

MECHANISMS OF WHIPLASH INJURY PREVENTION ATTRIBUTABLE TO ENERGY-ABSORBING SEAT

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INTRODUCTION

Motor vehicle crashes remain the leading cause of spinal injury [1]. In attempt to reduce whiplash injuries, manufacturers have incorporated active injury prevention systems in newer automobiles, such as the Whiplash Protection System (WHIPS) introduced by Volvo in 1998. Epidemiological studies have indicated potential benefits of WHIPS in reducing neck injury risk between 21 to 47%, as compared to conventional seats. The majority of previous biomechanical studies were manufacturer-sponsored or contain limited data.

The goals of this study were to investigate whiplash injury prevention mechanisms attributable to WHIPS using simulated rear crashes of a Human Model of the Neck (HUMON).

METHODS

HUMON consisted of a neck specimen (n=6) mounted to the torso of BioRID II and carrying a custom anthropometric head stabilized with muscle force replication (**Fig. 1A**). HUMON was seated and secured in a 2005 Volvo XC90 minivan seat, which included WHIPS and a fixed head restraint. The main components of the WHIPS recliner (**Fig. 1B**) included the energy-absorbing element; return spring; and pivot shaft, guide pin, and window for control of WHIPS motion (**Fig. 1C**). The WHIPS was activated by HUMON's momentum pressing into the seatback during the crash, causing rearward translation and extension of the seatback relative to the seat base and plastic deformation of the energy-absorbing elements. Rear crashes (9.9, 12.0, and 13.3 g) were simulated and motions of the head, neck, torso, pelvis, sled, seatback, and WHIPS were monitored. Significant increases ($P < 0.05$) in the spinal motion peaks relative to physiologic limits were determined.

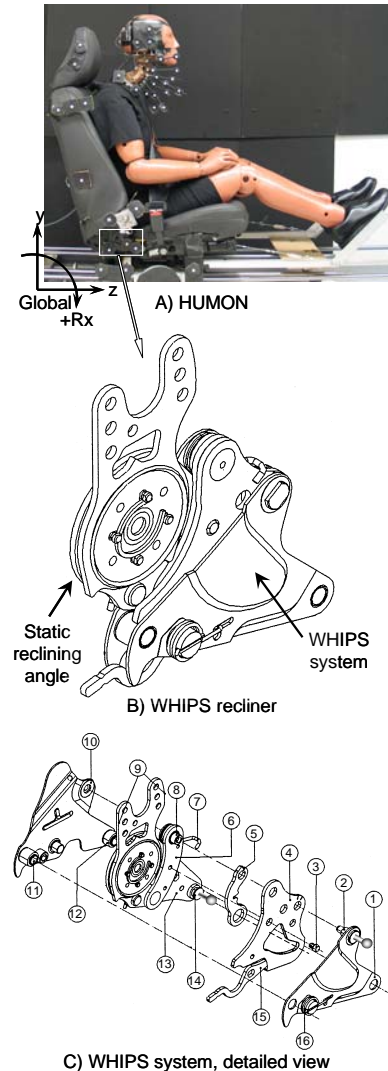


Fig. 1. A) Photograph of the Human Model of the Neck (HUMON) and rear crash apparatus. B) The WHIPS recliner. C) Detailed view of the WHIPS system including: outer (1) and inner (10) plates with attachment points to the seat base (11,12); indicator (3); folding bracket with WHIPS motion control window (4); energy-absorbing element (5); non-energy-absorbing element (6); pivot shaft (2,8), guide pin (14), and return spring (7) for WHIPS motion; conventional recliner mechanism (9) and bracket (13); latch (15) and spring (16) for folding of backrest. Figures 1B and 1C were adopted from Lundell et al, 1998 [2].

RESULTS AND DISCUSSION

Average WHIPS motions are presented graphically for the 13.3 g crashes (**Fig. 2A**). For all crashes, rearward and upward translations of the WHIPS guide pin within the control window were observed, with peaks reaching 4.1 cm for $-T_z$ and 1.6 cm for $+T_y$, occurring as early as 76 ms. Motions of the seatback relative to the sled consisted of extension and rearward and downward translations. Peak plastic deformation of the energy-absorbing elements, ranging between 0.6 and 1.2 cm, occurred at 72 ms. The post-crash position of the WHIPS guide pin within the control window (**Fig. 2B**) was consistent with the average computed data.

Average peak C7/T1 rotations significantly exceeded physiologic limits during the 13.3 g crash. The cervical spine maintained its S-shaped curvature throughout the duration of contact of the head with the head restraint. A 42% reduction in peak T1 horizontal acceleration, as compared to sled acceleration, was observed due to WHIPS.

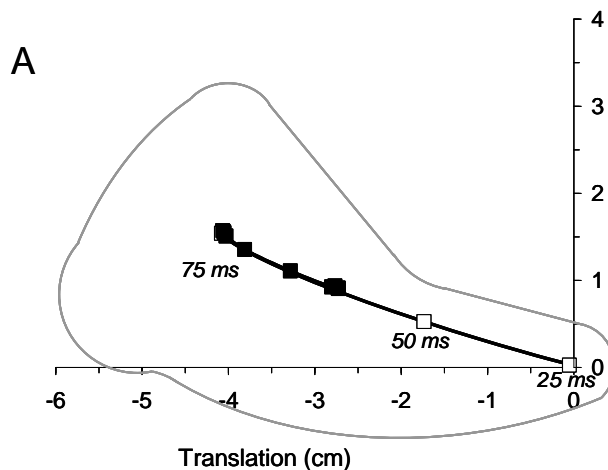


Fig. 2. A) Average motions of the right WHIPS guide pin during the 13.3 g rear crashes. B) Representative photograph of the right WHIPS recliner taken after the rear crash.

CONCLUSIONS

1. The present study investigated the whiplash injury prevention mechanisms attributable to the WHIPS energy-absorbing seat using simulated rear crashes of HUMON at 9.9, 12.0 and 13.3 g peak horizontal sled accelerations.
2. A 42% reduction in peak T1 horizontal acceleration, as compared to sled acceleration, demonstrated the energy-absorbing capacity of WHIPS.
3. WHIPS motion included simultaneous: rearward and downward translations and extension of the seatback; deformation of the bi-lateral WHIPS energy-absorbing elements; and reduction in distance between the head and head restraint.
4. Average peak C7/T1 rotations significantly exceeded physiologic limits during the 13.3 g crash. The cervical spine maintained its S-shaped curvature throughout the duration of contact of the head with the head restraint. Lower cervical spine injuries due to excessive motion may occur prior to or during contact of the head with the head restraint, even in the presence of WHIPS.
5. The present study provided insight into the crash-dynamics of the occupant, seatback, and WHIPS. These data may be useful for refining seat design to reduce neck injuries. Future whiplash injury prevention systems will most likely integrate beneficial design features, such as active head restraint and energy-absorbing seat, with more advanced features, such as accident avoidance technology.

REFERENCES

1. National Center for Statistical Analysis. Traffic Safety Facts. Washington, DC: NHTSA, 2008.
2. Lundell et al. SAE Paper No. 980301, 1998.

ACKNOWLEDGEMENTS

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