**Driver Lower Extremity Response to Out of Position Knee Airbag Deployment**

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**Introduction**

- 45% of AIS 2+ injuries for occupants involved in frontal crashes occur in the lower extremities, and lower limb incidence rate remained virtually unchanged over the past 15 years.
- Knee airbags (KAB) have been designed and implemented in many vehicles as a countermeasure to better control the occupant kinematics during a crash and to mitigate lower limb injuries.
- Real-world crash statistics have shown that the presence of a deployed KAB correlates with a decreased risk in thigh and hip injuries, but an increased risk in foot/ankle and tibia/fibula injuries.
- Hypotheses for the increased risk of lower limb injuries include limitations on airbag coverage and overloading changes in injury patterns relative to knee bolsters, and elevated loadings from out-of-position occupants interacting with deploying KABs.

**Objectives**

- Assess the potential for lower extremity injuries for out-of-position occupants during KAB deployment.
- Determine if KAB interactions could alter the occupant kinematics, that would potentially increase the risk of lower extremity injuries.

- 11 KAB static deployment tests, with a 5th percentile female Hybrid-III dummy seated in a simplified vehicle buck.
- A rear-deployed KAB was mounted on the reinforced instrument panel of the simplified buck. KAB assembly included a ARC hybrid gas inflator, 194 kPa maximum tank pressure at 24.65 ms, 28.3 L tank volume and 0.9 mole.
- Two dummy leg configurations: the standard Hybrid-III Denton lower leg and the advanced THOR-FLx.
- The dummy was positioned in various out-of-position configurations representative of real-world posture scenarios in frontal crashes, and in-position tests followed FMVSS 208 to establish the baseline condition.

**Methods**

- **Risk of AIS 2+ leg shaft fractures** based on tibia index (%)
- **Hybrid-III injury limit = 1.0**
- **THOR-FLx injury limit = 0.91**

**Results**

- **Summary of tibia index for all tests**
- **Test** Dummy Leg
- **Knee to instrument panel distance (mm)**
- **Left foot placement (mm)**
- **Left foot placement (mm)**
- **Knee airbag test matrix**

**Discussion**

- A geometric adjustment for the tibia moments was required for the Hybrid-III lower leg to compensate for the leg curvature and provide a more biofidelic measure.
- Real-world crashes would superimpose crash loads and intrusion onto the forces observed with KAB deployment and the effects on injury in a dynamic environment cannot be assessed in this study.
- Pre-impact braking and muscle bracing could influence the occupant motions and forces within the vehicle.
- Injury risks calculated in this study were high; multiple factors may account for elevated dummy lower extremity responses in the tests beyond that observed in production vehicles:
  1. The “rigid” boundary conditions of the instrument panel and floor pan may have prevented energy absorption by the supporting structures.
  2. The non-compliant flat seat could have constrained the dummy more than a cushioned-production seat, increasing the loads of the upper and lower tibia.

**Conclusions**

- Upper tibia index ranged from 0.95 to 1.31, and 0.78 to 1.21 for baseline tests of Hybrid-III and THOR-FLx, respectively. Lower tibia index varied from 0.3 to 0.46 (Hybrid-III) and from 0.51 to 0.79 (THOR-FLx).
- Translating the dummy to the full-forward position resulted in greater abduction of both legs during knee airbag deployment and an increase of tibia index.
- The risk of tibia shaft fractures was higher than foot and ankle fractures in all tests based on multiple injury risk functions applied to the lower extremity responses.
- The elevated dummy lower extremity response recorded in this study for out-of-position small female occupants suggests that occupant interaction during deployment needs to be a consideration during knee airbag design.

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