Characterizing Booster Seat Children Response to Reclined Seating Configuration During Lateral Oblique Pre-Crash Maneuver

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Introduction

Previous research conducted with the Large Omnidirectional Child Anthropomorphic Test Device (ATD), showed that the presence of a belt-positioning booster (BPB) prevented submarining in moderate and severe reclined seat-back angles during frontal crashes (Graci et al 2022). However, no studies on children volunteers have been conducted to understand the motion of reclined children in pre-crash maneuvers. It is also not clear if the BPB can prevent submarining also in lateral oblique loading conditions. The aims of this study are to investigate: 1) the motion of moderate and severe reclined children in lateral oblique low acceleration impacts, 2) the influence of two different types of BPB on the motion of reclined children.

Methods

Three human volunteers (1 male, 6-8 years old, weight 26.3 ± 3.28 kg, height of 132 +/- 5.35 cm). Two different BPB seats were tested: a standard and a lightweight design. The BPBs were placed on a production vehicle seat, oriented at a lateral oblique angle of 80° from frontal. Sled tests were performed at a nominal (~25°), a moderate reclined (~45°), and a severe reclined (~60°) seat-back angle with both BPBs. Each condition was repeated twice (12 tests total). Each child was secured with a 3-point belt and an adjustable B-pillar/D-ring assembly to simulate an integrated seatbelt. The sled peak acceleration was ~2g. A 3D motion capture system was used to extract peak head, trunk forward and lateral displacements, and peak head subtracted to peak knee forward displacement (as measure of submarining).

Results

Peak head and trunk displacements are greater in the lateral than the forward direction. The lateral displacements decrease with the increase in recline seat-back angle, while the opposite is true for the forward displacements which increase with the increase of the seat-back angle (Table 1). However, the forward displacement differences between seatback angles condition were low (10-30 mm). Overall, both booster seats conditions showed similar kinematic values (Table 1). Peak knee-peak head displacements were below 150 mm (submarining threshold, Klinich et al 2014) for both booster seats.

Table 1. Mean (SD) of head, trunk, and knee-head displacements.

		Peak head displacement (mm)		Peak trunk displacement (mm)		knee- head (mm)
BPB types	**Seatback angle**	**Forward**	**Lateral**	**Forward**	**Lateral**	**Forward**
Lightweight BPB	**25°**	51 (24)	259 (18)	38 (14)	150 (16)	24(18)
Lightweight BPB	**45°**	62 (11)	244 (7)	45 (11)	132 (9)	33 (9)
Lightweight BPB	**60°**	72 (15)	196 (24)	42 (13)	103 (1)	41 (7)
Standard BPB	**25°**	44 (12)	272 (9)	46 (9)	168 (11)	11 (9)
Standard BPB	**45°**	68 (16)	250 (10)	40 (4)	137 (8)	27 (11)
Standard BPB	**60°**	79 (24)	214 (7)	48 (9)	111 (3)	39 (18)

Conclusions

These findings suggest that submarining was not present in children seated on a reclined vehicle seat with both BPBs. However, the increase in forward displacement with the increase of the seatback angle could be amplified by more severe acceleration pulses. Future analysis on more participants and muscle activation will provide insights on sex differences and bracing strategies.