INTRODUCTION

- Knee bolster airbags are relatively new safety features which are currently making their debut into some vehicle models. These airbags deploy low on the dashboard and generally strike adults at the mid-tibia, as shown in Figure 1.
- The airbags serve a dual purpose:
  - Absorb forces of impact to prevent lower extremity injury
  - Prevent the occupant from submarining beneath the frontal airbag
- Some safety features that are designed for adults are hazardous to children. For example, frontal airbags have saved countless adult lives but have been blamed for the death of over 100 children [2].
- Although the back seat is the safest place for children [3], 12% children aged 4-7 years are front seat passengers (Figure 2).
- Little research has been done on pediatric lower extremities, due in part to the lack of instrumentation and biofidelity of pediatric ATD extremities. Injuries to this region, while generally not life threatening, can still cause severe impairment and permanent disability [5].

OBJECTIVES

- Identify real-world risk of pediatric lower extremity injury in frontal crashes
  - Age of affected population, typical seating positions, types of restraint used, mechanisms of injury
- Add instrumentation to a pediatric ATD to capture appropriate data
- Perform airbag deployment tests
  - Simulate many real-world situations
  - Compare data to published pediatric injury reference values [6, 7]

METHODS

- The standard six-year-old Hybrid III lower extremity is comprised of a fixed pelvis, clevis knee, and clevis ankle.
- Standard instrumentation is a load cell in the femur only.
- For this study, the instrumentation shown in Figure 4 was added to the ATD’s lower extremities. 3-au blocks record linear acceleration and angular rate about all three axes.
- The foot pressure sensors measure force in the z-direction.
- Static airbag deployments were performed with ATD in several realistic seating positions.
- Initial tests indicated the need for direct tibia force and moment measurements. The tibia strain gauges were introduced for Tests 007-012. They are capable of measuring force in the z-direction and moments about the x- and y-axes.

RESULTS & DISCUSSION

For three tests (Tests 004, 008, 012), the ATD’s feet were positioned flat on the floor with the knees at a 90° angle (Figure 5). In this position, the airbag made contact with the ATD at the knee. Axial forces were examined in the femur and tibia. The peak axial forces were near the predicted injurious range.

Several tests were executed such that the airbag made contact at the ATD’s feet (either the toes, soles, or heels). This often resulted in high foot rotation rates >1500 degrees/second. The foot reached the end of its range of motion and hit the hard stop in the ankle joint abruptly. Spikes in the tibia force and moment measurements occurred.

The tibia index (TI) is commonly used to predict tibia injury based on a combination of axial force and bending moment [8].

\[ TI = \frac{F_{\text{ax}}}{M_{\text{tx}}} \]

\[ F_{\text{ax}} \] and \( M_{\text{tx}} \) are critical force and moment values which have been scaled to age-appropriate values [6]; \( F_{\text{ax}} = 4.78 \text{ kN} \) and \( M_{\text{tx}} = 74.2 \text{ Nm} \). A tibia index value in excess of 11 indicates the potential for injury.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the National Science Foundation (NSF) Center for Child Injury Prevention Studies at the Children’s Hospital of Philadelphia (CHIPS) for sponsoring the study and its industry Advisory Board (IAB) members for their support, valuable input and advice. The views presented are those of the authors and not necessarily the views of the NSF, or the IAB members. Also, special thanks to Greg Langton and Sandy Meltzer from Honda R&D America, Inc., the members of the IAB, and all others who have contributed to this project.

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