Investigating the Relationship Between Vehicle Based and Biomechanics Injury Metrics in Car-to-End Terminal Crashes using a Human Finite Element Model

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Introduction

- The safety performance of guardrail end terminals in the United States is determined using crash tests outlined in the Manual for Assessing Safety Hardware (MASH) [1]
- MASH also outlines criteria for determining occupant injury risks based on the vehicle-based flail space model
- The flail space model [2] was developed in the 1980s and uses kinematic data such as velocity and acceleration to determine injury risk. It does not consider any safety equipment like seatbelts or airbags

Objectives

- To understand the relationship between vehicle based and biomechanics injury measures by using an FE model.
- By establishing a validated FE model, testing can be improved by reducing the need for costly physical testing

Methodology

Simulation

- The FE simulation was designed in LS-Dyna with a vehicle (Toyota Yaris), end terminal model validated in [3] (ET-Plus), and a human body model
- A seatbelt with pretensioner and load limiter and an airbag model were incorporated
- GHBMC-OS Male 50th percentile was positioned and settled.

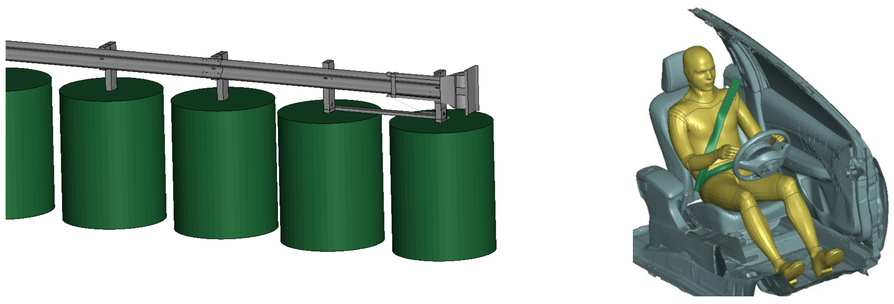

Figure 1. a) ET-Plus End Terminal Model **b)** Positioned and settled GHBMC in the car seat

- 20 Simulations were performed (5 initial velocities, 2 offsets, and 2 impact angles) to match MASH criteria

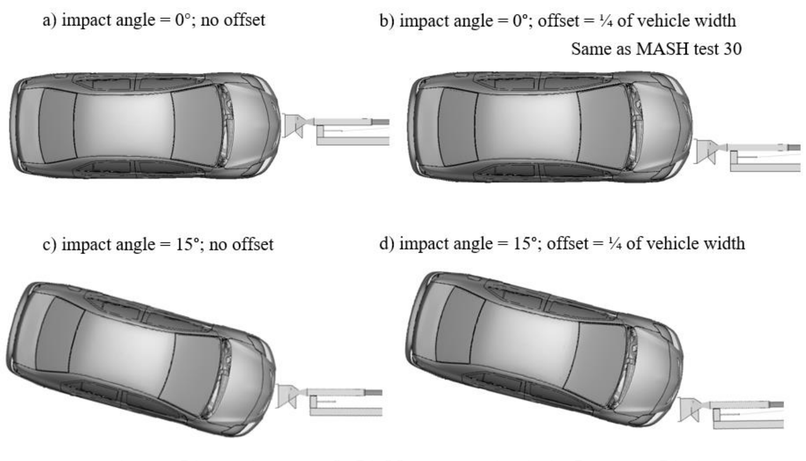

Figure 2. Visualization of different initial conditions

Injury Measures

- Vehicle based measures recorded were Occupant Impact Velocity (OIV), Occupant Ridedown Acceleration (ORA), and Acceleration Severity Index (ASI)
- Injury measures recorded from the GHBMC included head (HIC15), brain (BrIC), neck (Nij, Nt, Nc), chest (CD), thigh (F_F), and leg (F_{UT},F_{LT},RTI)
- An overall injury probability was created as a combination of head, neck, and thigh risk

Acknowledgements

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References

[1]AASHTO. 2009. Manual for Assessing Safety Hardware
[2] Michie, JD. 1981. Transportation Research Record; 796: 1-9
[3]Meng, Y. 2019. SAE International journal of Commercial Vehicles; 12(4): 271-280

Results

- The end terminal models performed as expected, successfully redirecting the vehicles without any intrusion

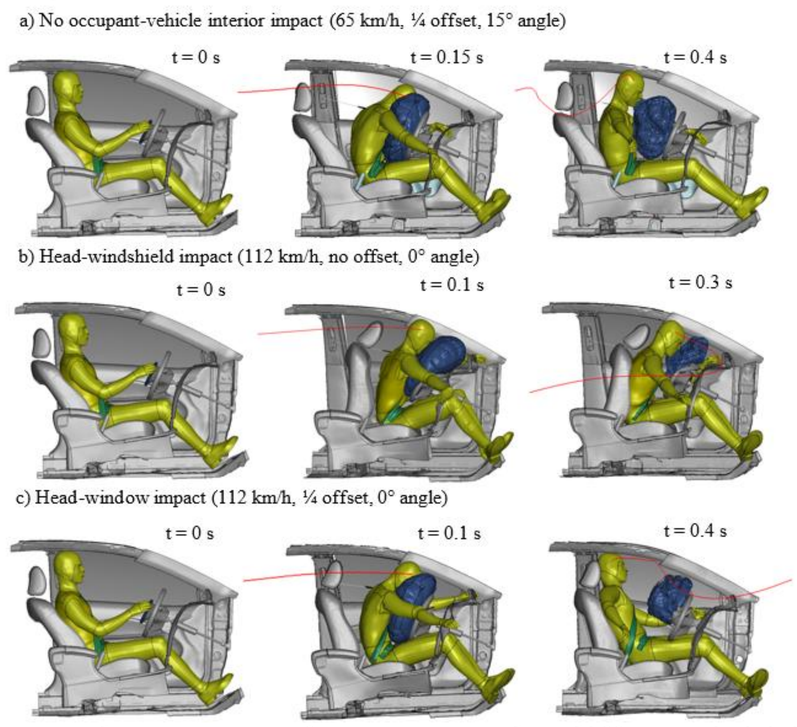

Figure 3. Crash response of GHBMC under different initial conditions. Note the high-speed impacts with offset cause a secondary impact due to rotation

Table 1. Correlation of vehicle-based with full body injury risks

Vehicle-based severity metrics	a	b	p-value of a	Correlation
OIVx (m/s)	0.1785	21.1259	0.0270	Yes
ORAx	0.0265	70.4749	0.0252	Yes
	0.0136	131.3400	0.5325	No
ASI	0.9181	3.2082	0.0082	Yes
	2.1749	2.4338	0.0165	Yes

Good Correlation

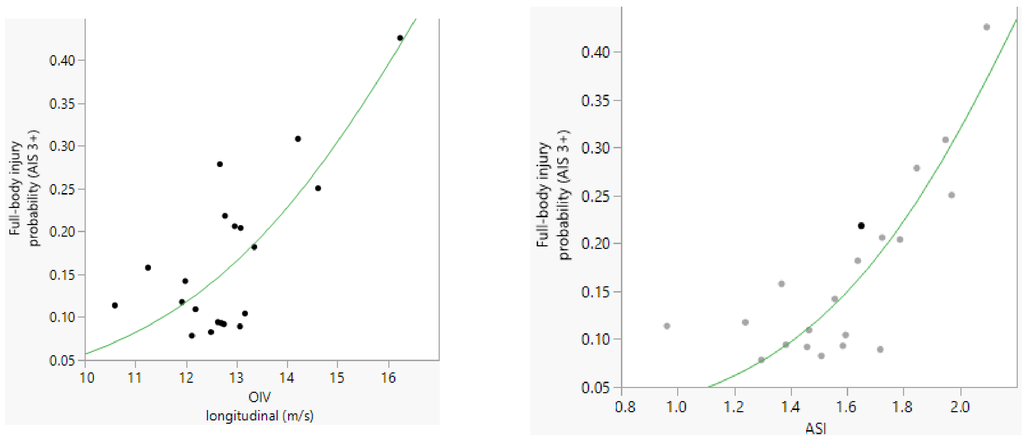

Figure 4. Overall injury risk compared with **a)** OIV and **b)** ASI

Poor Correlation

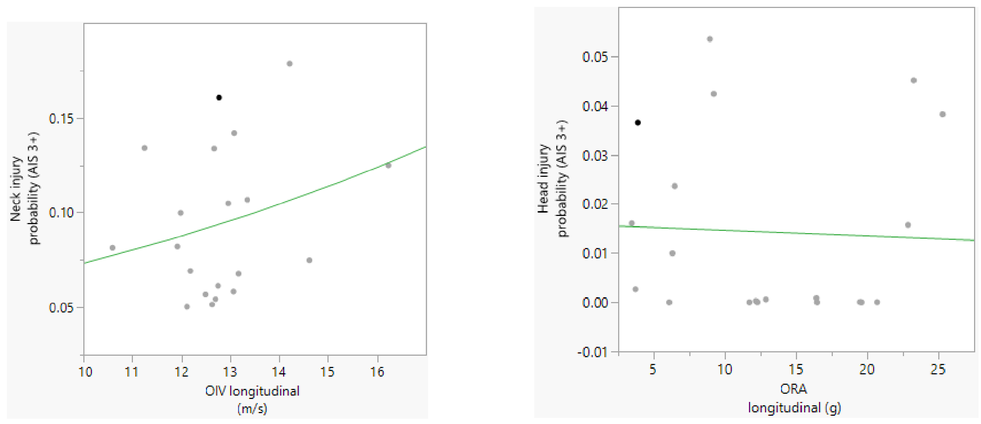

Figure 5. **a)** Neck injury risk vs OIV **b)** Head injury and ORA

Conclusions

- Overall, vehicle-based measures correlated well with total body injury risk
- OIVx, ASI, and THIV correlated well with chest thigh, upper tibia, and lower tibia injuries but not for the remaining measures, and those for the head and neck
- Head and neck injuries were not predicted by vehicle-based measures, so certification efforts could include similar computations