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)**

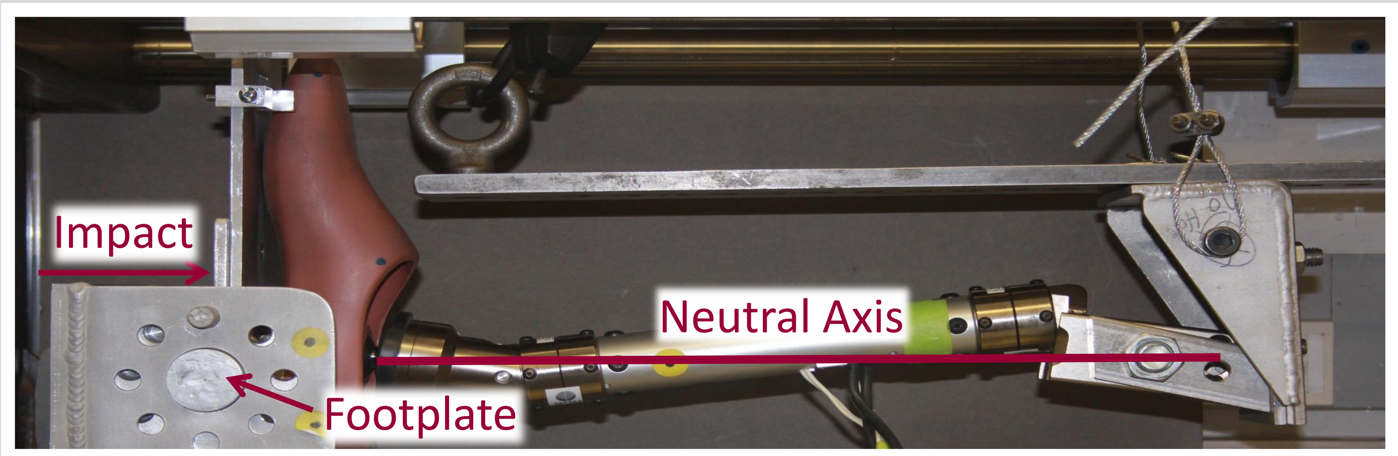

Figure 1: Impacts were applied to the sole of the foot using a pneumatic impactor, with a custom footplate in line that allowed independent control of the three axes of the ankle.

- **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**

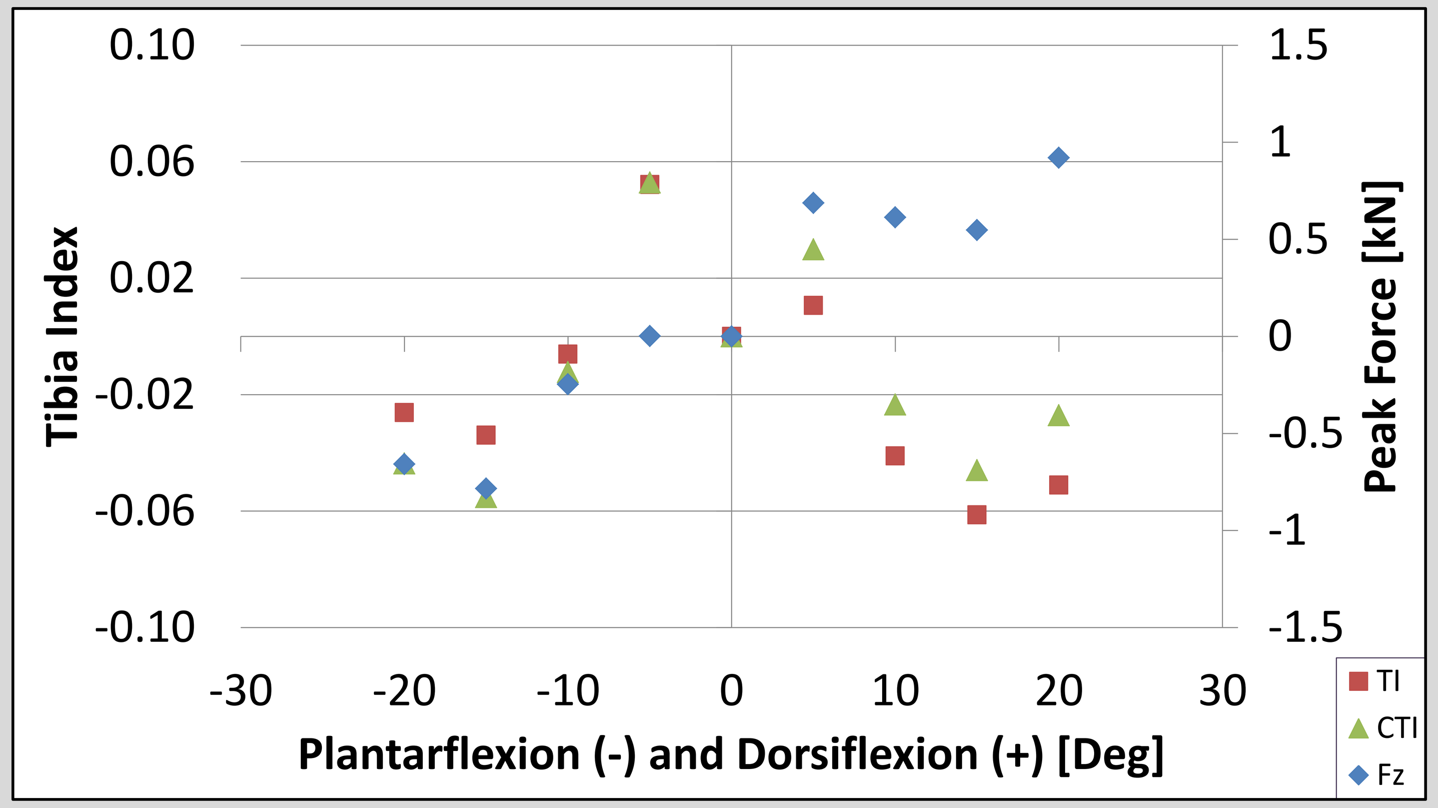

Figure 2: Effect of Ankle Flexion. Peak axial force (difference from neutral) increased from plantarflexion to dorsiflexion. TI and CTI did not vary greatly with postural changes.

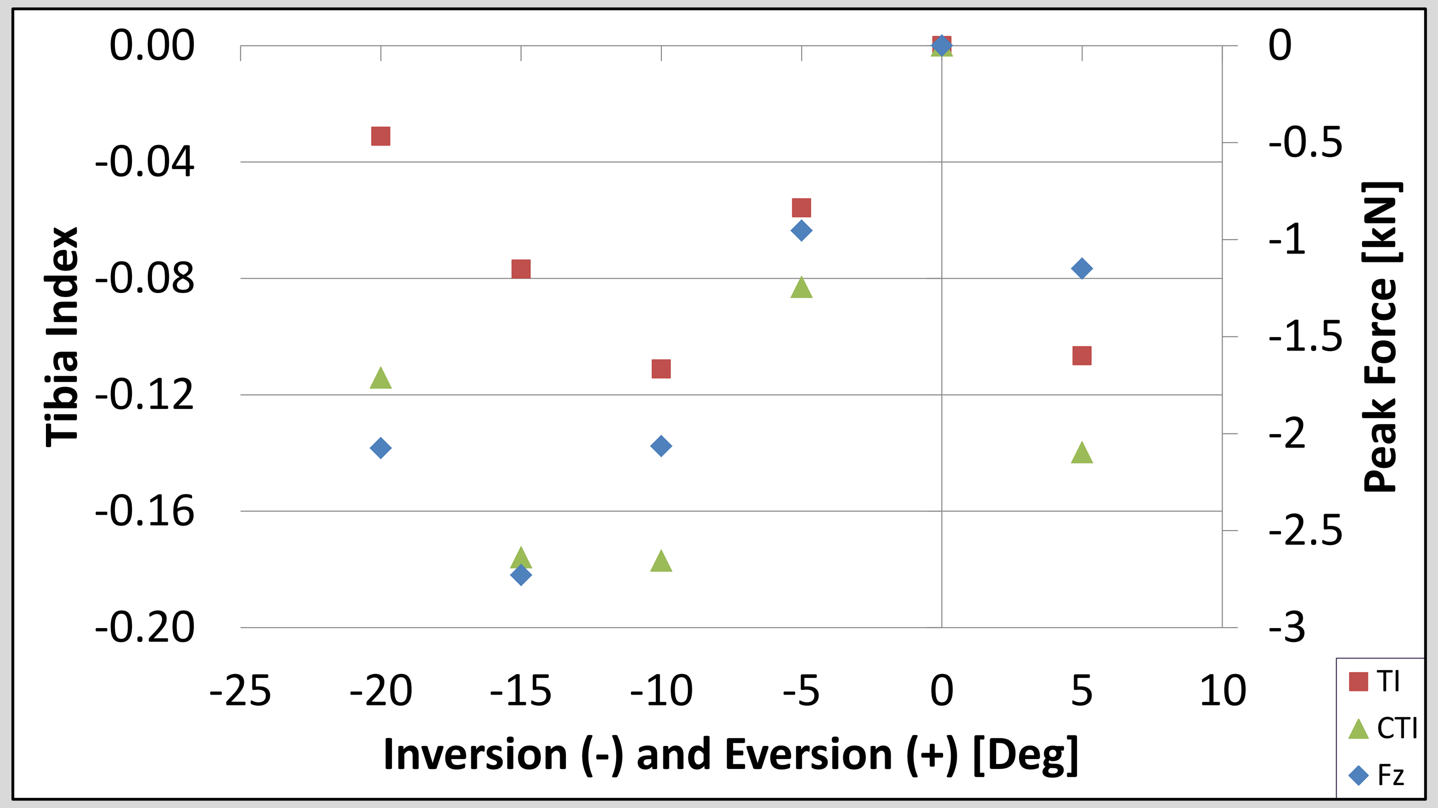

Figure 3: Effect of Ankle Version. Peak axial force (difference from neutral), TI and CTI were greatest in the neutral posture.

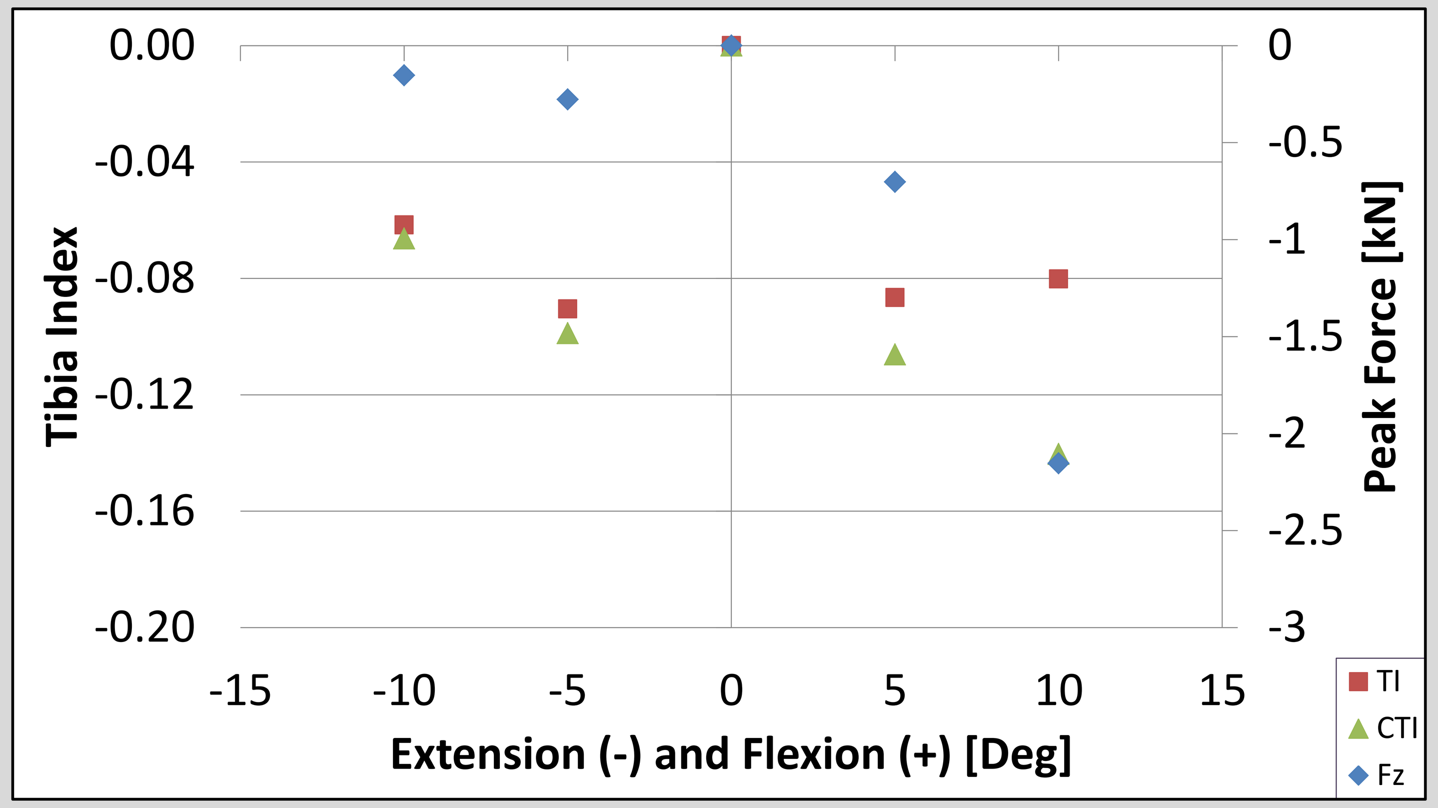

Figure 4: Effect of Knee Posture. Axial force was most affected by knee flexion. TI and CTI did not vary greatly with postural changes.

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

[1] Ramasamy A, Hill AM, Phillip R, Gibb I, Bull AM, & Clasper JC. (2011). The modern "deck-slap" injury--calcaneal blast fractures from vehicle explosions. *The Journal of trauma*, *71*(6), 1694–8.

[2] Quenneville CE, Fraser GS, & Dunning CE. (2010). Development of an apparatus to produce fractures from short-duration high-impulse loading with an application in the lower leg. *Journal of biomechanical engineering*, *132*, 014502.

[3] Insurance Institute for Highway Safety. (2009). *Frontal Offset Crashworthiness Evaluation- Guidelines for Rating Injury Measures*

ACKNOWLEDGMENTS

The authors would like to thank General Dynamics Land Systems - Canada for generously lending us the ATD leg