ASSESSMENT OF GENDER VARIATIONS IN THE CERVICAL RESPONSE TO REAR IMPACTS

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INTRODUCTION

Vehicle dynamics including accelerations resulting from changes in velocity (ΔV) are correlated to occupant kinematics in low speed rear impacts [1,2]. The ability to determine cervical Injury Assessment Reference Values (IARVs) results from decades of research examining the mechanics and biomechanics of segmental effects [3]. Gender is a contributing factor to injury risk. Females have a higher incidence of neck injuries than males in similar accident scenarios [4]. Along with vehicle dynamics and gender, head restraints (HRs) affect occupant kinematics in rear impacts. Recently, this has led to an upgrade of the Federal Motor Vehicle Safety Standard (FMVSS) 202 to increase HR height and proximity to the rear of the head [5].

Mathematical Dynamic Modeling (MADYMO, Tass Americas, Livonia, MI), is a commercially available software package used for complex multi-body dynamic modeling. It allows development and analysis of collision simulations and has been widely used in accident reconstruction (vehicle, pedestrian, industrial, etc.). This work used MADYMO simulations to examine the differences in cervical IARVs between male and females in the same rear impact scenarios across a range of ΔVs as well as the biomechanical effects on the neck of HR versus no HR.

METHODS

MADYMO 7.0 (TASS Americas, Livonia, MI) was used to create and analyze output dynamics during rear impacts to an auto seat configuration with restrained Hybrid III 50th percentile male and female dummies. They were seated in the multi-body modeled driver's seat with a defined reference position and an analytical seatbelt. Both genders were modeled in seats with and without HRs. For the simulations with a HR, it was modeled in a high position (Fig. 1). The modeled dummy, HR, steering wheel and/or seat positions were adjusted based on size to maintain consistent relative position. Analyses had a 250 ms duration with a time step of 1 E-05 s. A linear progression of ΔV values ranging from 0-16 kph (0-10 mph) was analyzed. A haversine impulse with a 100 ms duration was applied to the models to simulate a rear impact motor vehicle accident. It was applied as a position versus time pulse and simulated a 1 mph ΔV impact. This replicates the FMVSS 202 pulse for motor vehicle sled tests [6]. The pulse was linearly scaled to reach a ΔV of 16 kph (10 mph).

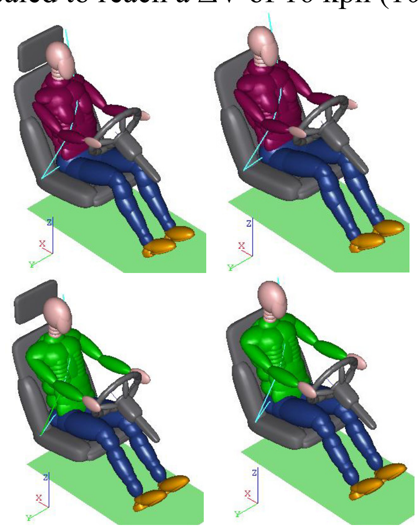

Figure 1: 50th percentile female (top row) and male (bottom row) Hybrid III dummy models seated for rear impact simulations with HR (left) and without HR (right).

The biomechanical Neck Injury Predictor (N_{ij}) for tension-extension (TE), tension-flexion (TF), compression-extension (CE), compression-flexion

(CF) and the overall sum was examined. This IARV was chosen to examine the differences between genders and the effect of headrests on injury prevention. The N_{ij} values were plotted against ΔV to examine the trends with increasing speeds and to determine if any injury thresholds were crossed through the range of 0-16 kph (0-10 mph). N_{ij} has an injury threshold of 1.

RESULTS AND DISCUSSION

The results for N_{ij} TE (NTE) and the sum of the four N_{ij} components are plotted in Figures 2 and 3, respectively. NTE is displayed as a representation of the trend for all N_{ij} components across male versus female and HR versus no HR. NTE is the majority contributor towards the N_{ij} summation.

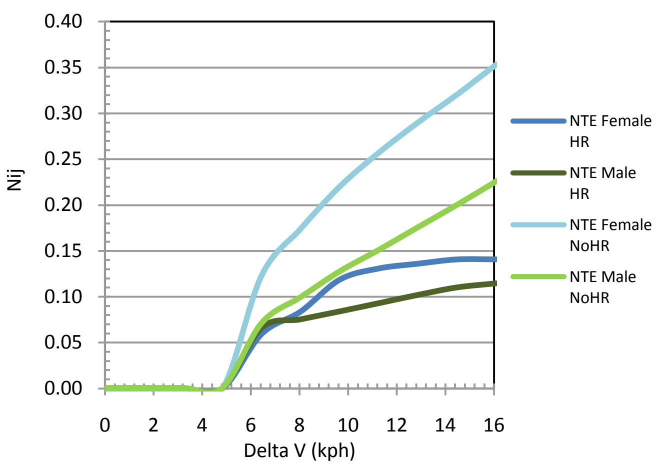

Figure 2: Comparison of NTE values for males and females with and without headrest (HR).

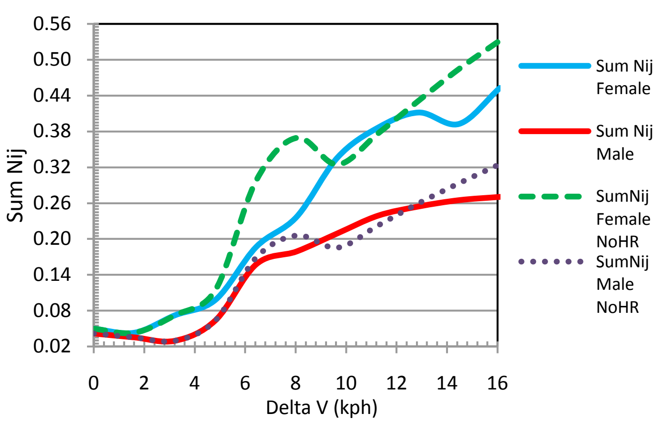

Figure 3: Comparison of N_{ij} sum values for both males and females with and without headrest (HR).

As Figure 2 shows, NTE remains near zero for all four models until approximately 6 kph (4 mph). After this departure from near zero values, each model expresses a near linear positive trend with increasing ΔVs. These results show that the female models have consistently higher values than the male models. More importantly, the models without HR, have much higher slopes and values over twice as high as their gender-matched counterpart at 16 kph (10 mph). The overall sum of N_{ij} exhibits a similar pattern. However, it shows a greater intra-gender difference than inter-gender. At 16 kph (10 mph), the N_{ij} sum is greatest in the female without HR, followed by female with HR, male without HR and male with HR.

CONCLUSIONS

The gender variations seen in this work are consistent with previous studies as well as reports from motor vehicle accidents [4,7]. This points to mechanical and biomechanical differences in the cervical spine between males and females as the seating position and headrest were adjusted for the size of the modeled occupant. As a validity test of the model, the results were compared to a study in which Hybrid III 50th percentile male dummies were subjected to rear impact sled tests using a HR. The NTE results of this work agree with those results in the dummy sled tests [8]. Biomechanical methods of assessment in this study are effective in distinguishing results that differ by gender, i.e. male versus female.

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