Influence of Ankle Posture and ATD Model on the Distribution of Forces on the Foot Under Impact Loading

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INTRODUCTION

- Lower extremities are now the most frequent AIS 2+ injuries to occur in frontal motor vehicle collisions[1]
- Anthropomorphic Test Devices (ATDs) are used to assess injury risk to this region, typically instrumented only with upper and lower tibia load cells
- Ankle posture affects the load pathway through the foot[2], but ATDs are relatively insensitive to postural changes[3]
- An instrumented boot was designed to provide regional load data of the foot under axial impacts, in an effort to evaluate injury risk to this typically neglected region[4]

PURPOSE

To evaluate how ankle posture affects the axial load and corresponding injury risk in two ATD models at five different postures, using the instrumented boot.

METHODS

- Two commonly used lower leg ATD models were tested: Hybrid III 50th Male and MIL-Lx (Humanetics Innovative Solutions)
- Each ATD was tested at five postures:
  - 20°-dorsiflexion (20°DF), 10°-dorsiflexion (10°DF), neutral posture (NP), 10°-plantarflexion (10°PF), and 20°-plantarflexion (20°PF)
- Impacts of 6 m/s for 20 ms were targeted, representative of a frontal automotive collision, delivered via a pneumatic impacting apparatus (Figure 1)
- Peak force and Tibia Index (TI) were assessed at the distal tibia load cell for the Hybrid III leg and the proximal tibia load cell for the MIL-Lx, per industry standards[5]
- Impacts were repeated five times and averaged

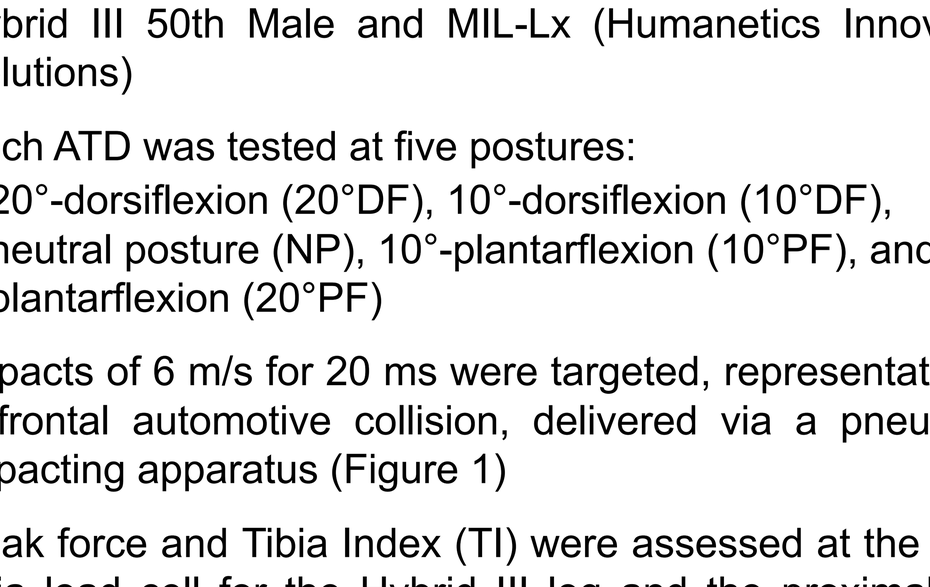

Figure 1: The MIL-Lx suspended in the pneumatic impacting apparatus fitted with the instrumented boot and positioned in 20°-plantarflexion.

RESULTS

- The Hybrid III reached a higher peak force over a shorter duration (16.4±1.2 ms), whereas the MIL-Lx had a lower peak force over a longer duration (22.1±2.5 ms) (Figure 2a)
- Hybrid III TI's were not greatly affected by posture, and MIL-Lx TI's showed a decreasing trend as the ankle rotated from the dorsiflexed to the plantarflexed postures (Figure 2b)
- The hindfoot carried most of the load across all impacts in both models, but as the ankle moved from neutral to PF this load was transferred primarily to the forefoot (Figure 2c)

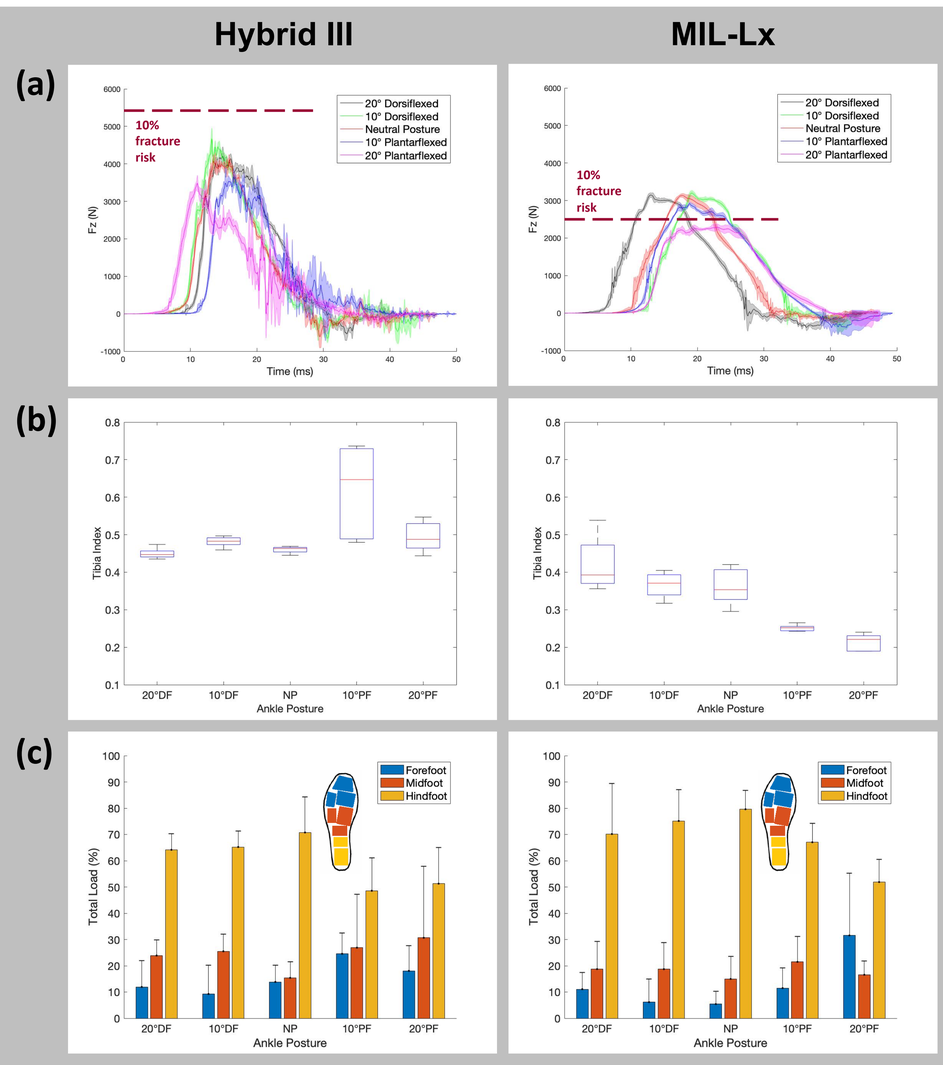

Figure 2: Axial force-time traces with 10% risk of foot/ankle fracture indicated in red dashed line (a), Tibia Indices (b), and average regional sensor loads (c) between the two ATDs, at five tested postures.

DISCUSSION

- Moving into PF altered the distribution of foot loads, which resulted in reduction in standard metrics (e.g. TI for MIL-Lx)
- This reduction would suggest increased safety in this posture, but may lead to increased forefoot fracture risk
- The two ATD models reflected postural changes differently, with the MIL-Lx being more sensitive to changes
- In identical impacts, the Hybrid III 'passed' all tests, whereas the MIL-Lx 'failed' 4 of 5 (based on peak force), indicating these are not equivalent test subjects
- Fore- and mid-foot injury limits are needed to properly assess this region

REFERENCES

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