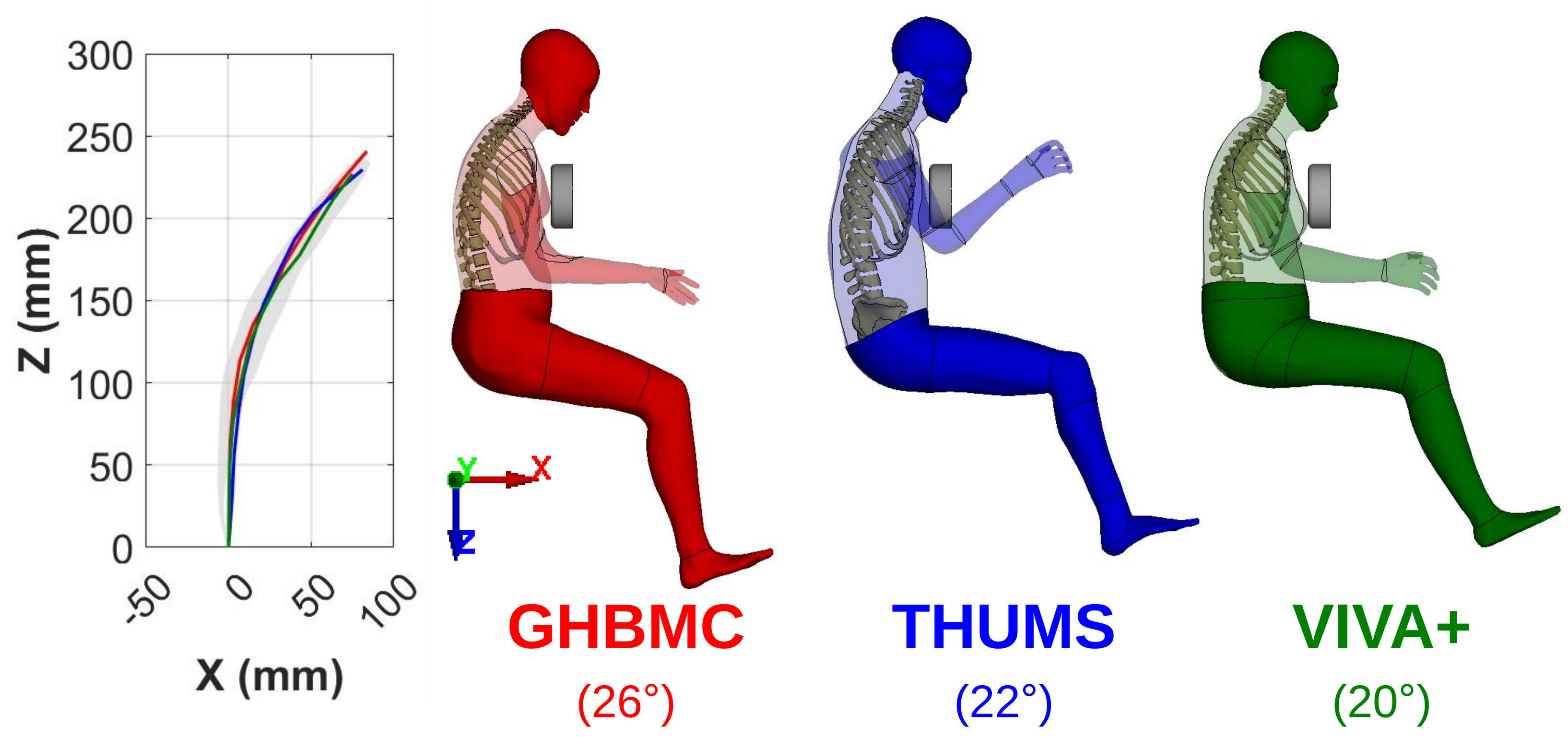
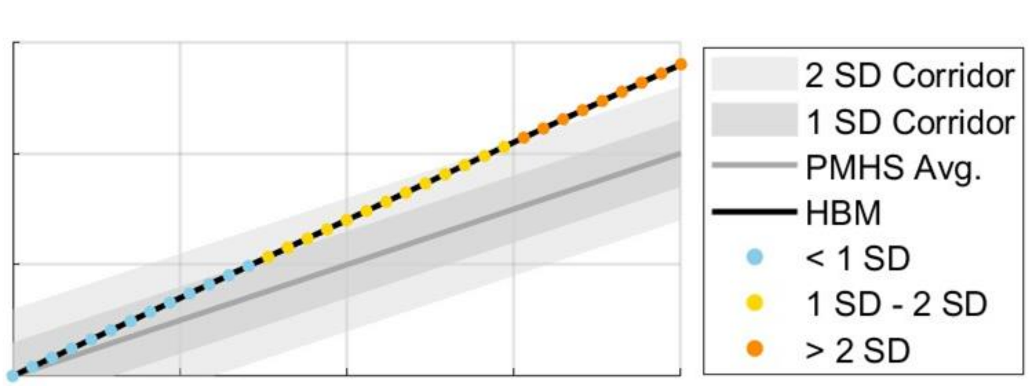



***Figure 1:*** *HBM thoracic spine curvatures compared to 1 SD PMHS corridor (left); HBMs in position with applied Y-rotations (right).*

- Thoracic % deflection was defined as the relative X-displacement between the impactor and T8, normalized by initial chest depth.
- PMHS corridors (1 SD) were constructed for % deflection-time (DT), force-time (FT), and force-deflection (FD) responses.
- The NHTSA Biofidelity Ranking System (BRS) [7], Correlation and Analysis (CORA) [8], and Corridor Agreement Score (CAS) (Figure 2) methods were used to quantify biofidelity from 0-35 ms.




$$CAS_1 = \frac{n_{\bullet}}{n_{\bullet} + n_{\bullet} + n_{\bullet}} \times 100\%$$

$$CAS_2 = \frac{n_{\bullet} + n_{\bullet}}{n_{\bullet} + n_{\bullet} + n_{\bullet}} \times 100\%$$

***Figure 2:*** *CAS example*

## RESULTS

- All simulations reached normal termination at 100 ms (Figure 3).
- Computation time and thoracic response for each HBM are shown in Figures 4-6.

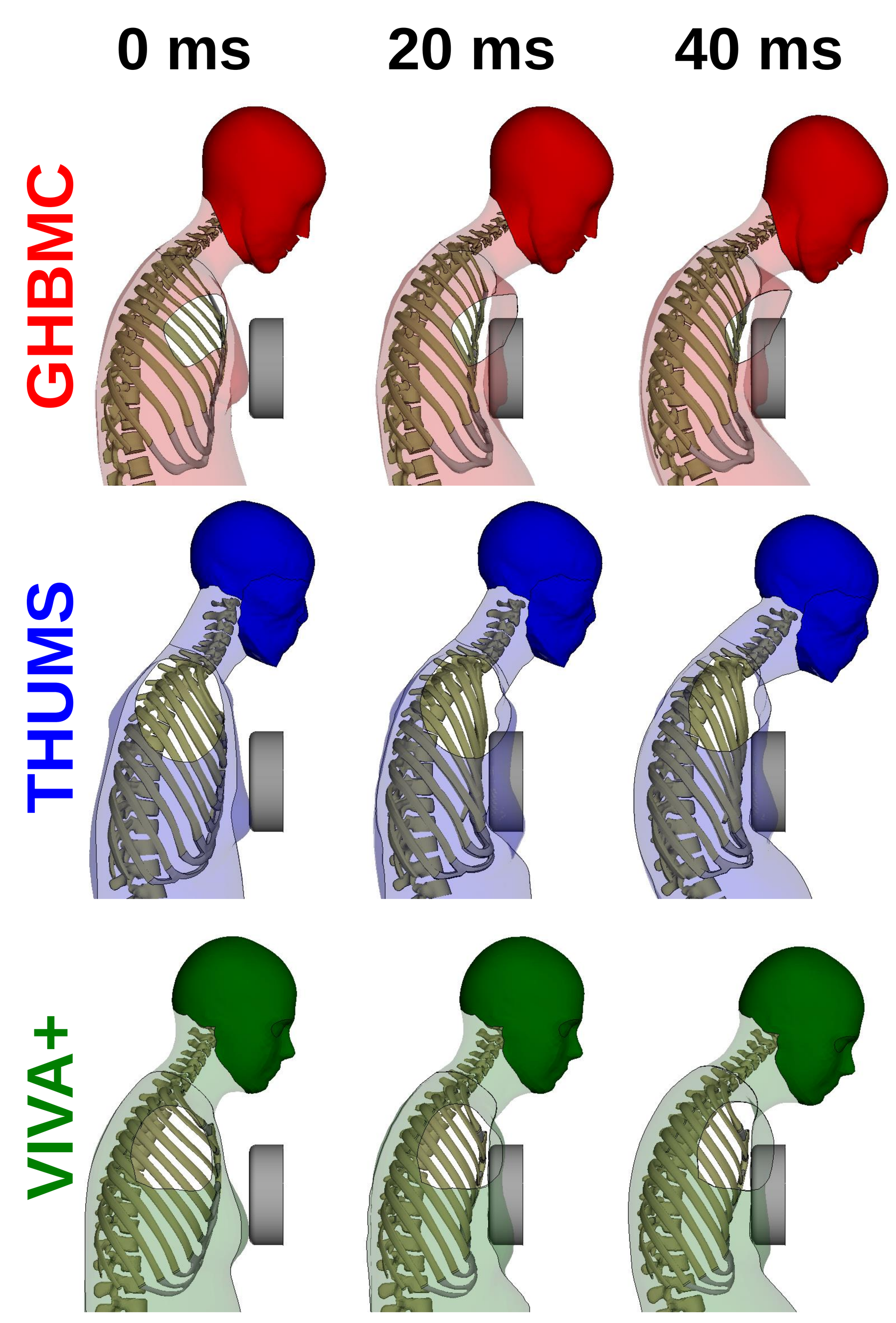



***Figure 3:*** *Simulation still frames*

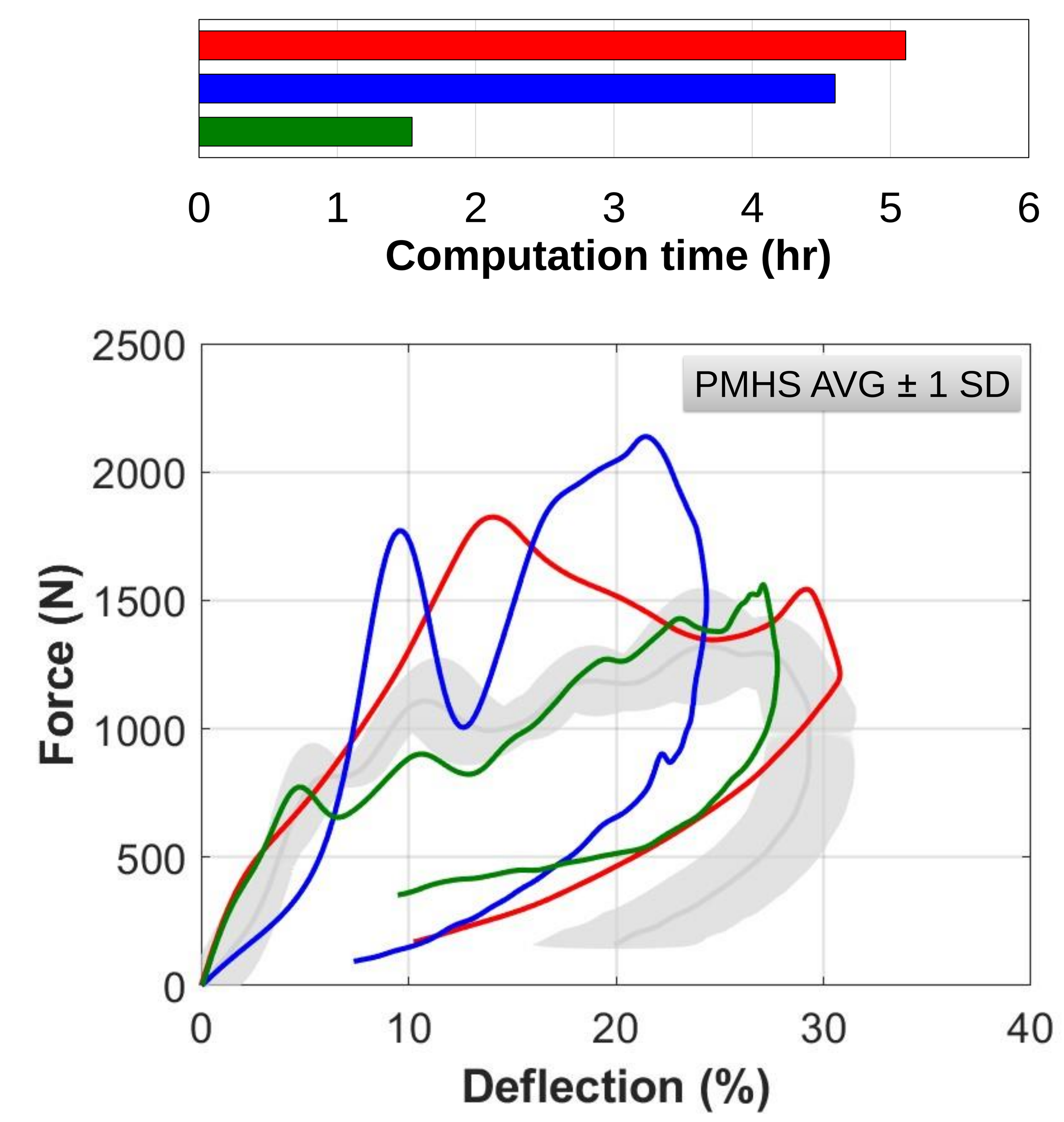



***Figure 4:*** *Simulation computation times (top); HBM FD responses compared to PMHS corridor (bottom)*

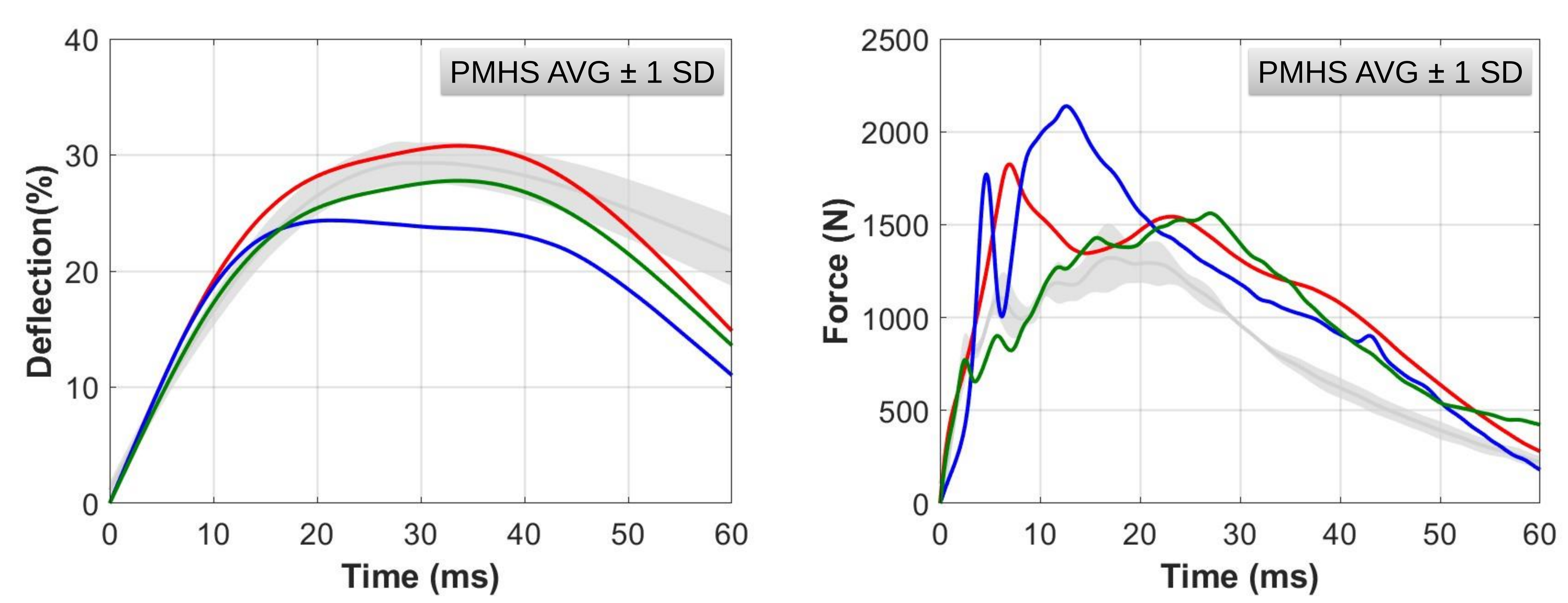



***Figure 5:*** *HBM DT (left) and FT (right) responses compared to PMHS corridors*

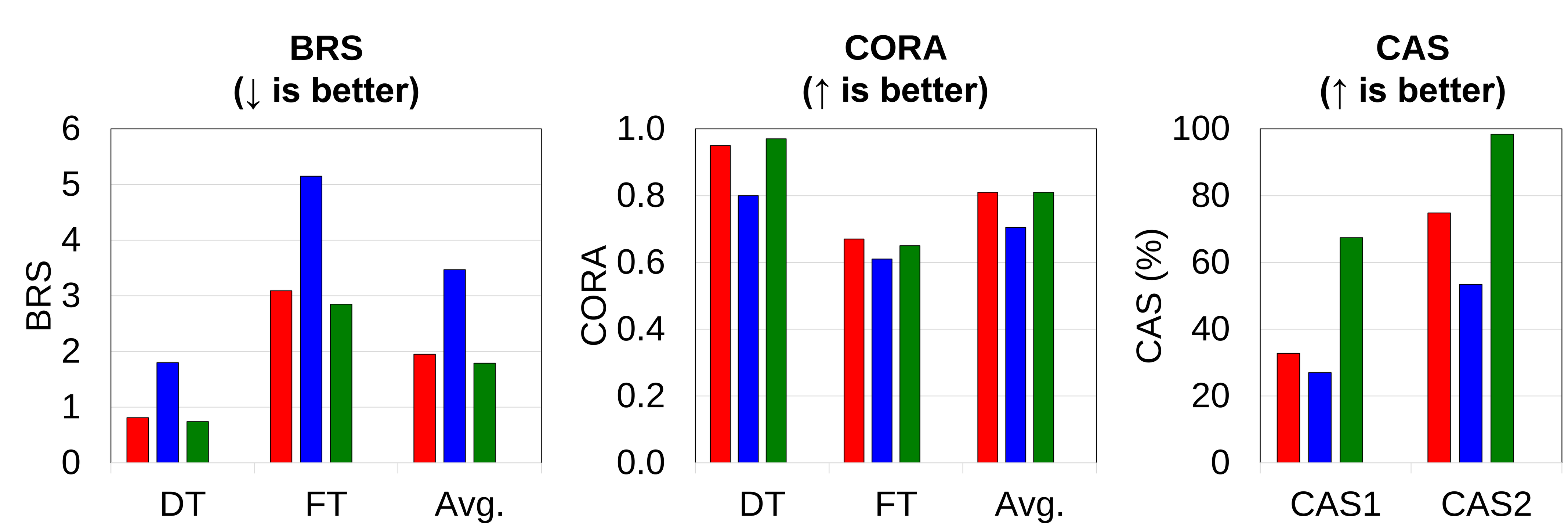



***Figure 6:*** *Biofidelity metrics*

## DISCUSSION & CONCLUSIONS

- PMHS thoracic response was consistent, as evidenced by the relatively narrow response corridors, although the sample size was small.
- Overall, GHBMC and VIVA+ biofidelity scores were better than THUMS, but all HBMs show room for improvement.
- BRS and CORA scores were nearly equivalent between GHBMC and VIVA+, but CAS1 and CAS2 were both substantially higher for VIVA+. While BRS and CORA are robust biofidelity tools for evaluating time-domain signals, CAS may be more sensitive for evaluating FD response.
- While the VIVA+ FT response was a similar shape to the PMHS, the GHBMC and THUMS FT responses had a sharp inertial peak that was not observed in the PMHS. This discrepancy is unsurprising given the lack HBM validations using female biomechanical data.
- Female HBMs can be improved as more female biomechanical data are generated. Future work includes frontal impact simulations with more detailed body positioning, as well as modeling of a bra and chestband.

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**REFERENCES CITED**
[1] Forman *et al.*, 2019. [2] Robinson *et al.*, 2023. [3] Toyota Motor Corporation, 2024. [4] John *et al.*, 2022. [5] Kroell *et al.*, 1971. [6] Kang *et al.*, 2022. [7] Hagedorn *et al.*, 2022. [8] Gehre *et al.*, 2009.



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