

# POSTERIOR CRUCIATE LIGAMENT RESPONSE TO PROXIMAL TIBIA IMPACTS

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## INTRODUCTION

Shearing and flexion of the knee joint are recognized as two important injury mechanisms associated with frontal automobile impacts. In a frontal collision, the automobile is decelerated over a short period of time. Due to inertia the occupant's lower extremities travel until arrested by safety belts, air bags or the knee bolster/steering column. In frontal crashes dynamic loading of the flexed lower extremity by the knee bolster/steering column causes the posterior cruciate ligament (PCL) to be the most frequently injured structure.

There is currently no acceptable injury threshold for PCL injuries in frontal crash testing. Kuppala et al.<sup>a</sup> defined 15 mm of knee slider displacement (tibia subluxation) as the current 50% probability of injury to the midsize male anthropomorphic test device (ATD).

Crash tests were conducted with Hybrid III (HIII) ATD's to determine impact testing input parameters. Impact testing was then carried out on flexed HIII lower extremities and flexed post mortem human subject (PMHS) lower extremities. A comparison was made in an effort to relate PMHS tibia subluxation and PCL injury timing to HIII knee slider displacement.

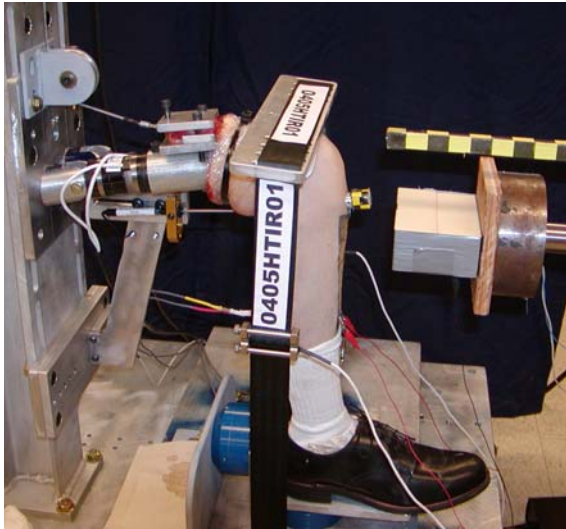
## METHODS

An impact protocol to determine PCL response of PMHS lower limbs was developed from a series of 10 frontal ATD crash tests conducted at the Transportation Research Center in East Liberty, Ohio. This protocol was then used in proximal tibia impacts to both HIII ATD and PMHS lower limbs for comparison of tibia subluxation and PCL injury timing.

Ten (10) PMHS lower extremities were tested at the Biotrauma Laboratories at The Ohio State University. Eight (8) lower extremities were tested dynamically with a pneumatic impactor striking the tibial tuberosity normal to the surface at impact energy ranging from 110 J to 434 J (3.1 m/sec to 6.2 m/sec). Two (2) lower extremities were tested quasistatically [Bionix, MTS Systems, Eden Prairie, MN] to verify instrumentation technique and determine knee stiffness.

## RESULTS AND DISCUSSION

From eight (8) dynamic impacts (Figure 1) it was determined that the 50% likelihood of AIS 2+ (moderate to severe) injury to the lower extremity occurred at an impact energy of approximately 125 J with a 22.75 kg impactor. This energy corresponded to a knee slider displacement of roughly 10 mm in the HIII midsize male ATD under the same impact scenario.

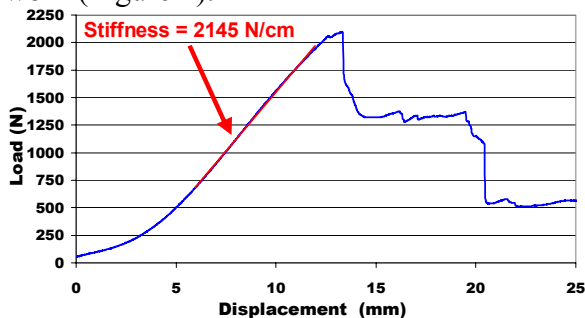


**Figure 1:** Experimental set-up for PMHS lower extremity impact testing

Additionally, two (2) quasistatic tibia posterior displacement tests were performed and the average stiffness of the knee joint complex was found to be approximately 2100 N/cm. The current stiffness value for the midsize male ATD knee slider was found by Viano et al.<sup>b</sup> to be 1490 N/cm.

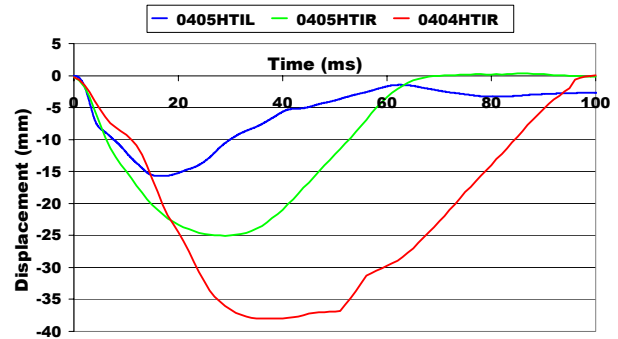
### SUMMARY

The current 50% probability of injury to the midsize male ATD is 15 mm of knee slider displacement. The results of the eight dynamic impacts indicated that this value might not be conservative enough to prevent injury. Additionally, the quasistatic knee stiffness (at 0.5 mm/sec) value was shown to be higher than that obtained in previous work (Figure 2).



**Figure 2:** Quasistatic Knee Stiffness Test

Finally, the tibia was able to sustain significant posterior subluxation in several tests with little or no apparent injury to the PCL and knee complex (Figure 3).



**Figure 3:** Posterior tibia displacement from three subject legs which did not result in visible PCL injury

Clinically, tibia posterior displacement of 15 mm of a flexed lower extremity would be classified as a grade III PCL injury (complete rupture.) These displacements indicated a greater elastic component in the knee complex without injury than previously thought.

### REFERENCES

<sup>a</sup>Kuppa, S. et al. (2001). *Proc. 17<sup>th</sup> ESV*, Paper No. 457, NHTSA, Washington, DC.

<sup>b</sup>Viano, D.C. et al. (1978). *SAE Paper No. 780896*, Society of Automotive Engineers.

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