Human cadaveric bi-Segment impact experiments at different postures

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I. INTRODUCTION

Modern insurgency warfare is characterised by the extended use of indirect methods of attack, such as improvised explosive devices (IEDs) [1]. Victims of IEDs that have presented 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 under-body 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]. There is evidence in the literature, however, that posture affects the response of spinal motion units in quasi-static conditions [5]. 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 (Figure 1a). A stabilising ring that 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 Figure 1b. Moments and axial force histories for the specimen in flexion are shown in Figure 1c. Axial force and vertebral strain histories for the specimen in flexion are shown in Figure 1d.

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. Force and moment history profiles were obtained as well as strains on the T12 vertebra during impact. 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 (Figure 1e). These preliminary results may 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 [6], 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.

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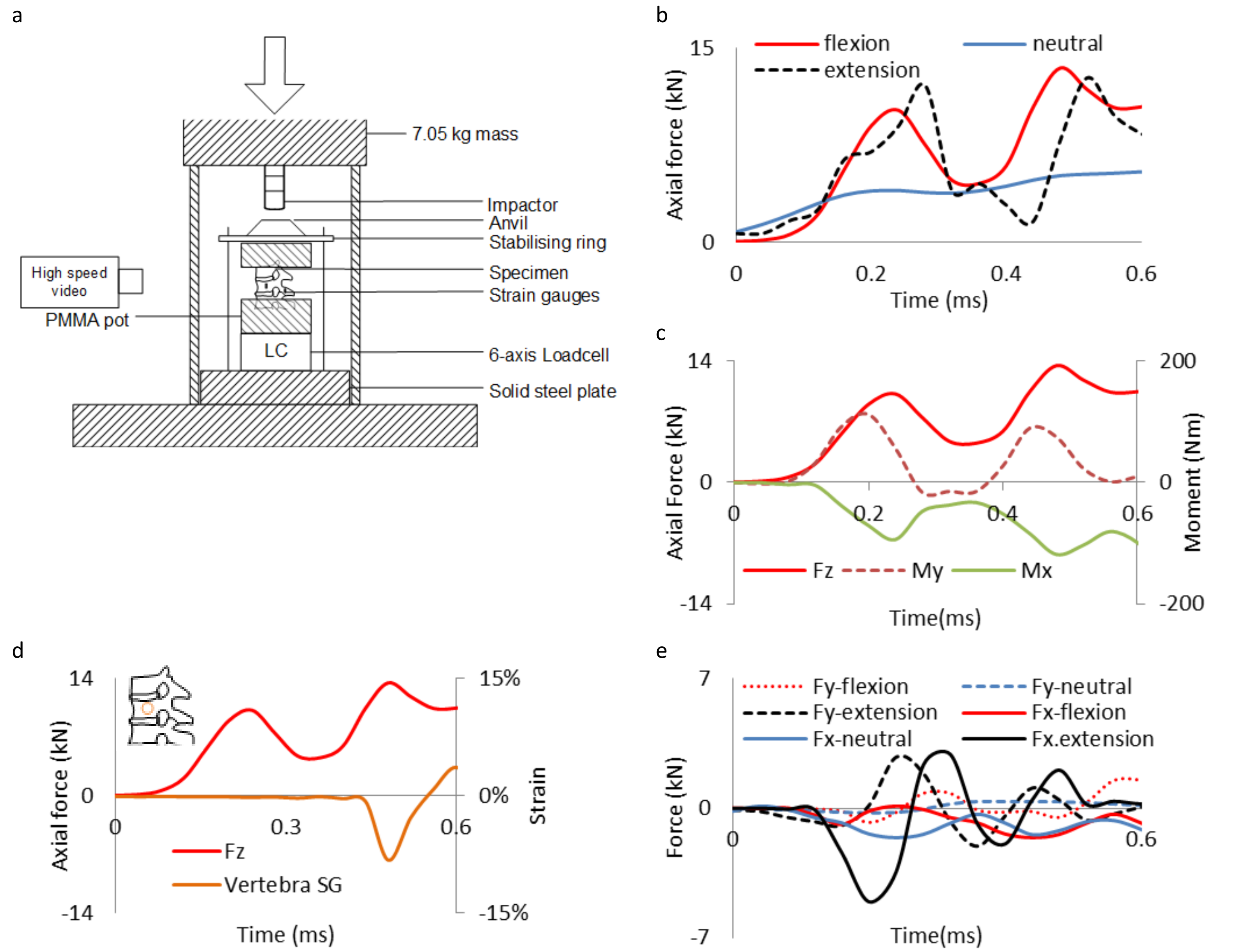

Figure 1: a) Diagram of the testing rig. b) Axial forces measured per posture. c) Example of measured moments in correlation to axial force during impact. d) strains on the vertebral body. Peak strain at the vertebral body and peak axial force occur at the time of fracture. e) Non-axial forces history per posture.

V. References

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