Comparison of lower extremity kinematics in side-facing seats for aircraft crashworthiness

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Federal Aviation Administration (FAA) requirements for occupant protection during emergency landing primarily focus on forward and rearward facing seats. Many business jet aircraft utilize side-ways facing seats which are certified by either an exception from some safety standards or by complying with additional test and design requirements. Human biomechanics and injury tolerances have been shown to differ significantly in the sagittal and coronal planes such that most crash test dummies are primarily biofidelic in one plane or the other, but not both. Injury criteria and dummies specific to the lateral loading vector have been developed and can be used to determine whether side-facing seats provide an equivalent safety level as forward-facing seats. While considerable effort has been made in the automotive industry to understand injury mechanisms and criteria in side impacts, comparatively little research has been conducted on side-facing seats in the aircraft environment. Preliminary studies by the Civil Aerospace Medical Institute (CAMI) noted significant flailing of the lower extremities in ES-2 dummy sled tests using a standard aircraft seat and restraint system. This flailing is not typical in auto impacts and no injury criteria are available to assess the injury potential. This is of particular concern as lower extremity injuries may significantly delay occupant evacuation, and thus require a better understanding of the biomechanics of this modality. The overall goals of this study are to quantify the lower extremity kinematics of the ES-2 dummy at different velocities and compare these motions to injury patterns of matched pair post mortem human surrogates (PMHS) tests. Nine ES-2 dummy sled tests were conducted at 13.6, 12.5, and 8.7 m/s in a standard aircraft seat environment to better understand the biomechanics of these injuries. Occupants were seated on a seat covered with an aircraft cushion and armrest on a sled such that the acceleration vector was oriented laterally, left to right. The internal rotation the femur was measured by instrumenting the leading tibia of the ES-2 dummy with Angular Rate Sensors (ARS) and retroreflective markers whose 3-d motion was measured using a 12 camera optical motion tracking system (Vicon). Average peak femur rotation in the coronal plane ranged between 95 and 102 degrees with average peak angular velocities between 16 and 21 rad/s. Using matched pair analysis with PMHS injuries in equivalent sled tests and acknowledging the limited sample size, it may be reasonable to limit the rotation of the tibia in the coronal plane between 25-50 degrees to reduce injuries in side-ways facing seats in aircraft.