# Pelvic Response of a Total Human Body Finite Element (FE) Model During Simulated Under Body Blast (UBB) Impacts


**Caitlin M. Weaver[1,2] and Joel D. Stitzel[1,2]**

1. Virginia Tech – Wake Forest University Center for Injury Biomechanics, Winston-Salem, NC, 2. Wake Forest University School of Medicine, Winston-Salem, NC


## Introduction

Injuries to the warfighter caused by explosive mechanisms have increased from 7% in World War II to 81% during Operation Iraqi Freedom (OIF) and Operation Enduring Freedom (OEF) [1]. UBB events in theater are the cause of many serious injuries sustained by the warfighter to the pelvis, spine, and lower extremities [2]. These injuries are often debilitating, resulting in increased healthcare expenses and a reduced quality of life. Injury prediction for UBB events continues to be a challenge due to the limited availability of UBB-specific test studies. UBB injury prediction methods are subject to injury criteria developed for motor vehicle crash injury prediction, often limited to automotive loading rates [3].

## Purpose

This study focuses on the pelvic injury response of the Global Human Body Models Consortium (GHBMC) 50th percentile seated FE human body model (v4.3) [4]. The input data used for this study was obtained from testing performed by the Biomechanics Product Team (BIO PT) for the U.S. Army Warrior Injury Assessment Manikin (WIAMan) project. Evaluation of GHBMC model fidelity and injury response is based on biofidelity targets (corridors) created using pelvis accelerations obtained from experimental testing of UBB-type loading using post mortem human subjects (PMHS) [5].

## Methods

The input data used for this study was obtained from experimental testing performed by the Biomechanics Product Team (BIO PT) for the Warrior Injury Assessment Manikin (WIAMan) development effort. Acceleration pulses obtained from accelerometers attached to the floor and seat of the experimental test vehicle rigs were used to perform UBB FE simulations. Acceleration data from 133 nodes in the S1 region of the pelvis of the GHBMC were extracted from the simulations. These nodes represent the surface area and location of the accelerometer used to obtain S1 data in the PMHS experimental testing. The extracted FE S1 acceleration data was compared to experimental S1 data using preliminary biofidelity corridors created from the WIAMan experimental PMHS test data.

**(a)** **(b)**

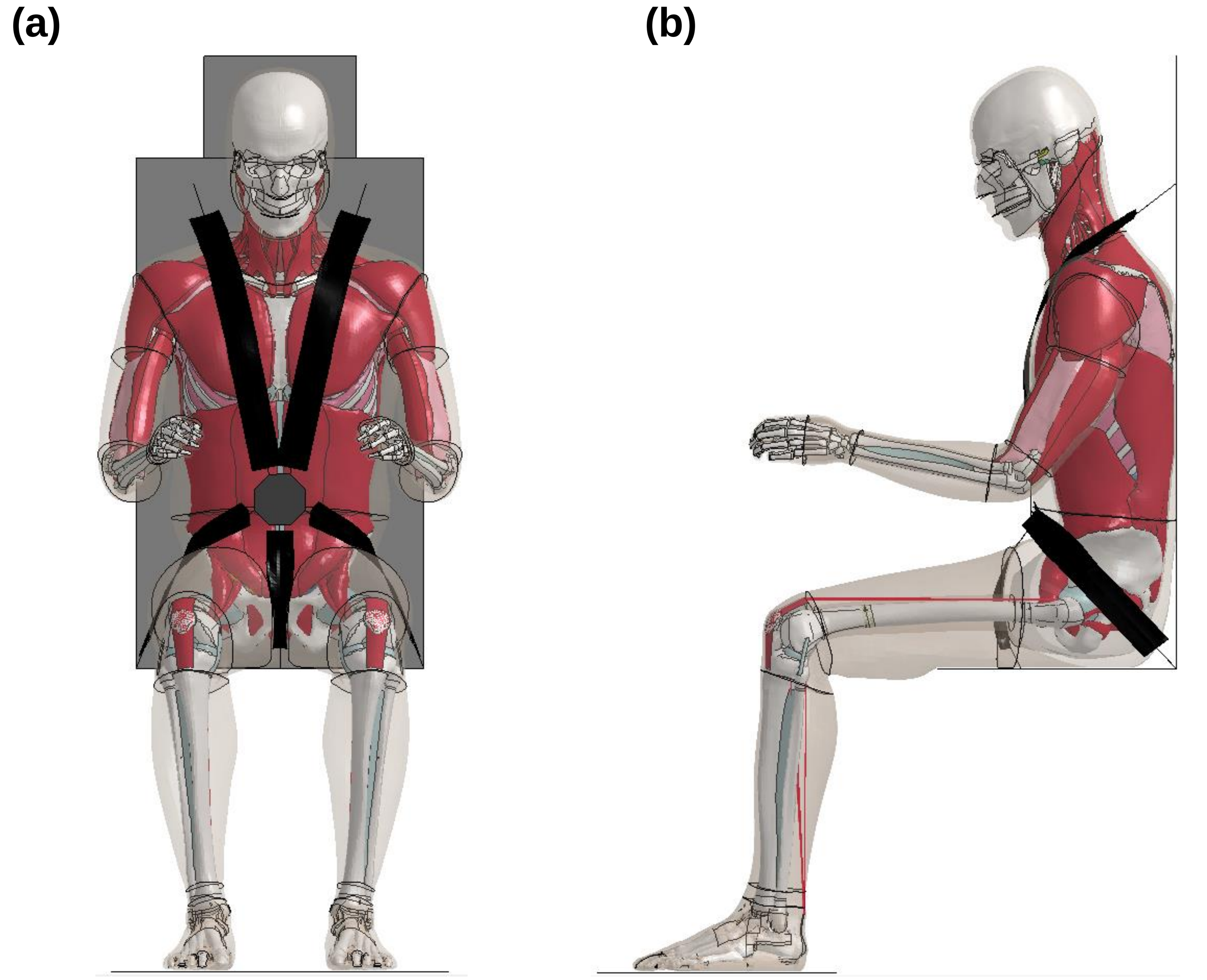

**Figure 1: Test Rig Design with belted GHBMC (a) Front View (b) and Side View**

## Methods, Cont.

Corridors were created using data filtered at 1050Hz. The corridors were generated using a standard approach determined by the Biofidelity Response Corridor (BRC) working group. The approach aligns non-normalized signals using the Nusholtz method, transforms signals to principal component space using eigenvectors and eigenvalues, and generates ±1 and ±2 standard deviation equivalent corridors [6]. The frequency value used to filter the data used in these corridors was determined from preliminary work performed by the Signal Analysis Working Group (SAWG). For this PMHS test data, 1050 Hz is the average frequency at which the change in frequency with respect to peak magnitude begins to level off for each data trace.

## Results

The FE S1 acceleration showed good correlation with the preliminary biofidelity corridors. An analysis was performed using an objective rating method (CORrelation and Analysis, CORA) using the preliminary biofidelity corridor curves and S1 outputs from four FE UBB simulations. The ±1 and ±2 SD curves were used for the inner and outer corridor limits, respectively. The average corridor curve was used as the cross-correlation reference. The CORA analysis showed good correlation (70% or higher) with an average of 80.8% for the four test with data filtered at 1050Hz (Table 1). Figures 2 and 3 show the CORA analysis of FE simulations that had a CORA score of 83.7% and 85.8%, respectively. For these figures, the cross-correlation reference curve is represented in yellow, the inner corridor limit curves are represented in green, the outer corridor limit curves are represented in blue, and the FE simulation data curve is represented in red.

**TABLE 1**
**CORA SCORES FOR TEST RESULTS**

| Test Number | CORA Score (1050 Hz) |
|---|---|
| 1 | 83.7 |
| 2 | 76.8 |
| 3 | 76.8 |
| 4 | 85.8 |

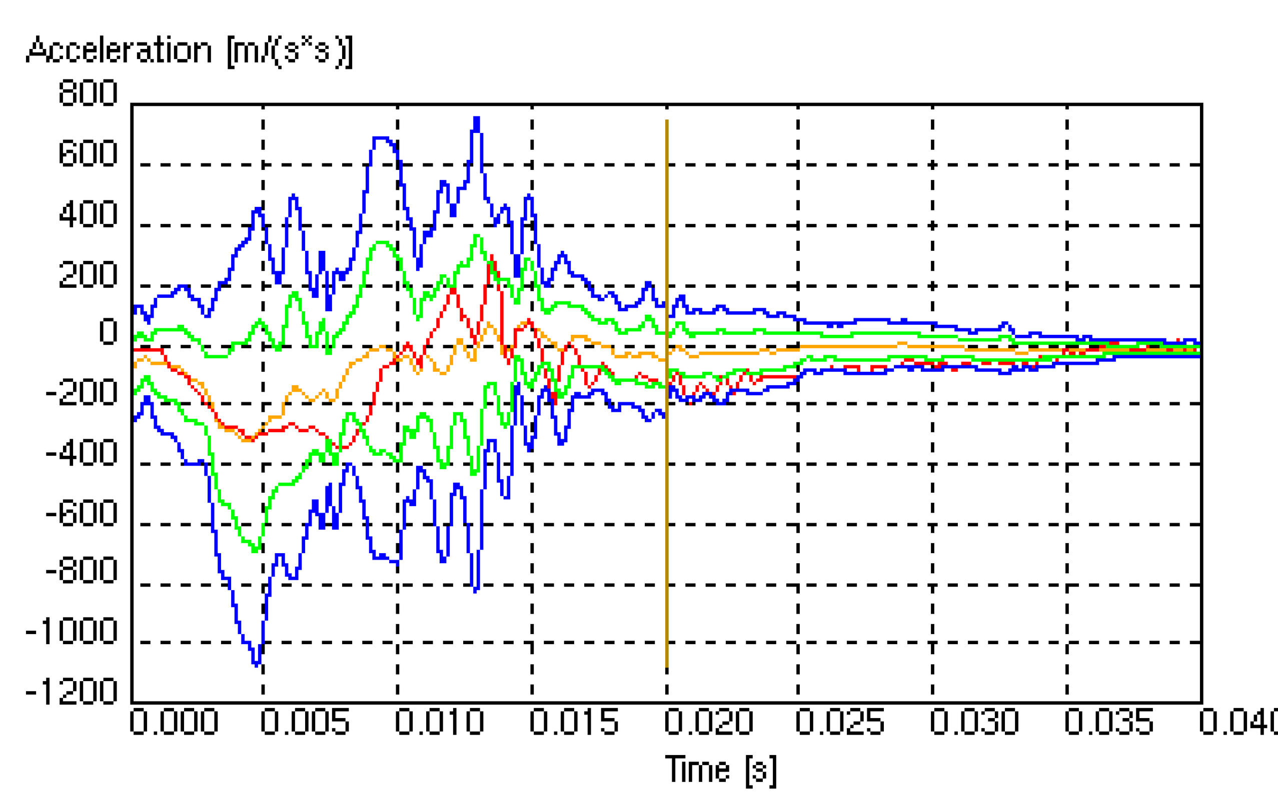


**Figure 2: CORA Rating for Curve Comparison Between Biofidelity Corridors Generated with PMHS Test Data and an FE Simulation with GHBMC filtered at 1050 Hz with CORA Score of 83.7%.**

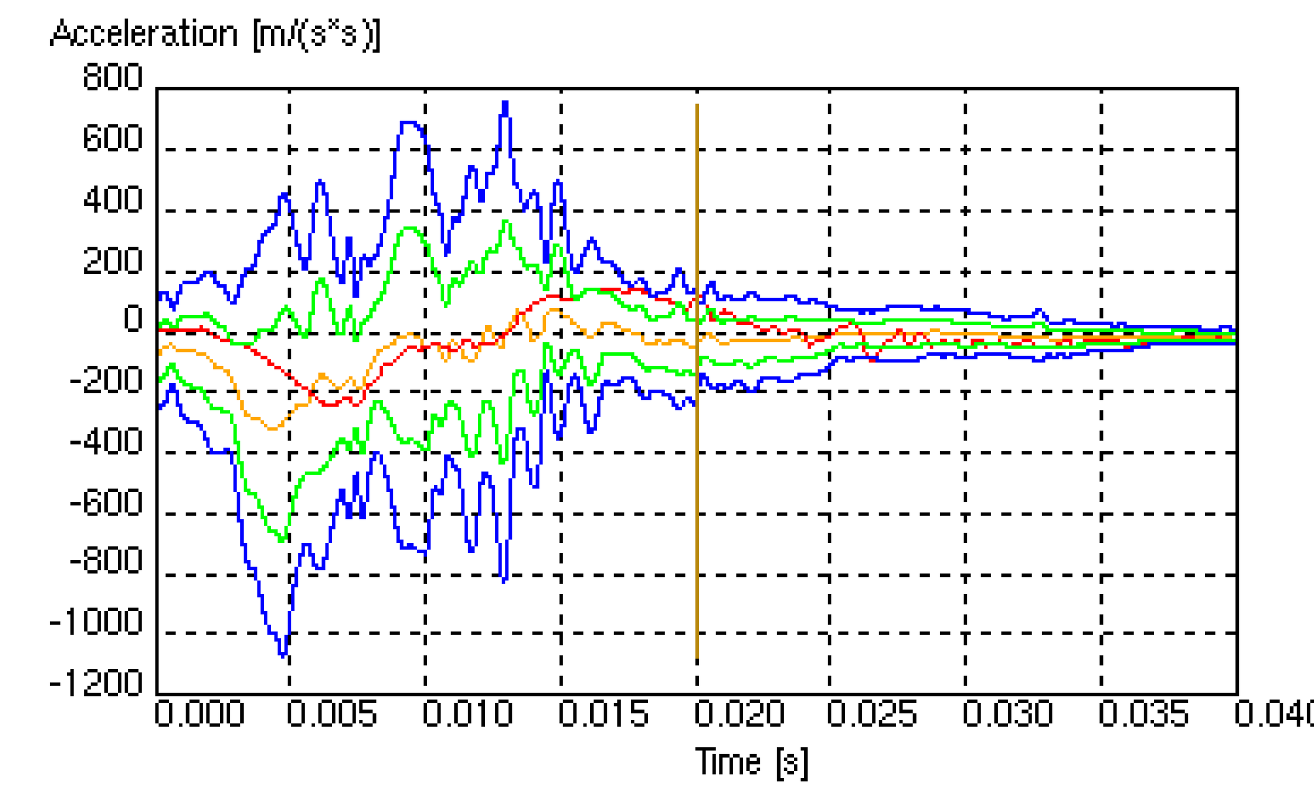


**Figure 3: CORA Rating for Curve Comparison Between Biofidelity Corridors Generated with PMHS Test Data and an FE Simulation with GHBMC filtered at 1050 Hz with CORA Score of 85.8%.**

## Conclusions

This study focuses on the pelvic injury response of the 50th percentile male Global Human Body Models Consortium (GHBMC) FE human body model. This study is a preliminary validation of the GHBMC for pelvic injury resulting from UBB-type loading using the metric of S1 acceleration produced in PHMS experimental testing and FE simulations. This study was performed using FE simulations in LS-DYNA software and input data from vertically accelerative load testing performed on PMHS by the Biomechanics Product Team (BIO PT) for the U.S. Army WIAMan project. The initial results for this FE study have shown good correlation for results comparison between PHMS experimental testing and FE human body model acceleration outputs of the S1 region of the pelvis. Further FE UBB impact simulations and additional human body model metrics will be compared to the experimental biofidelity corridors. To date, the comparison of full body UBB experimental testing to drive and compare with full body FE simulation metrics for UBB is unique. This data was acquired with the explicit purpose of developing an enhanced capability to predict the risk of injury for mounted soldiers who are subjected to the effects of UBB loading with the goal of enhanced vehicle and Soldier survivability.

## Acknowledgement


The authors would like to acknowledge the US Army Research Lab, the WIAMan project, the John Hopkins University Applied Physics Laboratory, and the Science, Mathematics And Research for Transformation (SMART) Scholarship for Service Program for their support and collaboration.


## References


[1] Yoganandan, et. al. Clinical Biomechanics. 28 (2013) 302-609.
[2] Merkle, A. C., et. al. John Hopkins APL Technical Digest, Vol. 31. No. 4. 2013. 286-295.
[3] Bailey, A. M., et. al. IRCOBI Conference 2013. IRC-13-25. 158-170.
[4] Vavalle, N. A., et. al. Ann Biomed Eng, vol. 41, pp. 497-512, Mar 2013.
[5] Chancey, Carol, et. al. Program for Warrior Injury Assessment Manikin (WIAMan). Presented at USAMRC Industry Day, March 15-18, 2011.
[6] Nusholtz, Guy S., et al. Statistical Considerations for Evaluating Biofidelity, Repeatability, and Reproducibility of ATDs. No. 2013-01-1249. SAE Technical Paper, 2013.



Virginia Tech
Wake Forest University
School of Biomedical Engineering and Sciences

Virginia Tech – Wake Forest University
Center for Injury Biomechanics