

## Critical review of proposed injury risk curves and injury criteria for THOR chest deflection

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### I. INTRODUCTION

NHTSA and EuroNCAP plan to introduce the THOR dummy in future frontal impact scenarios. This new frontal impact dummy has a superior biofidelity to the currently used H3 dummy and also has more measurement capabilities to possibly assess injury risks to occupants in frontal impacts in more detail. Injury risk functions and assessment criteria for the THOR dummy were first proposed by NHTSA in the Request for Comments for an updated consumer rating in 2015 [1]. Since then, several frontal impact tests have been conducted and injury risks for driver and passenger have been assessed based on the proposed injury risk functions and criteria.

Using the injury risk functions described in [1], THOR measurement-based predictions of sustaining an AIS3+ thoracic injury in frontal impact scenarios used by consumer rating programs tend to be greater than those predicted by the H3 dummy in matched tests. The THOR-derived risks also appear to be greater than risks reported for similar collision severities in real-world accident data. The present study investigates some potential factors that may contribute to differences between the THOR-derived risk, H3-derived risk and risk observed from the field data. Furthermore, this study aims to support future collaborations to develop new injury risk curves (IRC) and dummy-based injury criteria (IC) capable of predicting real-world risk.

### II. METHODS

Published test results of Full Frontal impacts were analysed for predicted thoracic injury risks for THOR and H3 50% dummies in identical or very similar loading conditions, e.g. frontal full overlap impacts with 56 kph closed velocity.

The NASS-CDS database was queried for front-row occupants in passenger-type vehicles who experienced a frontal impact with a principal direction of force of 300° to 60°. Additional database criteria were also considered: front-seat occupants; vehicles 10 years old and newer; belted occupants; no rollover; and no ejection. AIS3+ chest injury risk was calculated for a 40yo occupant and plotted against the reported vehicle change in velocity (delta V [kph]).

In addition, two factors were investigated that may contribute to the difference in risk prediction between the Hybrid III and the THOR.

1. Thoracic deflection responses of THOR and H3 50% in pendulum and sled tests were compared, in the context of the design specifications for chest stiffness of both dummies.
2. Outcome measures used to define the injury prediction targets for the THOR and H3 IRC development were reviewed to evaluate comparability.

### III. INITIAL FINDINGS

Using the maximum resultant IRC described in [1], THOR dummy chest measurements from the 56 km/h frontal barrier tests available from NHTSA indicate risks of 25–73% of sustaining AIS3+ injuries for a 40yo when seated in driver position. Results of H3 50% dummy in the same vehicle published by NHTSA in its NCAP program show injury risks below 10%.

This preliminary assessment of injury risk with the THOR dummy would indicate that 40yo drivers in frontal impact have a much higher risk of getting seriously injured than indicated by currently used consumer evaluation programs. By contrast, the accident data show an injury risk for 30–49yo occupants of approx. 5% for the delta V in question. This is similar to the H3-based predictions for that age group.

The difference in injury risk predictions may be affected by the design and biofidelity requirements of the dummies, and by the injury risk functions which describe the relationship between a measured injury indicator

(e.g. max rib deflection) and the risk of sustaining an injury (e.g. 7+ rib fractures).

First, the differences in the dummy hardware were examined based on rib deflection under identical loading. It was found that the THOR thorax exhibits approx. 40%–60% more chest deflection than the H3 50% thorax in the investigated loading conditions.

These results can be explained by the differences in design specifications used for both dummies. H3 rib cage stiffness is designed based on a shifted force-deflection corridor from Kroell [2], whereas THOR reflects the force-deflection corridor without any muscle tone adaptation [3]. Approximately 25% of stiffness differences could be accounted for by the different design criteria. Other fundamental differences in dummy design (shoulder, geometry of rib cage, lumbar spine) contribute to the higher chest deflection measurement in the THOR dummy. To illustrate the potential effect of chest stiffness on the injury risk prediction, Fig. 1(a) demonstrates how the IRC would change if shifted to account for differences in stiffness between the H3 and THOR.

Secondly, the assumptions for IRC development were reviewed. The THOR IRC used in [1] defined AIS3+ chest injury based on the number of fractures observed in PMHS, classified based on the 2008 update of the 2005 version of the AIS [6-7]. In that AIS version, AIS3+ is classified as three or more fractured ribs (NFR) [4]. In the current H3 IRC, the AIS3+ injury outcome was defined based on 7+ fractured ribs observed in PMHS, chosen based on the AIS version 1998 [8], with an additional shift to account for an estimated difference between fractures observed in PMHS compared to living persons [5][9]. To evaluate the influence of chosen injury indicator (NFR) on the injury risk prediction, the THOR IRC was reconstructed using 7+NFR (Fig. 1(b)).

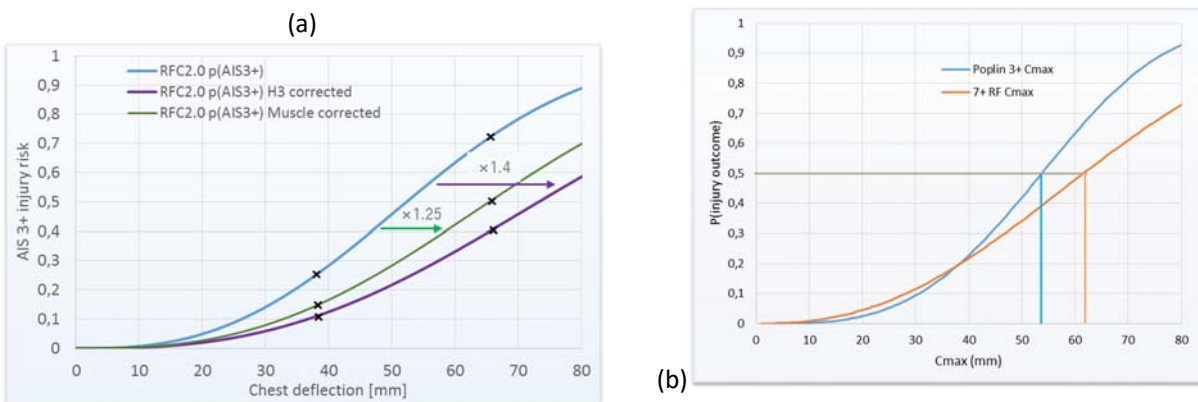


Fig. 1. Modified THOR AIS3+ IRC for chest injury: (a) based on chest stiffness, (b) based on NFR.

#### IV. DISCUSSION

The above factors are two potential differences between the H3 and the THOR that may contribute to the observed differences in predicted injury risk. When these and other differences are observed, they should be evaluated critically to ensure that they are reflective of restraint interactions and risks that occur in the field. This should be done in collaboration with existing groups of experts from regulation, scientific authorities and industry.

For a first introduction of the THOR dummy a pragmatic approach can be applied: use the scaled injury risk curves as shown in Fig. 1(a) to derive reasonable limits for chest deflection for the intermediate use of THOR in consumer rating programs.

#### V. REFERENCES

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