Effect of Reclined Seat Back Angles and Booster Seat on Small Female Vehicle Occupants During Sled-Simulated Evasive Swerving

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Introduction

- Rise of automated driving encourages reclined seating configurations as occupants may prefer more comfortable postures (Koppel et al 2019).
- **Reclined seating** rotates lumbar spine and pelvis rearward, potentially leading to:
  - Suboptimal lap belt fit in frontal crashes → higher risk for **submarining** in small adult occupants.
- A booster seat was found beneficial in reclined children (Graci et al 2022,2023); they experienced decreased lateral head and trunk motion in lateral-oblique pre-crash motion (Graci et al 2023) and no submarining tendencies.
- Given the similarity in anthropometry, it is possible that a booster could also reduce out-of-position postures in low-acceleration lateral-oblique impacts for reclined small adult occupants prone to submarining, such as the 5th percentile female occupant.

**Objectives**

1. Understand the kinematics of small female vehicle occupants in simulated lateral-oblique impacts
2. Investigate the effect of recline angle and booster seat presence on occupant kinematics

**Test Matrix**

<table>
<thead>
<tr>
<th>Booster</th>
<th>Angle</th>
<th>Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>25°</td>
<td>2</td>
</tr>
<tr>
<td>Yes</td>
<td>45°</td>
<td>2</td>
</tr>
<tr>
<td>Yes</td>
<td>60°</td>
<td>2</td>
</tr>
<tr>
<td>No</td>
<td>25°</td>
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<tr>
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<td>2</td>
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</tbody>
</table>

**Reclined Conditions**

- **25° Angle (Nominal)**
- **45° Angle (Moderate)**
- **60° Angle (Severe)**

**Sled Acceleration**

Hydraulically controlled low-speed crash sled: used to induce 2g peak lateral pulses on the occupant

**Test Setup**

- THOR AV 5-F: 5th percentile female occupant.
- OptiTrack Prime 13W 10-camera 3D Motion Capture Systems
- Load cells placed on lap & shoulder belt.
- Low back booster seat
- Simulated seat-integrated seatbelt

**Head and Trunk Kinematics**

- Less lateral displacement with increased angles
- With no booster, more lateral displacement and greater variability

**Knee-Head Distance**

- Knee-head forward distance is below submarining threshold (150/200 mm) and increased without booster. The 60° reclined angle recorded greatest distance regardless of booster presence.

**Seat-Belt Loads**

- With booster, loads increase with recline angle, suggesting lap belt engagement with pelvis.

**Conclusions**

- With the booster in reclined seatback angle configurations, lateral out-of-position posture may be decreased in evasive swerving.
- Booster may decrease displacement variability and consequently increased kinematic consistency/predictability. This is important for the effectiveness of countermeasures (i.e. pre-pretensioner and pretensioner belts, airbags).
- Booster-like mechanisms/new seat pan designs that elevate occupants may be beneficial for small reclined adult occupants.
- Future studies with more intense pulses are warranted (submarining may be present at higher pulses).

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