Comparison of Novel Wheelchair Occupant Restraint with Standard Occupant Restraints for Occupants Travelling in Transportation

Paul Harrington, Gina Bertocci, Ciaran K. Simms*

I. INTRODUCTION

Wheelchair-users are advised to transfer to a vehicle seat when travelling in transport. Often this is not possible and the wheelchair then becomes a vehicle seat. At present there is limited information about the safest way to transport these occupants if they remain in their wheelchair. International standards [1] are used by equipment manufacturers, service users and clinicians to guide risk-management strategies. Proposed updates to these standards include the use of five-point harnesses for wheelchair occupants below 22 kg. However, a detailed risk–benefit analysis for these changes has not been completed. Therefore, the goal of this Short Communication is to assess the influence of restraint system type on injury risk for small wheelchair occupants in frontal impact.

II. METHODS

MADYMO computer simulations were used to predict the relative risk of 3 types of occupant restraint systems for 3 representative occupant sizes. Models representing 50 kg, 21 kg and 15 kg wheelchair occupants were developed and fitted with a 3-point vehicle-mounted restraint [2], a novel wheelchair integrated restraint and a five-point harness restraint (Fig. 1). Each model was subjected to a 20 g frontal crash pulse in accordance with ISO 7176:19.

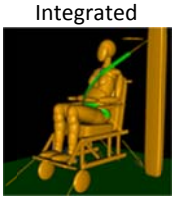
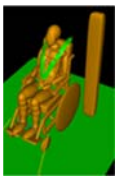
		Benchmark 	Integrated 	Harness 
5th percentile female Hybrid III ATD (50 kg)		Model from original research [2] was set up for 5th percentile female.	Design, build and fit novel occupant restraint based on previous sled test with 50% male ATD.	Design, build and fit occupant restraint based on harness used for child occupant [3].
6-year-old Hybrid III ATD (21 kg)		Set up 6-year-old ATD. Refit wheelchair to suit dimensions of ATD. Refit occupant restraint.	Refit occupant restraint.	Refit occupant restraint.
3-year-old Hybrid III ATD (15 kg)		Set up 3-year-old ATD. Refit wheelchair to suit dimensions of ATD. Refit occupant restraint.	Refit occupant restraint.	Refit occupant restraint.

Fig. 1. Test matrix of three ATD occupant sizes and three occupant restraint configurations detailing work undertaken in present study to build and run the models.

* P. Harrington is an M.Sc. student in Medical Physics and Clinical Engineering at King's College London, UK (tel: +44 (0) 1865 227566; e-mail: paul.harrington@ouh.nhs.uk). G. Bertocci is an endowed Professor at the University of Louisville, Kentucky, USA. C. Simms is an Associate Professor of Engineering at Trinity College Dublin, Ireland.

III. INITIAL FINDINGS

Figure 2 shows a kinematic snapshot of the model results. Figure 3 shows bar charts of the peak head excursions, lumbar loading and head acceleration results for the nine configurations tested. All models successfully met excursion limits for ISO testing. Harness type arrangements subjected occupants to the greatest lumbar spine loads. Integrated solutions subject occupants to the smallest peak head accelerations.

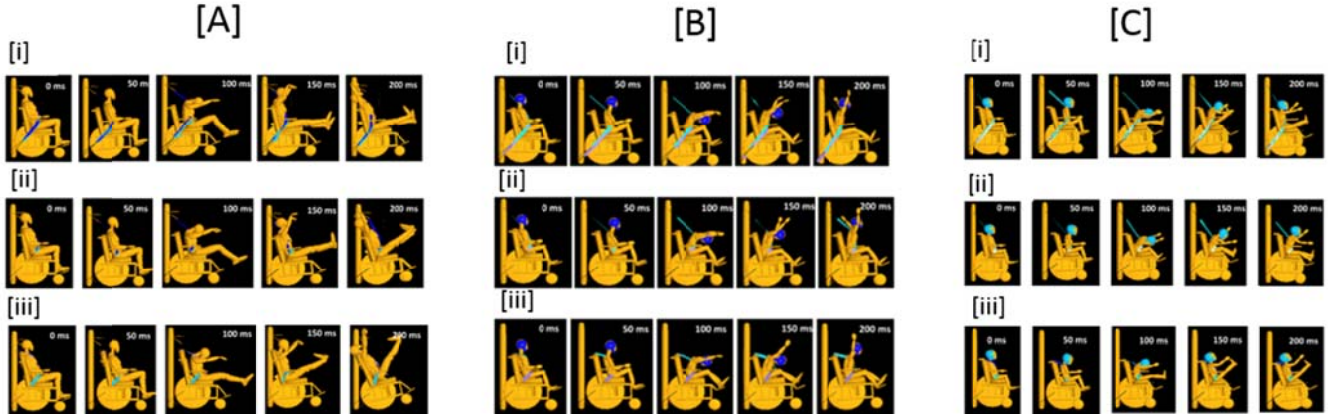


Fig. 2. Kinematic results of nine tests. Matrix [A] shows 5th percentile female, [B] is 6-year-old child ATD and [C] is 3-year-old child ATD. Rows [i], [ii] and [iii] are benchmark restraint, integrated restraint and harness, respectively.

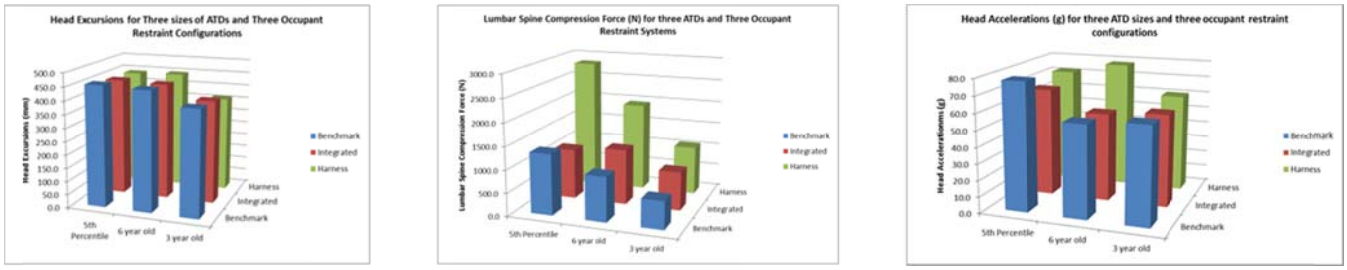


Fig. 3. Head excursions, lumbar loading and head acceleration results for the nine test configurations.

IV. DISCUSSION

The safety of occupants cannot be judged solely on excursions. Head accelerations in all cases were below 50% of limits set in automobile industry standards. Traumatic injury thresholds for compression of the lumbar spine are not available in current versions of automotive standards but manual handling guidelines suggest an upper limit of 3400 N [4]; lumbar loading is trending towards this value in the 5th percentile female case. To reduce injury risk, future standards should include other outcome measures than solely excursion limits. The integrated occupant restraint model requires configuration for each individual every time they move to a new mode of transportation, which introduces risk of misuse. A five-point harness would be set up and worn in the same way all day, thus reducing risk of misuse. However, further work is needed to assess the benefits of a five-point harness for the sub-22kg population both in terms of usability and injury prevention during crashes. This work has applied a model that was validated for a 50% percentile male ATD [2] and applied it to three groups of smaller ATDs. Although this allows direct comparisons to be made in terms of trends in performance between three occupant restraint configurations, absolute values should be treated with caution. Ideally sled-tests would be conducted to validate the models, however an intermediate step will be to compare the results to published sled-test data [3] and revise the model parameters accordingly.

V. REFERENCES

[1] ISO (2008). 7176-19, Wheelchairs: Wheeled mobility devices for use in motor vehicles. *International Organization for Standardization*.
[2] D'Souza, R., et al. *Med Eng and Physics*, 2010.
[3] Manary, M., et al. *Proceedings of the 29th RESNA Conference*, 2006.
[4] Waters, et al. *Ergonomics*, 1993.