THE EFFECT OF ANKLE POSTURE ON MEASURED FORCES AND MOMENTS IN AN ANTHROPOMORPHIC TEST DEVICE TIBIA DURING IMPACT TESTS

John Van Tuyl[1], Timothy Burkhart[2], Cheryl Quenneville[1,3]

[1]Department of Mechanical Engineering, McMaster University, Hamilton, ON
[2]McBain Biomechanics Laboratory, Western University, London, ON
[3]School of Biomedical Engineering, McMaster University, Hamilton, ON

INTRODUCTION

- Anthropomorphic test devices (ATDs) are used in crash testing to evaluate injury risk to an occupant
- The forces and moments measured using load cells in the ATD are related to injury criteria based on cadaveric testing
- Lower leg injuries are a major concern, as they are frequently sustained in automotive crashes and battlefield explosions [1] and are associated with high morbidity
- Ankle posture is not constrained in crash tests, potentially leading to incorrect safety assessments when compared to injury criteria developed using a neutral posture

PURPOSE

- To evaluate how ankle posture affects the forces and moments measured in the lower leg of an ATD

METHODS

- A Hybrid III lower leg (Humanetics Innovative Solutions, Plymouth, MI) was mounted in a pneumatic impactor [2] using a custom footplate that allowed for control of ankle posture (Figure 1)

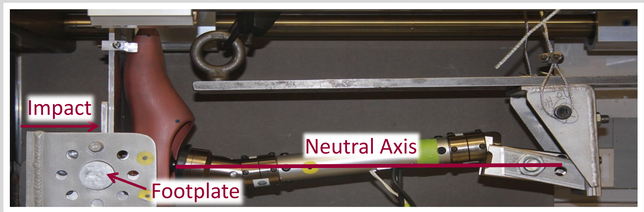

Figure 1: Impacts were applied to the sole of the foot using a pneumatic impactor, with a custom footplate in line that allowed independent control of the three axes of the ankle.

- Signals from load cells in the upper and lower tibia were recorded at 15 kHz while the foot was impacted at a velocity of 5 [+/- 0.1] m/s
- The following posture trials were tested (5 impacts each):
  - 20°, 15°, 10°, and 5° dorsiflexion and plantarflexion
  - 15°, 10°, and 5° ankle inversion and 5° ankle eversion
  - 10° and 5° knee extension and flexion
- The leg was tested in a neutral posture for each series (three trials)
- Peak axial force, Tibia Index (TI), and Corrected Tibia Index (CTI) calculated for each posture; the difference from neutral for each was determined

RESULTS

- Peak axial forces were consistent among the five impacts for each trial (impacts were, on average, 6% different from the trial mean)
- As the ankle moved from plantarflexion to dorsiflexion, the peak axial force increased (range: 1.8 kN, Figure 2); TI and CTI did not vary greatly with posture
- As the ankle moved away from neutral (in/eversion), the peak axial force increased (range: 2.7 kN, Figure 3); both TI and CTI were greatest when tested in the neutral posture
- Extension of the knee did not greatly influence peak force, whereas flexion resulted in smaller peak axial forces (range: 2.2 kN, Figure 4); TI and CTI did not vary greatly with posture

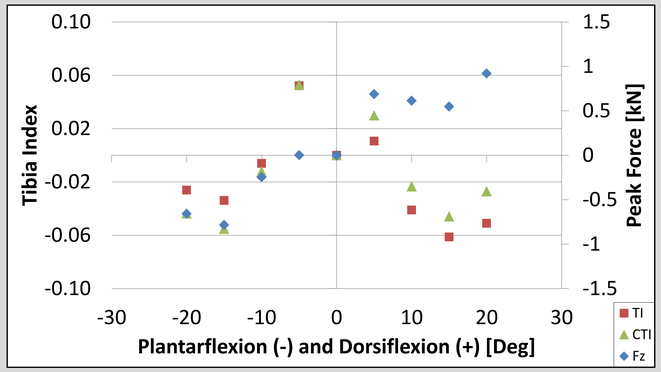

Figure 2: Effect of Ankle Flexion. Peak axial force (difference from neutral) increased from plantarflexion to dorsiflexion. TI and CTI did not vary greatly with postural changes.

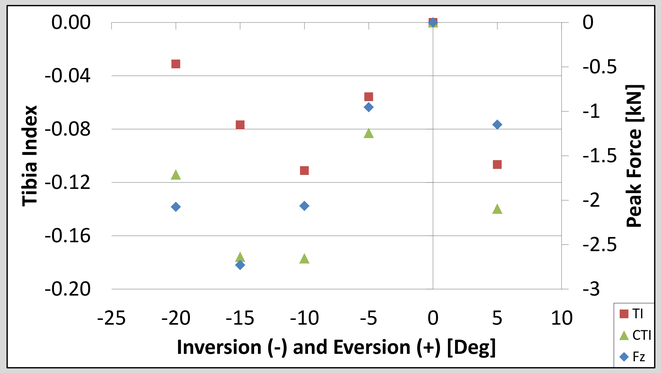

Figure 3: Effect of Ankle Version. Peak axial force (difference from neutral), TI and CTI were greatest in the neutral posture.

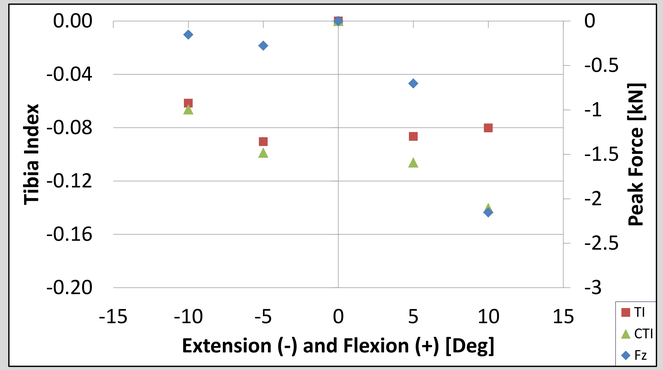

Figure 4: Effect of Knee Posture. Axial force was most affected by knee flexion. TI and CTI did not vary greatly with postural changes.

DISCUSSION and FUTURE WORK

- The range of postures tested represents the natural range of the human lower leg in controlled increments
- Peak axial force, TI and CTI are common measures used to rate injury risk in crash testing [3]; the CTI applies a correction for moments produced by pure axial loading in the Hybrid III leg
- Ankle posture affected the measured peak axial force by a magnitude that would have substantially affected safety ratings
- The influence of posture on TI and CTI was less clear as these depend on both axial force and moments; further testing is needed
- ATDs should, as much as possible, be loaded in a neutral posture to reflect how current injury limits were developed and to avoid underestimating injury risk
- Injury limits for the lower leg in non-neutral postures are needed, and metrics other than peak force should be explored

REFERENCES

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