Using Event Data Recorders to Compare the Frontal Crash Injury Prediction Capabilities of Six Vehicle-Based Crash Severity Metrics

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Introduction

Roadside safety hardware crash tests are prescribed in the Manual for Assessing Safety Hardware (MASH) [1]. These tests use the flail space model (FSM), to assess occupant injury risk. The FSM has not been reevaluated since 1981, despite advances in passive and roadside safety. This study used real-world frontal crashes to examine the ability of the FSM and alternative vehicle-based metrics to predict occupant injury.

Methods

1. Front-striking passenger vehicles with available event data recorder (EDR) data were extracted from the Crash Investigation Sampling System (CISS).

Analysis Dataset
Sampled cases: 542 (62 MAIS2+F)
Weighted cases: 436,728 (25,046 MAIS2+F)
Case years: 2017 through 2019

2. The EDR delta-v crash pulses were used to compute the following six crash severity metrics (Figure 1):

- Maximum delta-v (MDV)
- Occupant impact velocity (OIV)
- Ridedown acceleration (RA)
- Occupant load criterion (OLC)
- Acceleration severity index (ASI)
- Vehicle pulse index (VPI)

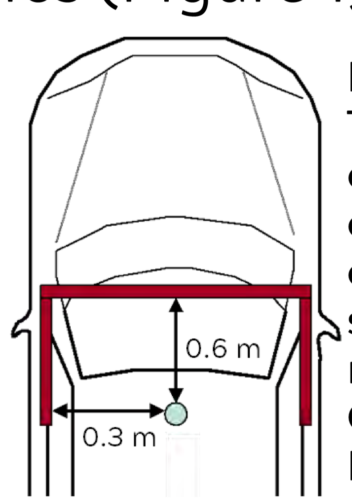

Figure 1. The FSM consists of two crash severity metrics: OIV and RA.

These metrics make varying assumptions about the occupant's belt status, and attempt to capture crash severity by transforming the crash pulse data.

3. Logistic regression models were constructed to predict MAIS2+F injury probability using seven covariates: the metric, belt status, age, sex, obesity, principal direction of force (PDOF), and vehicle type. The final models included only the significant covariates.

4. Model performance was evaluated using the F2 scores from the training data.

$$F2 = \frac{5 * \text{Precision} * \text{Recall}}{(4 * \text{Precision}) + \text{Recall}}$$

Results

Besides RA, every crash severity metric was statistically significant ($p<0.05$) in the final models. Belt status was significant in every metric's final model (Table 1). Additionally, age was significant in the final MDV and OIV models. Being belted and being younger than 65 years old had protective effects. Injury risk curves were constructed for each metric (Figure 2).

$$\text{logit} = \beta_0 + \beta_1(\text{metric}) + \beta_2\text{BeltStatus} + \beta_3\text{Age}$$

Table 1. Coefficients for final model covariates.

Model	Intercept	Metric	Belt Status	Age
MDV	< 0.001*	0.003*	0.004*	0.040*
OIV	< 0.001*	< 0.001*	0.010*	0.039*
RA	< 0.001*	0.054	0.005*	–
OLC	< 0.001*	< 0.001*	0.017*	–
ASI	< 0.001*	< 0.001*	0.017*	–
VPI	< 0.001*	< 0.001*	0.012*	–

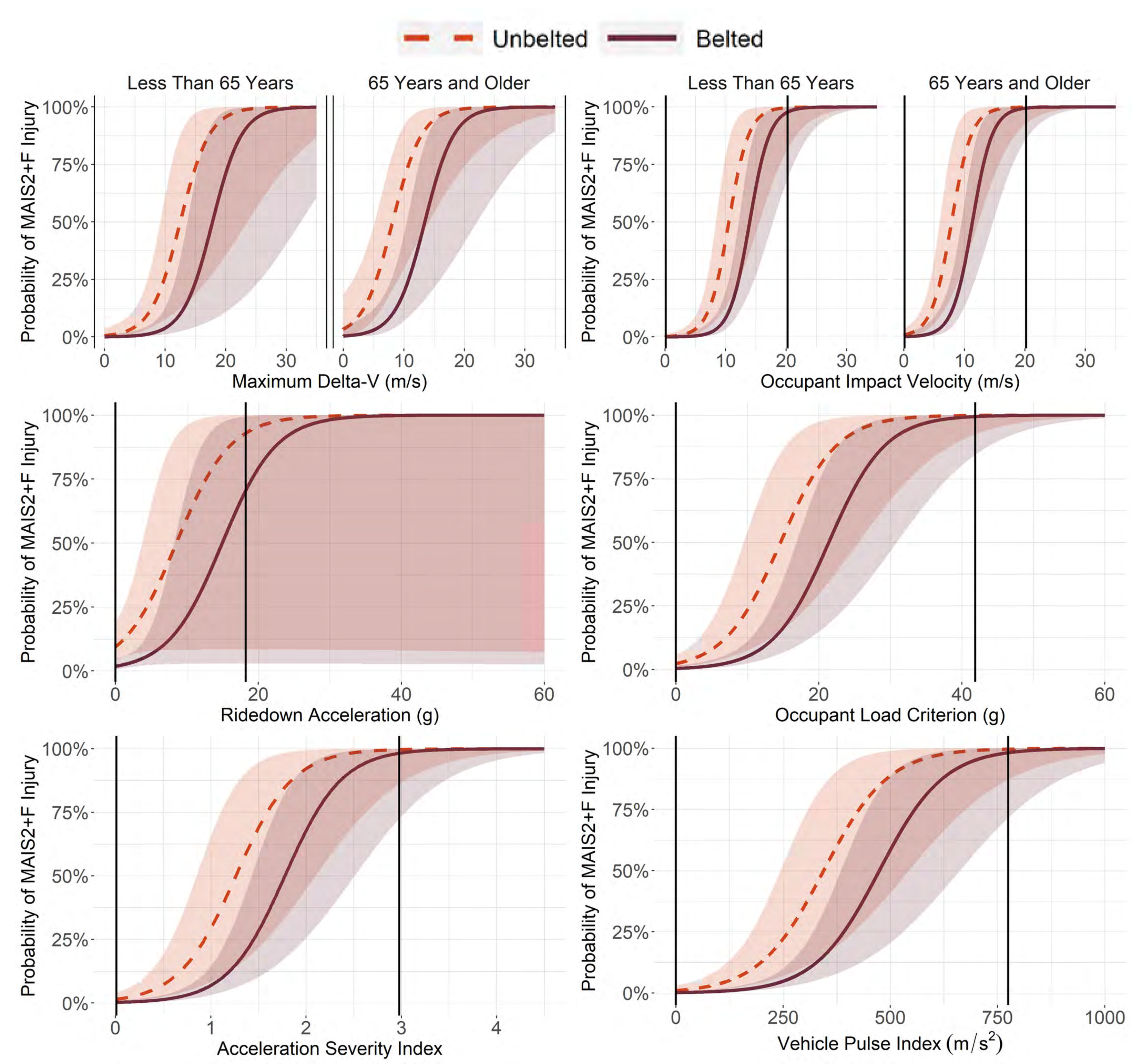

Figure 2. MAIS2+F injury risk curves. The shaded regions represent the 95% confidence intervals and the vertical lines represent the minimum and maximum metric values in the training data.

Model Comparison

MDV performed best on the training data while RA performed the worst (Table 2). Of the statistically significant metrics, VPI performed the worst.

Table 2. Training data F2 scores.

Model	Training Data F2 Score
MDV	0.70
OIV	0.67
RA	0.41
OLC	0.64
ASI	0.64
VPI	0.62

Using the OIV and ASI models, the injury risk associated with current preferred and maximum testing thresholds were computed for a best- and worst-case scenario occupant (Table 3). This allows for comparison of allowable risk across various metrics and occupants.

Table 3. Occupant injury risk at current thresholds.

Case	Injury Risk at Thresholds				
	OIV (m/s)		ASI (--)		
	9.1	12.2	1.0	1.4	1.9
Best	5.0%	25.6%	6.9%	22.0%	60.0%
Worst	67.6%	93.2%	29.3%	61.2%	89.4%

Conclusions

- Metrics provided a reasonable means of predicting real-world occupant injury risk in frontal crashes.
- MDV performed best while RA performed the worst.
- Belt use and age had significant influence on occupant injury risk.
- Next steps will include validating the models using an independent test dataset.

Acknowledgements

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References

[1] American Association of State Highway and Transportation Officials. Manual for Assessing Safety Hardware Second Edition. 2016.

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