The Effect of the Posture of the Lower Limb in Anti-Vehicular Explosions

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I. INTRODUCTION

The lower extremity has been the most prevalent region of injury in cases of anti-vehicular mine attacks with the ankle joint being most commonly affected [1]. These injuries have been reported to be severe, difficult to treat and are associated with high rates of amputation. They occur as the axial loading, caused by the rapidly deforming floor of the vehicle above the explosion, is transmitted proximally through the lower limb [2]. Various traumatic platforms that replicate the physical incident and the respective loading environment have been used in the past to investigate the incident [3]. However, most of these experimental protocols set the lower limb at a 90°-90° seated posture prior to testing (Figure 1a). As suggested by NATO (HFM 198 report) the seated posture of a plantar-flexed ankle and a knee flexed less than 90° knee (Figure 1b) is as likely to be adopted by soldiers in military vehicles as the 90°-90° seated posture. The aim of this preliminary study was to investigate whether a different seated posture than 90°-90° alters the injurious outcome and the severity of an anti-vehicular attack.

Figure 1 – (a) 90°-90° and (b) 120°-120° posture of the seated occupant.

II. METHODS

Lower limb surrogates, including 2 fresh-frozen cadaveric lower limbs (male, 49 and 54 y.o.), and the lower limb of the Hybrid-III (H-III) dummy (Humanetics, MI, USA), were tested using the anti-vehicular under-body blast injury simulator (AnUBIS) at Imperial College London [4]. The accelerating plate of the rig was instrumented with two force sensors (200C20, PCB Piezotronics, NY, USA) located underneath the plantar hindfoot (heel) and the plantar forefoot (metatarsal heads), and with an accelerometer (350C23, PCB Piezotronics, NY, USA) (Figure 2) recording at 25 kHz. Measurements were recorded from both lower and upper tibial load cells of the H-III. Strain gauges were attached along the tibia and at the heel in the cadavers. High speed photography (Phantom v210, VRI, NJ, USA) was used to monitor the ankle region during the event. The signals from the accelerometers were filtered with a low-pass Butterworth filter of a cutting frequency of 1 kHz.

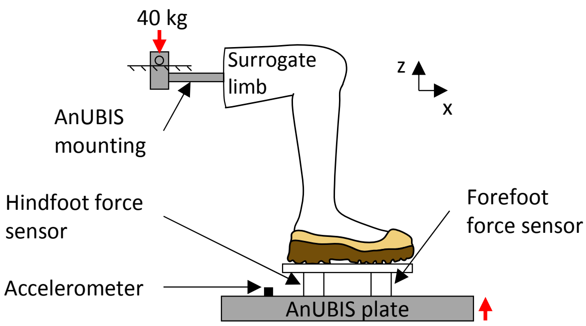

Figure 2 – Experimental setup.

Each of the cadaveric limbs was used for only one of the postures of interest (Figure 1). The angles of each

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setup were measured using a digital inclinometer. The Meindl Desert Fox combat boot (Lukas Meindl GmbH & Co, Germany) was put on all surrogates.

The characteristics of the loading scenario for both cadaveric tests were similar but different to those for the H-III tests as its load cells were expected to be overmatched (Table I). Therefore, all H-III tests were performed at a consistent, but lower severity to that of the cadavers. Since the aim of this study was to look at the effect of posture on injury, not to compare results between surrogates, this is not a limitation of this study.

TABLE I

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

Test	Surrogate	Posture	Peak velocity [m/s]	Time to peak velocity [ms]	Peak acceleration [g]	Time to peak acceleration [ms]
1	Cadaver	A	13.7	7.9	380	3.3
2	Cadaver	B	14.5	8.7	363	4.0
3	Hybrid-III	A	8.7	10.2	171	4.9
4	Hybrid-III	B	9.5	9.9	192	3.8

III. INITIAL FINDINGS

The comparison between postures using the Hybrid III suggests a higher likelihood of injury in posture A than in posture B (Figure 3a). Conversely, strain values (Figure 3b) and the injurious outcome of the cadaveric tests suggest the opposite, with the cadaver in posture B sustaining calcaneal and tibia-pilon fractures (Figure 3c) while the other did not sustain any skeletal injury. As only two cadaveric specimens were tested for this preliminary study, further investigations are required prior to concluding on the effect of the posture in the injurious outcome.

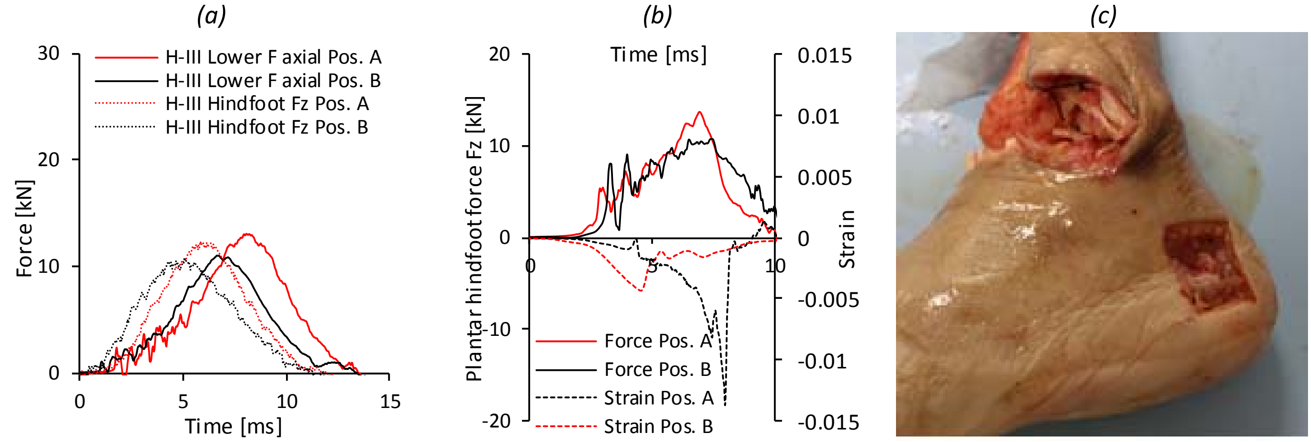

Figure 3 – (a) The axial force measured by the lower loadcell of the H-III and the hindfoot force measured by the plantar force sensor for both tests of different postures (Pos. A and B). (b) The hindfoot force measured by the plantar force sensor and the strain measured by a strain gauge located at the distal anterolateral side of the tibia. (c) Calcaneal and tibia pilon fractures were reported for the cadaver tested at Posture B.

IV. DISCUSSION

The results of this preliminary study suggest that seated postures different than the typical 90°-90° should be further investigated for their effect on the injurious outcome of anti-vehicular explosions. They also suggest that the force values obtained from the H-III dummy when its placement deviates from the typical 90°-90° might be substantially misleading if used to assess injury risk in the human lower extremity.

V. REFERENCES

[1] Ramasamy et al, J R Soc Interface, 2010
[2] Ramasamy et al, J Trauma Inj Infect, 2011
[3] Bailey et al, Int J Crashworthiness, 2017
[4] Masouros et al, Ann Biomed Eng, 2013