Pediatric and adult passenger kinematics in manual and autonomous emergency braking

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Introduction

Automotive passive safety research has historically focused on the impact phase of a crash, yet up to 80% of crashes are preceded by pre-crash maneuvers such as emergency braking (Seacrist, 2017). Braking may influence passenger kinematics and lead to less optimal positioning at the moment of impact. As the automotive field moves to more active safety technologies, the method by which braking is achieved is changing – from driver-applied manual braking to vehicle-triggered autonomous braking. Previous research has documented that autonomous braking leads to increased head and sternum excursions compared to manual braking; however, only driver kinematics were examined (Osth, 2013). While the driver is aware of the impending manual braking, an unaware passenger could exhibit a different response between the two braking systems. Thus, we compared rear passenger kinematics for pediatric and adult human volunteers in driver-applied manual emergency braking (MEB) and autonomous emergency braking (AEB) via test-track testing.

Methodology

18 participants (5 adults (age 22.0±1.9 years), 7 teens (age 14.9±1.2 years), 6 children (age 10.8±1.6 years)) were seated in the rear right passenger seat of a modern 4-door sedan. The pre-crash maneuvers were performed at the Transportation Research Center Inc. (East Liberty, Ohio) by a trained professional driver. For MEB an average deceleration of ~1 g was achieved by the driver pressing the brake pedal with maximum effort while the vehicle was moving at 50 km/h with cruise control. The AEB was triggered by the vehicle radar detecting a 3D Soft Car (Dynamic Research, Inc.) while travelling at 50 km/h with cruise control, achieving an average deceleration of ~0.8g. Maneuvers were repeated twice in a randomized order. Vehicle dynamics were collected with an Inertial and GPS Navigation system (Oxford RT 3003, Oxford Technical Solutions Ltd.) and kinematics were collected with an eight-camera 3D motion capture system (Optitrack, NaturalPoint, Inc.). Photo reflective markers were placed on the participant's head and sternum. Mixed two-way repeated measure ANOVAs were performed to compare head and trunk displacement normalized by seated height during the steady-state vehicle deceleration phase, and peak body segment velocity between age groups and braking method.

Results

Mean normalized head (0.18) and trunk (0.10) displacement for MEB were greater than mean head (0.14) and trunk (0.08) displacement for AEB ($p<0.005$). Body segment velocities showed similar results; head (1.12 m/s) and trunk (0.46 m/s) velocities during MEB were greater than head (0.64 m/s) and trunk (0.25 m/s) velocities during AEB ($p<0.001$). There were no statistically significant effects across age, albeit adults tended to have reduced normalized trunk displacement and velocity compared to teens or children ($p=0.086$).

Discussion

The lower average steady-state acceleration of the AEB compared to MEB likely contributed to the reduced displacements and velocities observed. These results suggest that AEB systems may mitigate occupant motion pre-crash which could increase the effectiveness of restraint systems as the crash occurs. While not statistically significant, the larger normalized trunk excursions in children and teens compared to adults could aid in the development and validation of adolescent human body models for pre-crash simulations.