

Driver Lower Extremity Response to Out of Position Knee Airbag Deployment

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Abstract

Lower extremity injuries are the most common injuries for occupants in frontal crashes and account for 45% of all AIS 2+ injuries. Although knee airbags (KAB) have been shown to reduce knee, thigh and hip injuries, their effectiveness as a countermeasure for tibia, foot and ankle injuries remains unclear. A review of 29 frontal crash cases from the Crash Injury Research and Engineering Network (CIREN) found moderate to severe lower limb injuries despite the deployment of KABs. The frequency and severity of these injuries were higher for small female occupants. One hypothesis for this high injury occurrence with KAB deployment was the effectiveness of the KAB is reduced for out-of-position (OOP) cases.

This study investigated the biomechanics of lower extremities subjected to direct loading caused by the deployment of a KAB. A total of 11 static KAB deployment tests were performed on a 5th percentile female Hybrid-III dummy seated in a simplified vehicle environment. This rigid fixture matched dimensions typical of a compact sedan, with a flat rigid seat, and a non-production, rear-deployed KAB (ARC hybrid gas inflator, 200kPa, 28.3L tank volume, 0.9 mole) mounted on the reinforced instrument panel. The dummy was equipped with either the original Hybrid-III lower extremities (n=5) or the THOR-FLx (n=6). Baseline tests matched with driver positioning specifications in FMVSS208, and an OOP design of experiments was developed with multiple factors including knee to instrument panel distance, knee to knee distance, and foot placement.

Baseline tests showed acceptable repeatability, with significant variables (e.g., tibia forces) varying less than 15% in peak magnitude. In general, tibia and femur forces recorded in the THOR-FLx were comparable to those with the Hybrid-III LX. The Tibia Index (TI) was calculated using compression force and resultant moment responses for the upper and lower, left and right tibia. TI ranged from 0.31 to 1.28 (average: 0.76), and 0.51 to 1.21 (average: 0.77) for baseline tests of Hybrid-III LX and THOR-FLx, respectively. The Hybrid-III LX recorded 5 to 9mm greater knee slider displacements consistent with higher upper tibia shear force. THOR-FLx exhibited an average of 520N to 1036N higher compression force in lower tibia. Translating the dummy to the full-forward position (tibia shaft in contact with the bolster) resulted in greater abduction kinematics of both legs compared to the baseline position, with the average TI increased by 10%. With the right foot moved inboard from accelerator to brake pedal, the average TI increased 198% relative to baseline. Finally, the highest average TI, 284% greater than baseline, was recorded with the left foot moved inboard creating an adducted initial position. In addition, calculation of injury risk function of multiple lower extremity regions supported this finding.

The elevated OOP dummy lower extremity loads and moments recorded in this study suggest the need for further investigation of injury risk for vehicle occupants. Future research on OOP

response to KAB deployment will include dynamic conditions that provide a more accurate assessment of KAB performance.