

## The posture of the lower limb alters the mechanism of injury in under-body blast

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### I. INTRODUCTION

Victims of anti-vehicular mine attacks suffer mostly from severe lower limb injuries, and more specifically, fractures of the bones of the ankle joint; these are associated with high rates of amputation and poor outcome [1]. In previous studies, traumatic platforms have been used to replicate the loading environment of such an attack and test post mortem human surrogates (PMHSs) [2]. The outcome of these studies confirmed the mechanism of injury; the floor of the vehicle above the explosion deforms rapidly and transmits an axial load to the lower limb of the occupant. Furthermore, the axial load transmitted through the tibia was found to be an accurate injury predictor and was used to develop injury risk functions (IRFs) [3]. The experimental protocols of these studies directed the lower limb to be set at a 90°-90° seated posture, however, alternative seated postures, such as the 120°-120° seated posture, are often adopted by occupants of military vehicles [4-5]. The aim of this study was to investigate whether the 120°-120° seated posture (Figure 1) alters the mechanism of injury of an anti-vehicular attack and affects the predictive ability of current IRFs.

### II. METHODS

Nine PMHS lower limbs (male, 53±3.5 y.o.) were tested using the anti-vehicular under-body blast injury simulator (AnUBIS) developed previously at Imperial College London [6]. Two force sensors (200C20, PCB Piezotronics, NY, USA) were mounted on the accelerating plate of the rig, located under the plantar hind-foot (heel) and forefoot (metatarsal heads). Two accelerometers (350C23, PCB Piezotronics, NY, USA) were mounted on the plate and were recording at 25 kHz. Ten strain gauges were attached along the tibia and at the calcaneus of each PMHS. Two high speed video cameras (Phantom v210, VRI, NJ, USA) were used to monitor the lateral and medial ankle region during the event. The PMHS lower limbs were set at the 120°-120° seated posture; angles were measured using a digital inclinometer (SlopeView TLL-90E, MIB Instruments Co, Hong Kong SAR). All PMHSs were fitted with a Meindl Desert Fox combat boot (Lukas Meindl GmbH & Co, Germany), size UK 10. The peak velocities of the tests ranged from 8.6 to 14.5 m/s reached within 7.9 to 11.3 ms (Table I).

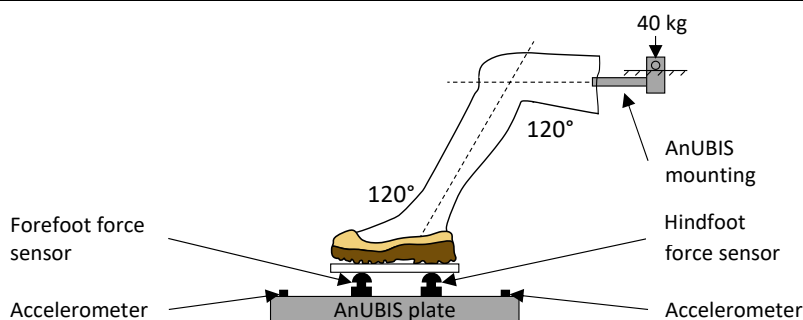


Figure 1 – Experimental setup.

Hind-foot and total plantar foot peak force were used as injury predictors to develop IRFs for the 120°-120° seated posture. For this purpose, a Weibull survival analysis was conducted using NCSS statistical software (Utah, USA) [7]. For the analysis, data were classified as uncensored when the PMHS did not sustain an injury of an Abbreviated Injury Scale (AIS) greater or equal to 2 [8], and right censored otherwise.

### III. INITIAL FINDINGS

All fractured PMHSs sustained at least a distal tibia pilon fracture as shown in Table I. The IRFs developed in this study are shown in Figure 2. The 50% possibility of an AIS+2 injury corresponds to a plantar hind-foot and

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total foot force of 8.4 and 14.9 kN, respectively.

TABLE I  
THE CHARACTERISTICS OF THE TESTS PERFORMED WITH THE LOWER LIMB SURROGATES.

Test	Peak velocity [m/s]	Time to peak velocity [ms]	Peak acceleration [g]	Time to peak acceleration [ms]	Peak hind- foot force [kN]	Peak forefoot force [kN]	Fracture
1	10.7	8.0	260	2.9	10.1	7.2	Distal tibia pilon
2	13.7	9.7	348	4.4	11.7	7.1	Distal tibia pilon
3	14.5	9.0	364	4.0	10.7	8.9	Distal tibia pilon
4	14.0	9.3	281	4.1	8.3	7.7	Distal tibia pilon & Calcaneus
5	8.3	11.3	113	4.5	3.8	4.0	None
6	10.9	9.8	192	2.8	5.9	5.0	None
7	8.6	10.2	143	4.1	8.7	4.1	None
8	12.1	9.0	246	3.1	7.0	6.7	Distal tibia pilon & Calcaneus
9	11.9	10.4	193	5.1	8.3	7.0	None

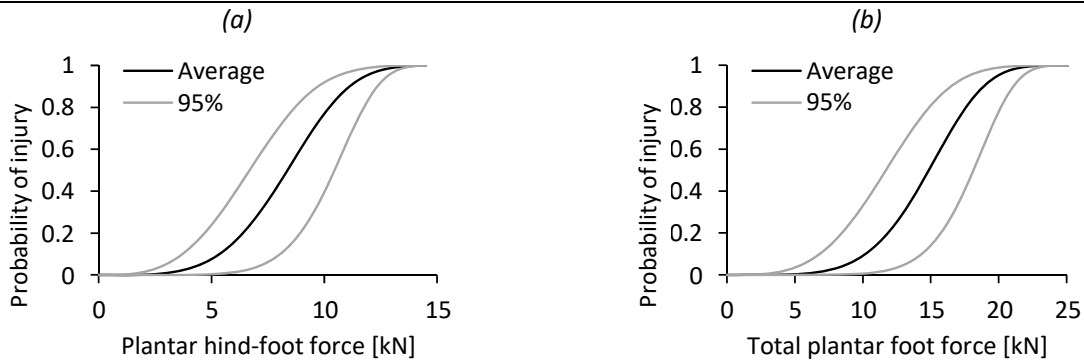


Figure 2 – Average and 95% confidence intervals IRFs for the 120°-120° seated posture using a) the peak plantar hind-foot force, and b) the total plantar foot force as predictors.

#### IV. DISCUSSION

The results of this preliminary study suggest that a 120°-120° seated posture activates a different mechanism of injury than the typical 90°-90° with distal tibia pilon fractures prevailing instead of calcaneal fractures [3,9]. The plantar hind-foot and total foot force that are predicted to be associated with a 50% probability of injury differ from previous studies that used the same injury predictors for a 90°-90° seated posture [2,10]. This discrepancy confirms the effect of posture in the mechanism of injury of under-body blast. Furthermore, due to the different mechanism of injury, alternative predictors, such as variables that combine forces and moments, should be assessed for their ability to predict injury for a 120°-120° seated posture.

#### V. REFERENCES

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