Driver Lower Extremity Response to Out of Position Knee Airbag Deployment

Xin Ye, Matthew B. Panzer, Greg Shaw, Jeff R. Crandall

Center for Applied Biomechanics
University of Virginia
Charlottesville, VA 22911, USA

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

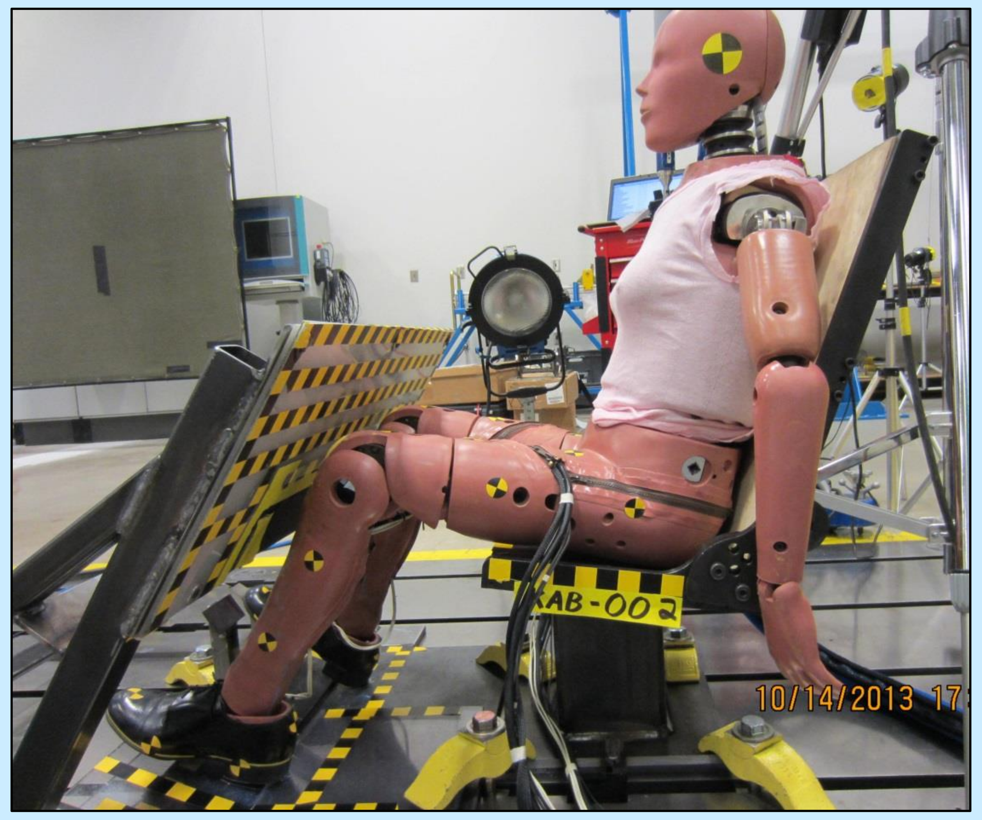
- Assess the potential for lower extremity injuries for out-of-position occupants during KAB deployment.
- Determine if KAB interactions could alter the occupant kinematics, that would potentially increase the risk of lower extremity injuries.

Methods

- 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, 194kPa maximum tank pressure at 24.65ms, 28.3L 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.
- Tibia index was applied as an injury criterion to determine the lower limb injury risk.

Knee airbag test matrix

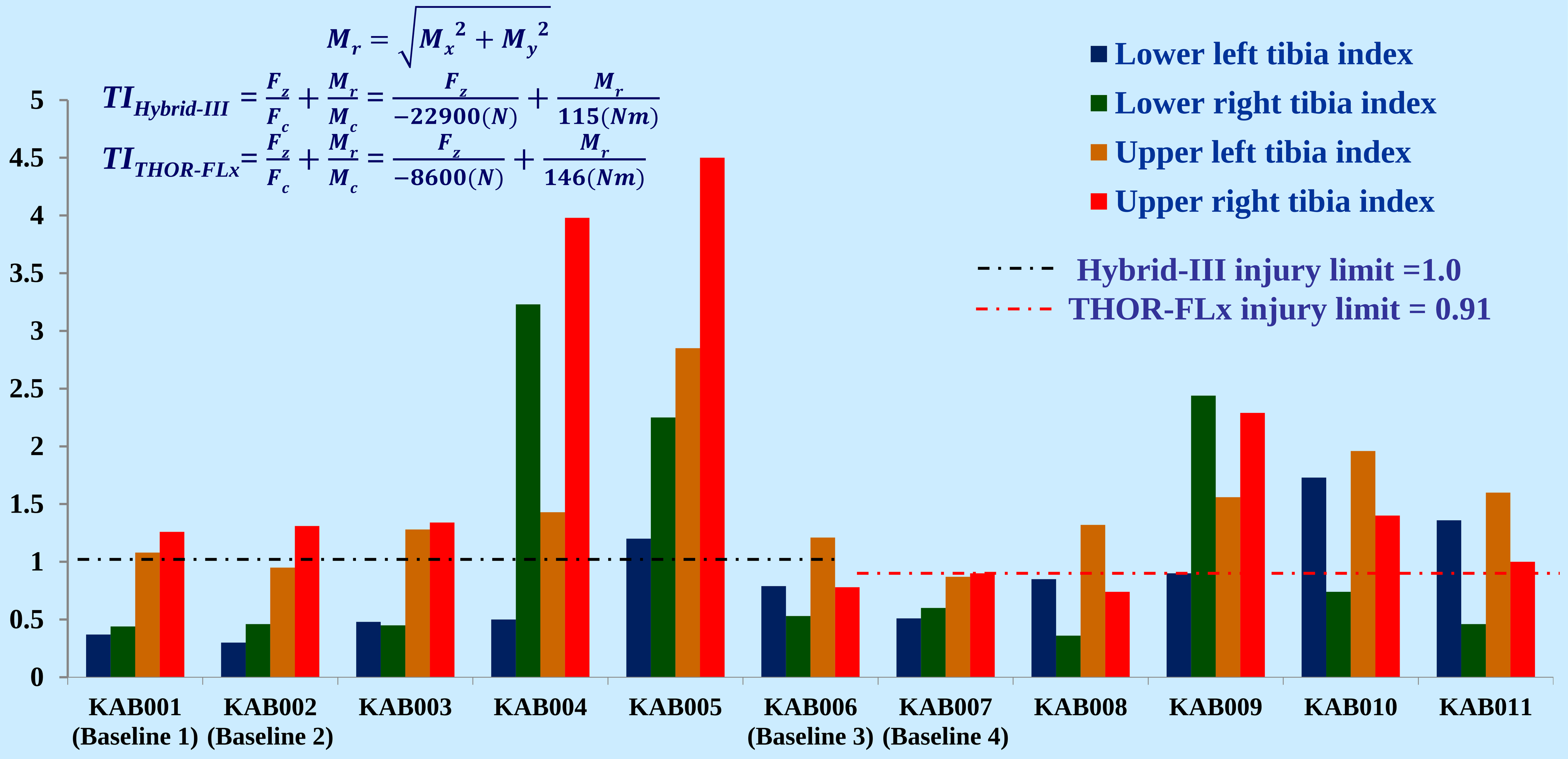
Test	Dummy leg	Knee to instrument panel (mm)	Knee to knee distance (mm)	Right foot placement	Left foot placement	Comments
KAB001	Hybrid-III	Right: 85 Left: 82	252	accelerator	footrest	Baseline#1
KAB002	Hybrid-III	Right: 85 Left: 82	252	accelerator	footrest	Baseline#2
KAB003	Hybrid-III	Tibia contacts knee bolster	252	accelerator	footrest	Dummy translated full-forward
KAB004	Hybrid-III	Tibia contacts knee bolster	180	brake pedal	footrest	Dummy at full-forward
KAB005	Hybrid-III	Tibia contacts knee bolster	158	brake pedal	footrest	Adducted, left foot inboard
KAB006	THOR-FLx	Right: 85 Left: 82	252	accelerator	footrest	Baseline#3
KAB007	THOR-FLx	Right: 85 Left: 82	252	accelerator	footrest	Baseline#4
KAB008	THOR-FLx	Tibia contacts knee bolster	252	accelerator	footrest	Dummy translated full-forward
KAB009	THOR-FLx	Tibia contacts knee bolster	180	brake pedal	footrest	Dummy at full-forward, right heel elevated
KAB010	THOR-FLx	Tibia contacts knee bolster	158	brake pedal	footrest	Adducted, left foot inboard
KAB011	THOR-FLx	Tibia contacts knee bolster	180	brake pedal	footrest	Dummy at full-forward



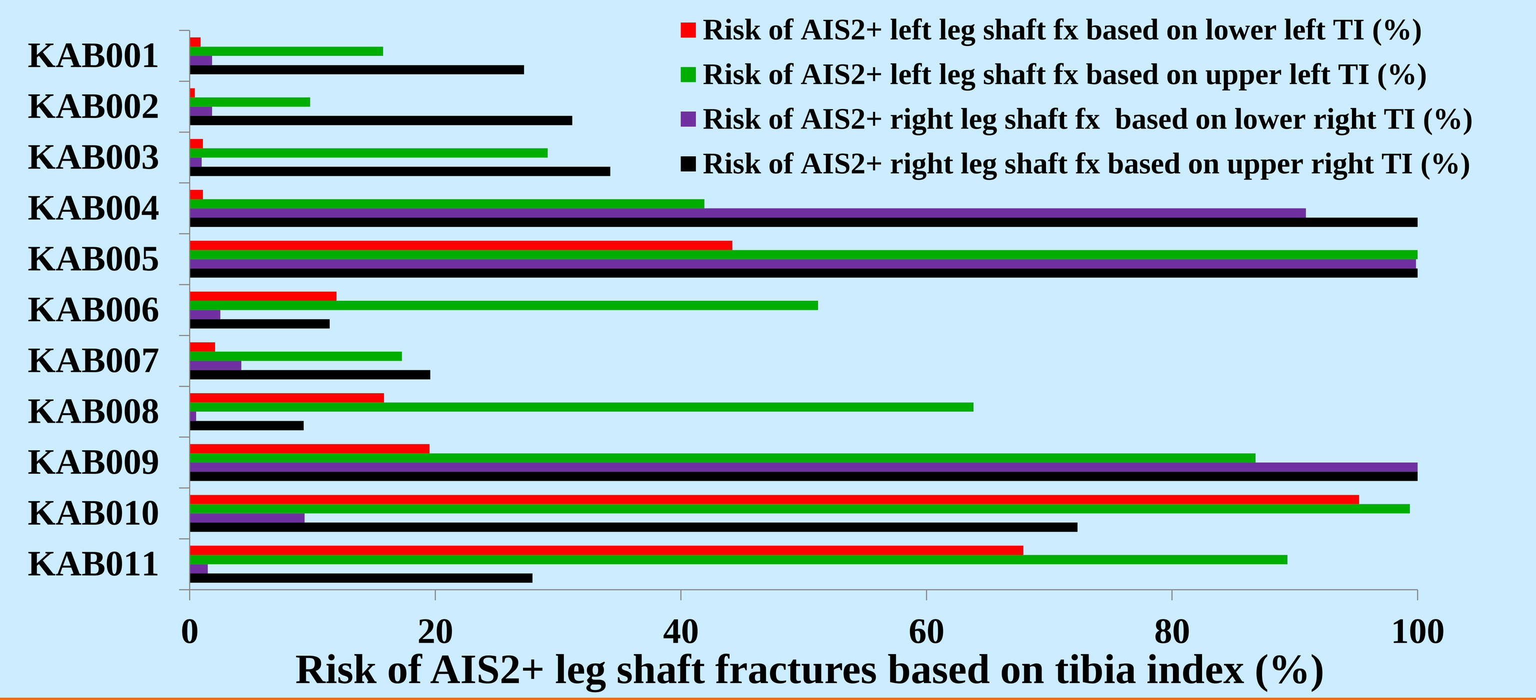
Test setup with positioned dummy

Results

Summary of tibia index for all tests



KAB deployment indicated by time-lapsed photo from high speed cameras



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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University of Virginia – Center for Applied Biomechanics

Xin Ye
4040 Lewis and Clark Drive
Charlottesville,VA 22911
xy3vp@virginia.edu