Human cadaveric bi-segment impact experiments at different postures

Alexandros K. Christou, Edward Spurrier, Grigoris Grigoriadis, Spyros D. Masouros*

I. INTRODUCTION

Modern insurgency warfare is characterised by the extensive use of indirect methods of attack, such as improvised explosive devices (IEDs) [1]. Victims of IEDs who have presented with spinal fractures in recent conflicts tend to have a high incidence of lumbar spine fractures [2]. Particularly for mounted victims, the injurious mechanisms for the spine in underbody blast are hypothesised to be primarily axial loading, combined with flexion [3]. Previous studies have looked into the injury threshold of thoracic and lumbar spines under axial loading, but not into the effect of posture on fracture [4]. Furthermore, experiments in compression conducted on either single segments or bi-segments did not focus into the effect of posture on fracture after impact [5-9] There is evidence in the literature, however, that posture affects the response of spinal motion units in quasi-static conditions [10]. This study aims to investigate the response of lumbar spine bi-segments in different postures under axial impact conditions.

II. METHODS

At the time of writing, three human cadaveric spines have been dissected (age 42–58, male) and T11-L1 bi-segments isolated. Muscle tissue was removed, while the major ligaments remained intact. The caudal and cranial vertebrae of each bi-segment were potted using bone cement. Desired postures were achieved by resting the vertebral bodies on 3D-printed wedges, placed at the bottom of each pot. Three potting postures were selected: (a) 10° flexion; (b) 0° flexion (neutral); and (c) 5° extension. Parallelisation of the pots was achieved by screwing the pots on tooling plates parallel to one another. Strain gauges were placed both on the vertebral body and the spinous process of T12. Each specimen was tested in a Dynatup 9250HV drop rig (Instron Inc., Norwood, USA) with a 7 kg weight at 3.5 m/s (Fig. 1 (a)). A stabilising ring, which disengaged at impact, was used to hold the caudal pot (top) horizontal. Forces were measured at the bottom using a 6-axis load cell (Sunrise Instruments, USA). A high-speed camera (Phantom V210, Vision Research, Ametek, USA) was used to capture displacements and fracture initiation. The impacted specimens were CT-scanned to identify the fracture pattern for each posture.

III. INITIAL FINDINGS

All three specimens fractured. Axial force histories for each posture are shown in Fig. 1 (b). Moments and axial force histories for the specimen in flexion are shown in Fig. 1 (c). Axial force and vertebral strain histories for the specimen in flexion are shown in Fig. 1 (d).

IV. DISCUSSION

A first step has been made to quantify the response of bi-segment spinal specimens under high-rate axial loading at different postures. Axial force to failure was similar for flexed and extended postures for this small sample size; the non-axial forces and the bending moments, however, were dissimilar between postures (Fig. 1 (e)). Whereas the desired segmental posture and stabilisation was achieved through potting, physiologically, this is achieved primarily through the muscles; at this stage it is unknown whether passive musculature affects injury. Due to the small number of samples it is possible that differences shown could be due to anatomical variability, however, they may also suggest that axial force alone is not adequate to predict injury in the lumbar spine. As metrics for spinal injury in surrogates take into account only the axial force [11], this programme of work may provide data for a better injury criterion and allow for a mechanistic understanding of the effects of posture on injury risk.

* A. K. Christou (tel: +44 20 75942646; e-mail: ac4012@imperial.ac.uk) is a Ph.D. student, E. Spurrier is a MD (Res) student and G. Grigoriadis is a Ph.D. student in the Royal British Legion Centre for Blast Injury Studies at Imperial College London, UK. S. D. Masouros is Lecturer in Trauma Biomechanics in the Department of Bioengineering, and the Blast Biomechanics Theme Lead in the Royal British Legion Centre for Blast Injury Studies, Imperial College London.

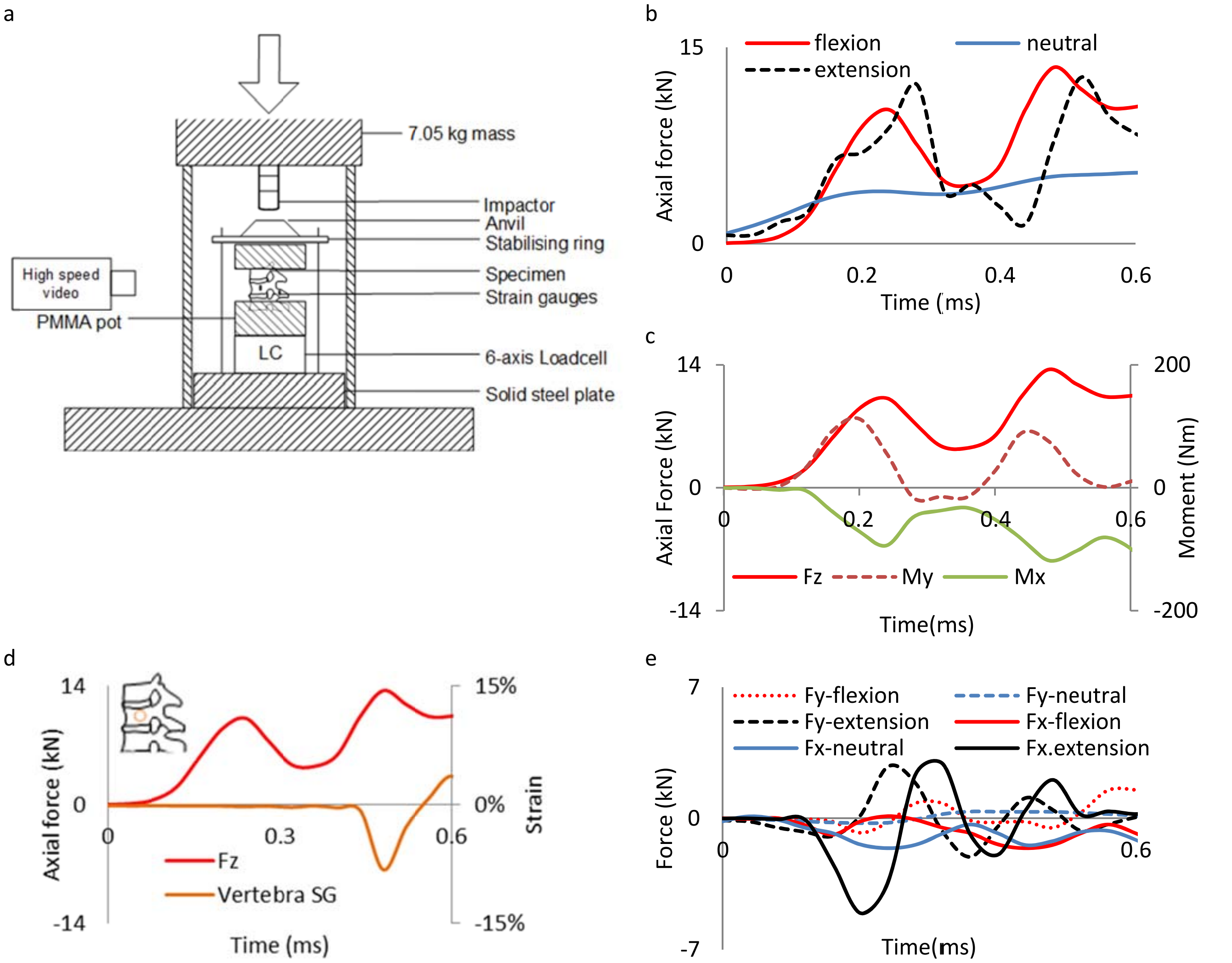

Fig. 1. (a) Diagram of the testing rig; (b) axial forces measured per posture; (c) example of measured moments in correlation to axial force during impact; (d) strains on the vertebral body – peak strain at the vertebral body and peak axial force occur at the time of fracture; (e) non-axial forces history per posture.

V. References

[1] Ramasamy, et al. *Phil. Trans. R. Soc. B*, 2011.
[2] Blair, et al. *J Bone Joint Surg Am*, 2012.
[3] Ragel, et al. *Spine*, 2009.
[4] Yoganandan, et al. *Ann Adv Automot Med*, 2013.
[5] Lochmüller, et al. Osteoporos Int,2008
[6] Moro, et al, Calcif Tissue Int, 1995
[7] Bürklein, et al, J Biomech, 2001
[8] Lagrana, et al, Spine, 2007
[9] Kemper, et al, Biomed Sci Instrum, 2007
[10] Adams and Hutton. *J. Bone Joint Surg. Br*, 1985.
[11] NATO HFM-090TG 25, 2007.