Anterior Tibia Impacts: A Biofidelity Study between PMHS & ATDs

Hannah Gustafson[1], Rod Herriott2, Joe McFadden[3], John Bolte IV[1]

[1]The Ohio State University, [2]TRC, [3]VRTC

ABSTRACT

Currently knee injuries account for 10% of all frontal car crash injuries. Although this is a small percentage of all injuries in frontal crashes, they are attributed to approximately 500 million dollars in societal cost each year. Injuries to the posterior cruciate ligament (PCL) commonly result from frontal automobile crashes when the occupant's tibia interacts with the intruding knee bolster of the vehicle. The goal of this research study was to better understand injury to the PCL due to this impact scenario and correlate injury with the response of the knee slider of today's crash test dummies. Over a span of two years, fourteen post-mortem human subject (PMHS) lower extremities were impacted on the anterior aspect of the tibia, just distal to the tibial tuberosity. The impactor was a 23.97 kg pneumatic ram with a padded face to simulate the stiffness of a standard knee bolster. The specimens were instrumented with accelerometers, to measure motion between the tibia and femur, a femur load cell, to measure the load through the femur, and the PCL was instrumented with a differential variable reluctance transducer (DVRT) to measure the stretch and time of injury of the ligament during the impact. The data from these PMHS impacts was used to define the stiffness of the knee during frontal impacts between the tibia and the knee bolster and to define an injury criterion for the PCL. The PMHS tests revealed the stiffness of the knee to be a viscoelastic response with an average stiffness of 212 N/mm at in impact velocity of 2.9 m/sec. It was also found that the tibia could displace almost 23 mm in relation to the femur before the occupant had a 50% chance of disrupting their PCL. Following the PMHS testing, six different anthropomorphic test device (ATD) lower extremities were subjected to the same impacts that were used with the PMHS. The tested ATDs included the Hybrid III 5th female, 50th and 95th, Thor-5th FLX, and Thor-50th LX all of which were equipped with calibrated ball bearing knee sliders and also tested was a HIII 50th equipped with a calibrated regulated knee slider. The instrumentation for the ATDs was the same as for the PMHS tests except that the PMHS tests were equipped with DVRTs on the PCL and the ATDs had a potentiometer for measuring overall tibia to femur displacement. The testing revealed that all of the ATD legs were repeatable and had a similar knee stiffness of 200 N/mm, regardless of the impact velocity. The displacement between the tibia and the femur in the ATDs never exceeded 15 mm, which brings into question the biofidelity of the ATD knee slider and its ability to predict PCL injuries.