The effect of a severe reclined seat back on the kinematics of the booster seated Large- Omnidirectional Child Anthropomorphic Test Device

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I. INTRODUCTION

Reclined seatbacks may represent a non-standard seating configuration in future autonomous vehicles. There is a gap in the literature investigating child occupants in reclined seats. To date, only two studies have investigated children in reclined seatbacks [1-2]. In one study, it was found that the presence of a belt positioning booster (BPB) seat prevents the Large Omnidirectional Child (LODC) dummy from submarining in frontal sled-simulated crashes when the seatback was reclined [1]. In the other study, it was found that a more rearward D-ring position improved the initial belt contact with the occupant torso and the pretensioner reduced head forward excursion and belt-slip off for the PIPER 6-year-old child model seated on child seats in frontal vehicle crashes [2]. Both studies examined the effect of counter measures such as child seats and belt configurations only in moderate reclined seatback angles (40°-45°). Severe reclined seatbacks (i.e. 60°) may become more common as occupants rest and sleep during travel in driverless vehicles. Therefore, the primary aim of this study is to compare the effect of the 60° reclined seatback versus the 25°(nominal) and 45° seatback angles on the booster seated LODC during a frontal vehicle crash. A secondary aim of this study is to understand the role of the pre-pretensioner (PPT) countermeasure on the LODC kinematics for severe reclined configurations.

II. METHODS

Nine sled-simulated frontal impact tests were performed (24 g peak, 80 ms duration, 56 km/h delta-V) with the LODC seated on a booster seat on a production type vehicle seat. An adjustable D-ring anchor simulated a seat integrated belt. A fixed load-limited 3-point seatbelt webbing system was used. Belt webbing was routed over the ATD lap and shoulder and routed per the CRS manufacturer's directions when used. The belt webbing was initially tightened to the FMVSS213 specification (9 – 18 N) at the shoulder and lap portions. For the tests with the simulated PPT, 100 mm of belt webbing was pulled out to pretension the webbing. The LODC sensors used to measure occupant response included: pelvis accelerometers, pelvis angular rate sensors, ASIS force transducers, abdominal pressure sensors, and lumbar force transducer. Belt force transducers collected webbing forces. Sagittal peak head and knee displacements were extracted in relation to the production door striker location. Peaks of abdominal pressures, seat-belt loads, Anterior-Superior-Illiac-Crests forces (ASIS, upper and lower), lumbar axial and shear force, and sagittal pelvis rotation and velocity were extracted. Left and right peaks were averaged for all outcome measures. Abdominal Injury risk was calculated according to the LODC abdominal Injury curves provided by NHTSA (Suntay et al 2021). We compared the following conditions: a) 60° vs 25° and 45° seatback angle b) PPT vs no-PPT in 45° and 60° seatback angles. Each test was repeated (except for the 60 deg without PPT condition due to technical issues).

III. INITIAL FINDINGS

Abdominal pressure, shoulder belt and ASIS forces show similar results across all the three seatback recline angle configurations regardless of the PPT presence (Figure 1). Abdominal injury risk was below 10% in the 60° seatback reclined angle, and it was lower than the 25° and 45° seatback configurations, although abdominal injury risk was low overall (Figure 1). ASIS upper and lower forces were low (between -0.4 and 0.3 kN). The pelvis showed forward rotation displacement in all seatback configurations. Forward pelvis rotational displacement and velocity were lower in all reclined configurations (45° and 60°) compared to the nominal seatback configuration (Figure 1). The lap belt forces were greater in the 60° degree configurations with and without the PPT compared to all other seatback configurations. Lumbar axial forces (Z forces) increased with increased seatback recline angle. Although lumbar shear forces (X forces) were below 1.5 kN in all the conditions, they were the smallest in the 25 and 60 seatback conditions without the PPT (about 0.5 kN) (Figure 1).

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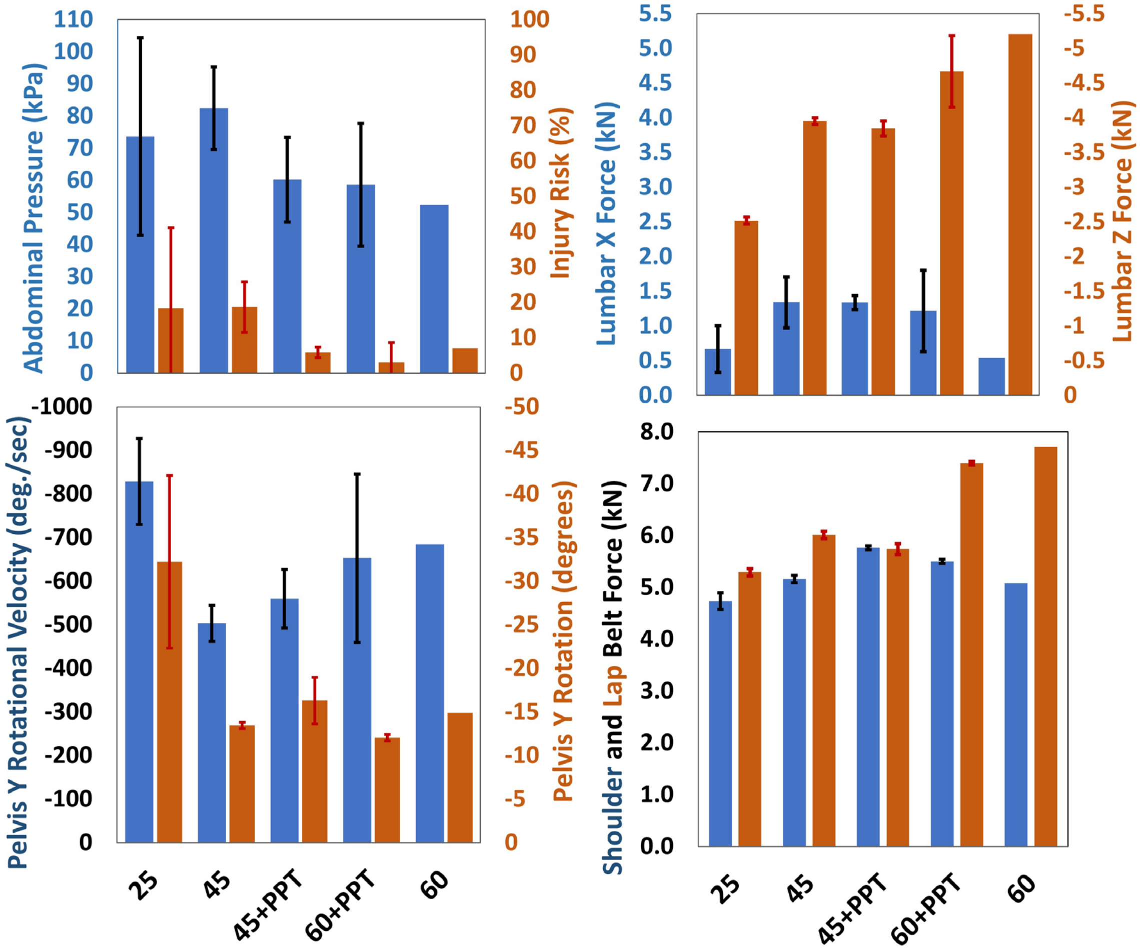

Figure 1. Mean (SD) for abdominal pressure and injury risk, lumbar axial and shear forces, sagittal pelvis rotation and rotational velocity, and shoulder and lap belt forces. The 60° condition without PPT bars represent data from only 1 test.

IV. DISCUSSION

The 60° seatback reclined configurations show similar abdominal forces and injury risk, and pelvis rotation to the 45° seatback reclined configuration with the BPB (Figure 1). However, some differences were found between the 60° seatback reclined configuration and the other seatback conditions. Firstly, the lap belt forces were greater in the 60° compared to the 25° and 45° seatback angles. This result suggests that although the seat belt was well engaged with the pelvis through the simulated frontal crash, the lap belt forces acting on the pelvis may be high. It is difficult to determine if those forces are related to injury without pelvis injury curves for the LODC. Secondly, the lumbar axial forces were also the highest in the 60° condition. These axial loads may be a consideration for future seat pan and BPB designs. The PPT did not show any evident benefit for the LODC motion in reclined configurations while the BPB seems to be beneficial. However, there is no validation data available for belt interaction in the LODC in reclined postures. The findings from this study suggest that the submarining could be prevented also in severe reclined configurations when a child is seated on a BPB. However more testing is needed in severe reclined configurations to better understand injury risk particularly for the pelvis and the spine.

V. REFERENCES

[1] Hauschild et al, *Protection of Children in Cars*, 2021.
[2] Bohman et al, *Protection of Children in Cars*, 2021
[3] Suntay et al, *IRCOBI*, 2021

VI. ACKNOWLEDGMENTS

The authors acknowledge the Center for Child Injury Prevention Studies at the Children's Hospital of Philadelphia (CHOP) and the Ohio State University (OSU) for sponsoring this study and its Industry Advisory Board (IAB) members for their support, valuable input, and advice. The views presented here are solely those of the authors and not necessarily the views of CHOP, CIRP, OSU, or the IAB members.