Repositioning Forward Leaning Occupants with a Pre-Pretensioner Belt in Static Conditions

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Introduction. Previous research has shown the effectiveness of pre-pretensioner (PPT) seat belts in repositioning forward leaning occupants during braking maneuvers (Graci et al 2022, Mishra et al 2023). Mishra et al 2023 simulated an automated emergency braking (AEB) pulse with a ramp-time of 200 ms and occupants were repositioned rearward by the PPT up to 220 mm in 200 ms with a 600 N PPT force. In Graci et al 2022, a pre-impact sled-pulse with a shorter ramp time of 90 ms was used and occupants were repositioned about 60 mm in 100 ms with a 300 N PPT force. Considering that AEB differs among vehicle models (Graci et al 2021), in some cases the PPT may not be able to reposition forward leaning occupants in time to avoid injury before a collision. This suggests that in case of extreme out-of-position postures the PPT may be needed to be activated in absence of a pre-crash motion as cautionary measure. Therefore, the aims of this study are: 1) to understand the effect of the PPT in repositioning a forward leaning occupant in static conditions, and 2) to characterize occupants' kinematic variability during repositioning.

Methods. Sixteen healthy volunteers (8 males, 8 females, 23.8 ±4.2 years old, height 175.5 ± 6.8 cm, weight 72.3 ± 8.3 kg) were seated with a 40° forward posture on a vehicle seat and restrained with a 3-point seat belt equipped with a PPT. Two seatbelt conditions were examined: low PPT (100 N), and high PPT (300 N). Head and trunk forward displacements relative to the initial forward leaning position at 350 ms from PPT onset were collected with a 3D motion capture system and compared between sexes, repetitions, and low and high PPT with Repeated Measure 3-way ANOVAs (p-level= 0.05).

Results. Head and trunk displacements at 350 ms from PPT activation were always in the rearward direction and they were greater with the high PPT (head -93.8 ± 9.3 mm, trunk -78.7 ± 6.7 mm) than the low PPT (head -44.6 ± 9.0 mm, trunk -39.7 ± 7.6 mm) ($p<0.001$). There were no statistically significant differences between sexes ($p>0.19$), repetition ($p>0.28$), and no interaction effects ($p>0.18$). There was greater inter-subject variability in the low (head -109.5 to -22.1 mm, trunk -105.1 to -17.5 mm) compared to high PPT (head -175.0 to -62.5 mm, trunk -128.4 to -54.8 mm) (Figure 1).

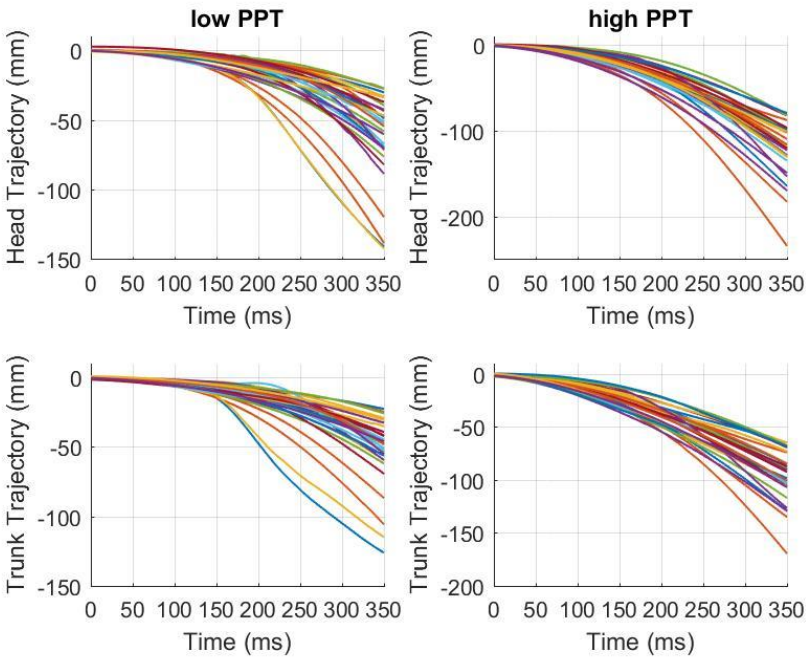

Figure 1. Head (top row) and Trunk (bottom row) trajectories for low (left) and high (right) PPT force levels.

Conclusions. Forward leaning occupants can be repositioned rearward of 60-70 mm in 350 ms with the PPT in static conditions, reducing out-of-position postures. Although no sex differences were found, likely due to height and weight similarities, there was high inter-subject variability suggesting that PPT timing and force level might not be designed as one-size-fits-all. This study also suggests that triggering the PPT in static conditions (or earlier than the AEB) could be beneficial as it could reduce the PPT force needed to reposition forward leaning occupants.