Investigation of Pressure-based Abdomen Injury Risk Function with Postmortem Human Subject and Porcine Data for THOR-AV 50M Dummy

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I. INTRODUCTION

Abdomen injuries occur in frontal motor vehicle crashes (MVC) with an Abbreviated Injury Scale (AIS) 2+ injury risk of 13.6% and 3.4% for unbelted and belted occupants respectively [1]. It was demonstrated that the product of force and compression is a good predictor of abdomen injury [2]. The **A**nthropomorphic **T**est **D**evice (ATD) design incorporated displacement sensors for abdomen injury predictions, such as **T**est device for **H**uman **O**ccupant **R**estraint (THOR) for frontal impact and SID-IIs and WorldSID for side impact dummies. Different displacement sensors, such as linear potentiometer and Infra-red Telescoping Rod for Assessment of Chest Compression (IR-TRACC) [3] were used in ATD designs; however, durability of these sensors and subsequent data loss have been major concerns in crash tests. To address the durability of the displacement sensors, pressure sensors were introduced into the dummy abdomen design and demonstrated for its potential for injury risk prediction [4]. Abdomen injury risk functions (IRFs) were developed for different dummies, such as the Large Omni-directional Child Dummy (LODC) [5], THOR with **Ab**domen **I**njury and **Su**bmarining **P**rediction (ABISUP) abdomen [6]. However, the abdomen injury risk functions for the dummies were based on porcine data from the study [7], although Postmortem Human Subject (PMHS) tests data were available. In this study, abdomen IRFs for THOR-AV 50M dummy were developed based on PMHS and porcine data, separately, for comparison.

II. METHODS

PMHS and porcine test data were used to fit IRFs separately with survival functions. The selection of PMHS data, preparation of dummy data and details for fitting survival function were outlined in the sections below.

PMHS Data Selection

Male PMHS abdomen tests conducted by [8] through [13] were chosen for PMHS-based IRFs development. Reference [7] data were used for porcine-based IRFs development. Out of the PMHS tests outlined above, there were a total of 31 male PMHS specimens tested. These tests consist of sled tests, belt pull tests and rigid bar impact tests. The porcine data scaled for 50th percentile male in [6], compromising a total of 43 tests, was used in this analysis.

ATD Data Preparation

THOR-AV matched-pair test data were used in the analysis whenever available. In cases where test data were not available, finite element (FE) analysis with Humanetics THOR-AV 50M FE model (v0.7) was employed to provide rapid data. The THOR-AV FE model shares many components with THOR-50M FE model (v1.81) and underwent further validation in several test conditions to ensure a strong correlation with physical dummy abdomen responses. A total of 43 matched-pair ATD data points were used in PMHS based IRF analysis, and twelve of them were from physical tests of THOR-AV. A total of 43 matched-pair tests were used in porcine base IRF analysis and all data were generated from ATD FE simulations.

Survival Function Fit Process

The abdomen injury risk function development in this investigation followed the process specified in ISO TS18506. Lognormal, loglogistic and Weibull survival functions were used to find the best fit. The most influential points were evaluated and removed from the final fit functions. The fit with the lowest Akaike Information Criterion (AIC) scores were selected as the final injury risk function.

III. INITIAL FINDINGS

Based on the AIC criterion, the Weibull distribution offered the best fit for all cases with the lowest AIC values. The results are summarized in Table 1, including the shape and scale of the Weibull survival function, and the

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injury thresholds for 25%, 50% and 75% derived from the PMHS and porcine data outlined above separately. The 50% injury risk for AIS2+ is 273 kPa derived from PMHS data, and 95 kPa from porcine data. The 50% injury risk for AIS3+ is 297 kPa derived from PMHS data, and 103 kPa from porcine data.

TABLE I
SUMMARY OF THE AIS2+ AND AIS3+ INJURY RISK FUNCTIONS AND INJURY RISK VALUES DERIVED FROM PMHS AND PORCINE DATA SEPARATELY WITH WEIBULL DISTRIBUTION FOR THOR-AV 50M DUMMY

Data	AIS	Shape	Scale	AIC	Injury Risk Values (kPa)		
					25%	50%	75%
PMHS	AIS2+	3.28639	304.92055	279	209	273	337
	AIS3+	3.91027	326.28005	218	237	297	355
Porcine	AIS2+	4.10525	103.62730	268	77	95	112
	AIS3+	4.61351	111.07676	206	85	103	119

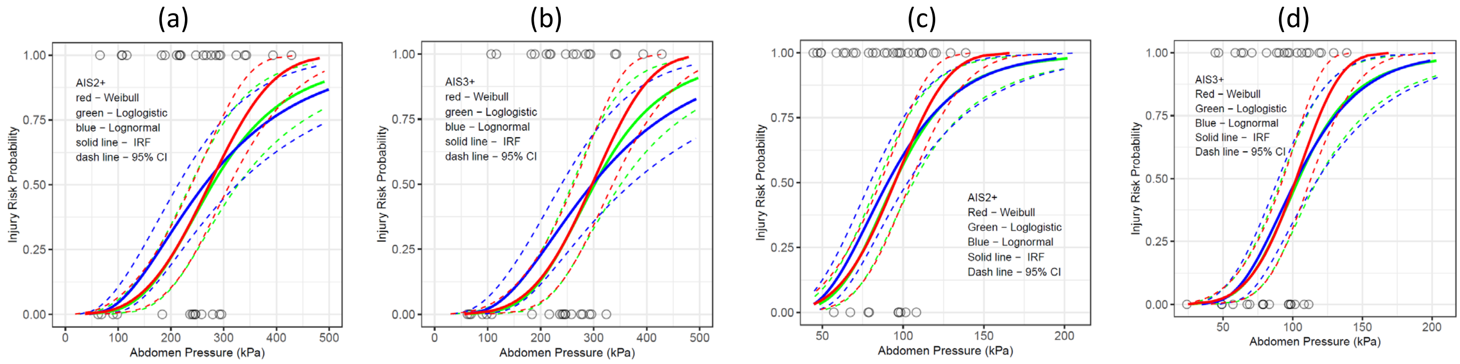

Fig. 1. THOR-AV abdomen injury risk curves (a) AIS2+, PMHS data, (b) AIS3+ PMHS data, (c) AIS2+, porcine data, (d) AIS3+, porcine data.

IV. DISCUSSION

A significant difference in injury risk threshold was observed between using PMHS data and porcine data in injury risk function development. It was argued that the porcine abdomen anatomy is like a human for justifying its usage for human abdomen injury risk function development; however, the scaling was based on theoretical assumptions that could not be validated. As we have noticed in recent years, scaling biomechanical responses for the 5th percentile from the 50th percentile male is not accurate though these two subjects have much more similarity in anatomy. It is highly possible that scaling porcine abdomen responses for human abdomen responses could generate large errors. Although porcine data provided a better confidence interval in the analysis, PMHS data for human abdomen injury risk function development seems more appropriate for vehicle restraint system development based on the matched-pair THOR-AV 50M test results. Furthermore, the porcine tests were conducted on a tabletop setup, which differs from the loading conditions for any vehicle occupants. The PMHS tests selected in this analysis are mostly belt tests that are much closer to the vehicle crash test environments and therefore would provide better injury risk prediction.

V. REFERENCES

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