Child Occupant Interactions with an Under-thigh Airbag in Reclined and Upright Seating Postures using Computational Models

Ryan Gellner, Ke Dong, Suzanne Johansson, Lisa Furton

I. INTRODUCTION

Automated vehicles are likely to bring about novel seating positions, which may require advanced restraint countermeasures to better protect occupants. Under-thigh airbags (UTA) are in production today to help limit lower torso forward excursion, and have shown efficacy in restraining at-risk occupants, especially related to prevention of submarining in reclined postures [1]. Many studies have explored the effects of frontal and side airbags on child occupants [2-4] and some child seat manufacturers prohibit use of their products with inflatable seat belt airbags [5], but no studies to date have explored the risks or benefits of UTA use with child occupants. The purpose of this study was to quantify the effects of UTA deployment and reclined seat backs on injury assessment values (IAVs) of child ATDs seated in child restraints in both static and dynamic environments using computational models.

II. METHODS

Three child seat models were fitted with the appropriate child occupant ATD model and affixed to the vehicle environment as defined by the manufacturer in the child seat manual. All child restraint models were based on Britax Röemer (Leipheim, Germany) products. The Q1.5 ATD was placed in the rear-facing Baby Safe child seat, which was restrained to the vehicle using the vehicle seat belts with an infant carrier only or the Lower Anchors and Tethers for Children (LATCH) with a base (including load leg). The infant carrier was propped up on a foam cylinder model to achieve proper recline. The Hybrid-III 3-year-old ATD (H3-3Y) was restrained in a forward-facing DuoPlus using vehicle seat belts or LATCH anchors and top tether. The Hybrid-III 6-year-old ATD (H3-6Y) was restrained in the Kidfix XP high-back booster with LATCH anchors and vehicle belt (across the occupant) or only the vehicle belt without LATCH anchors being engaged (Fig. 1).

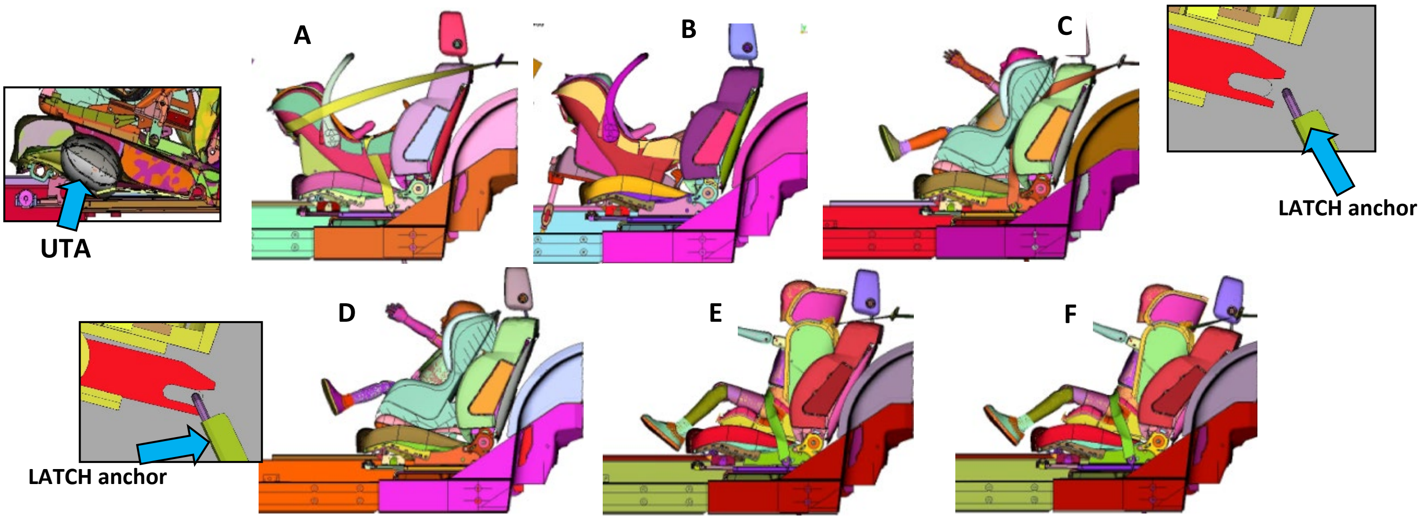

Fig. 1. Rear-facing Q1.5 attached with (A) belts and (B) LATCH anchors (with base). Forward-facing H3-3Y attached with (C) belts or (D) LATCH anchors and top tether. High-back booster with H3-6Y at (E) 28.9˚ recline and (F) 36˚ recline. *Top left inset:* section view of deployed UTA. *Top right inset*: LATCH disengaged. *Bottom left inset:* LATCH engaged.

Simulations were run with a vehicle sled model, consisting of components that were validated independently at a component level, but did not represent a specific production vehicle environment when combined. Simulations were run with either no pulse (static) or the AAMA 48 kph frontal crash pulse (dynamic). Belts had a non-load limiting retractor and no pretensioning, so the effects of the UTA could be isolated. The UTA deployed at 20 ms into the dynamic condition simulations, which does not necessarily reflect true vehicle sensing deployment timing. All seatback angles were 21.8° from vertical, as measured at the vehicle headrest, except the H3-6Y, which was run at either 28.9° (MID) or 36° (MAX), representing reclined seating conditions. All

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simulation runs utilized LS-Dyna as the solver, and all simulation outputs were filtered as described in SAE J211 [6].

III. INITIAL FINDINGS

Static deployment conditions for all occupants showed low risk of injury relative to values seen in dynamic conditions. In dynamic conditions, HIC15 was found to decrease for all occupants with the addition of an UTA, while N_{ij} (particularly neck tension-extension) increased in the Q1.5 and H3-6Y but decreased in the H3-3Y. Chest acceleration and compression values were comparable with and without UTA (Fig. 2).

Increasing the recline angle from 28.9° to 36° in simulations with the H3-6Y showed an increase in HIC15 for all conditions. Small changes or mixed results were found for other IAVs. Note that reclining the vehicle seat by this amount when a child seat is installed is currently considered misuse by nearly all child seat manufacturers and vehicle manufacturers, including General Motors.

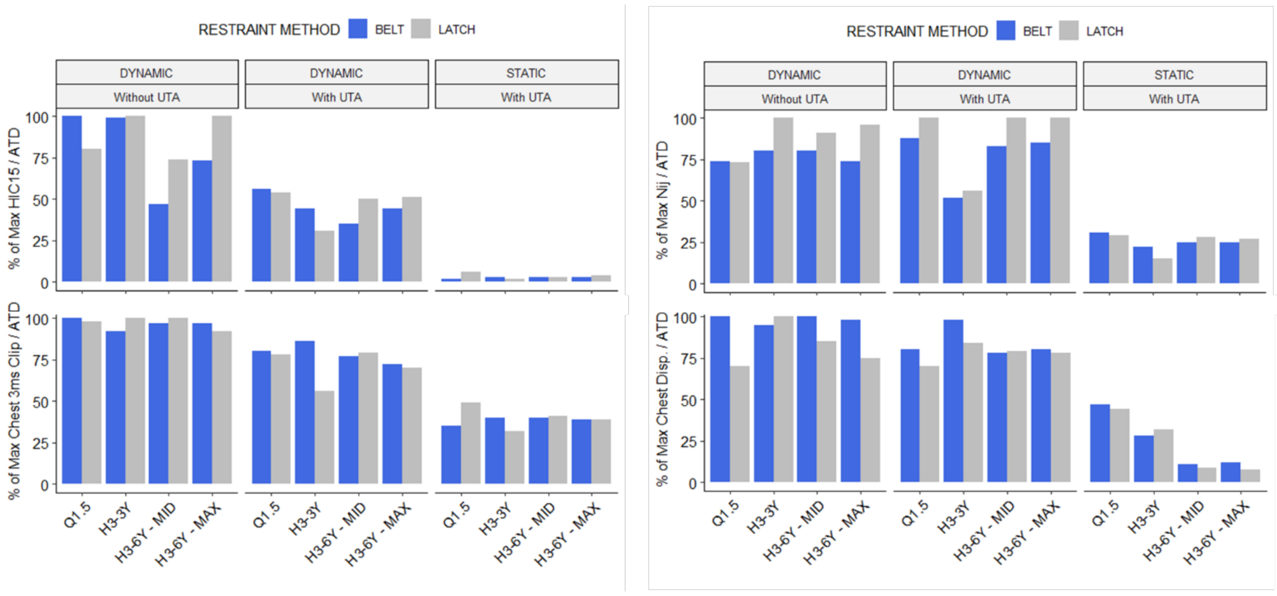

Fig. 2. Comparison across conditions of injury measures for the head, neck, and chest. Values are percentages of the maximum value of the IAV in all conditions for that ATD.

IV. DISCUSSION

These data provide valuable insights for vehicle manufacturers as they develop vehicles with UTAs and reclined seating positions. Child seat manufacturers and child passenger safety organizations may also consider these findings to create recommendations for end-users about these new restraints. The low risk of inflation induced injury from UTAs in both static and dynamic conditions for child occupants of a variety of sizes found in this preliminary study is encouraging. However, the potential increase in neck injury must be weighed against the potential benefits to head and other body regions for child occupants. Increasing recline angle appears to create additional risk to older child occupants' heads. The seat belts were not tuned for a child restraint in this model and changing belt energy absorption characteristics may affect the results.

Finally, the models used in this study are high-fidelity and are intended for use in frontal crash scenarios; however, assumptions still exist in the models. The child restraint models were developed in-house at General Motors over the past two decades using available European child restraints. In this study, effort was made to explore trends across a variety of occupant sizes and restraint conditions so that UTA and recline effect patterns could be identified. All results presented could be further validated using physical hardware in a representative crash test environment.

V. REFERENCES

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[5] Evenflo Company, Inc., EveryFit Manual, 2019.
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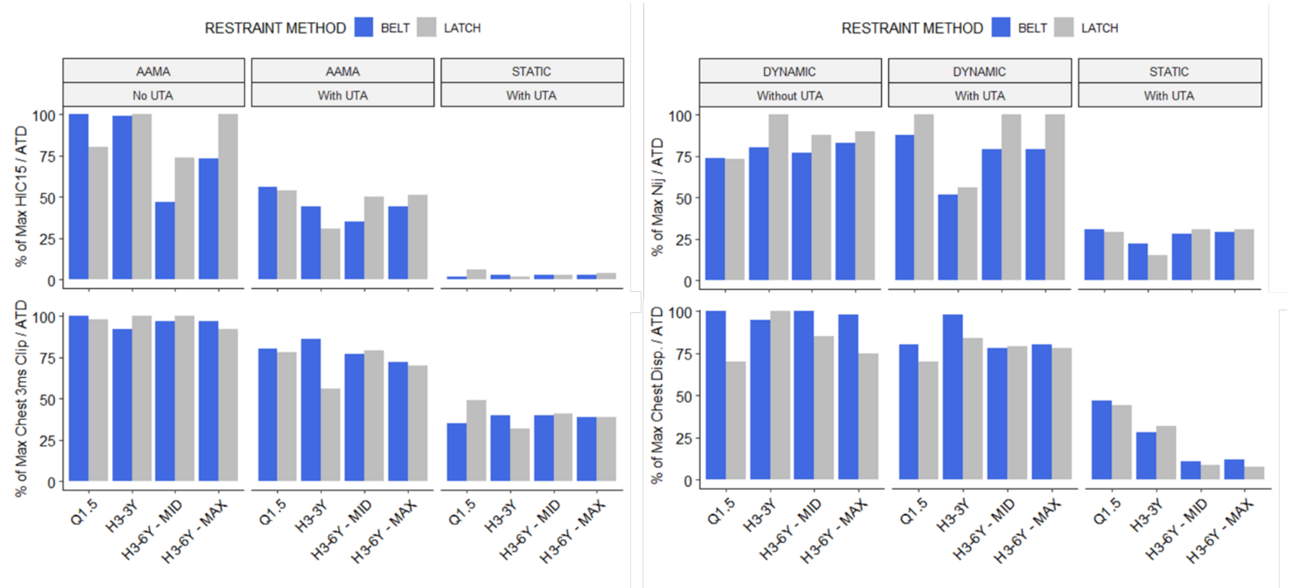
VI. ERRATUM

Summary

After publication, it was discovered that the moment about the y-axis for the neck upper load cell was incorrectly calculated for the H3-6Y. The moment was not corrected to the occipital condyle. This error carried over into the Nij calculation, which is reported in Figure 2. An updated figure is presented below. The minor changes to the Nij of the H3-6Y do not change the overall conclusions of the paper.



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