INCREASE IN BROADBAND EXCITATION IDENTIFIES VERTEBRAL ENDPLATE FRACTURES

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INTRODUCTION

Low back disorders impact up to 80% of workers during their lifetime [1-3]. Common injury sites include the intervertebral discs and vertebral endplates. One hypothesized mechanism of injury is cumulative loading, which results in changes to the load bearing behavior of the intervertebral joint [4-7]. Traditionally, failure identification has occurred from observation of decreases in motion segment height, changes in force-deformation response, and following dissection. The purpose of this study was to determine whether changes in acceleration could identify vertebral endplate failures.

METHODS

Cervical functional spinal units (FSUs), four C3/C4 and two C5/C6 (n=6), were dissected from porcine spines, with all surrounding musculature removed. FSUs were potted in aluminum cups and instrumented with tri-axial accelerometers (Series 2 Accelerometers, NexGen Ergonomics, Quebec, Canada). Specimens were mounted to a servo-hydraulic materials test system (Instron 8872, Instron, Norwood, MA), oriented with the axis of compression (Fig. 1). Specimens were loaded cyclically with an initial magnitude of 4 kN, at a rate of 2 Hz. After every 20 cycles, a 1 kN impulse load was applied. After 200 impulses, or 4000 cycles, the cyclic load magnitude was increased by 1 kN. This pattern was repeated until audible fracture (Fig. 2). Loading was designed to mimic lifting, with impulse load magnitudes similar to heel strikes.

Specimen axial compression was measured from materials test system crosshead displacement, applied load was measured from the materials test system load cell, and specimen acceleration was measured from the affixed accelerometers. Fracture was hypothesized to have occurred when acceleration magnitude exceeded 1.5x the maximum magnitude of the first loading cycle. Fracture presence in the endplate was determined following dissection.

RESULTS AND DISCUSSION

Of the six specimens, three reached the fracture threshold criteria of a 1.5x increase in acceleration magnitude. Specimens meeting the fracture threshold criteria all demonstrated high broadband excitation in acceleration after predicted fracture occurrence (Fig. 3). All specimens determined as fractured by the threshold criteria possessed major fractures upon dissection (Fig. 4). Three specimens did not meet the threshold requirement in increased acceleration response. These specimens either had minor fractures of the endplate or damage to the underlying trabecular bone.
The change in acceleration response following fracture occurred before a significant change in displacement response, suggesting that broadband acceleration may be more sensitive than force-deformation. Initial small changes to broadband excitation correspond to hypothesized micro-fracture development before eventual specimen failure.

Figure 2: Compressive load applied to the cephalad vertebrae of cervical functional spinal units (top). Displacement response of representative specimen (bottom).

Figure 3: Acceleration response of a representative specimen during loading (same specimen as Fig. 2).

CONCLUSIONS

Clear differences were determined in acceleration response between intact and fractured FSUs. The presence of broadband excitation may be useful as a tool to determine the presence of some vertebral endplate fractures. Broadband acceleration response appears to be sensitive to the type and severity of endplate fracture. This may reflect a limitation with this method, specifically, the need for post-test fracture identification. This approach also has limited capability for identifying the exact cycle of fracture initiation.

In future work, correlation between initiation of increases in broadband excitation and changes in force-deformation response will be performed. This may allow for increased characterization of fracture behavior. Prediction of some types of fractures, including micro-fracture formation, may be possible by detection of increases in broadband excitation. Evaluation of changes in acceleration response following fracture may lead to insights in fracture development and propagation.

Figure 4: Functional spinal unit, meeting threshold criteria, with typical fracture (same specimen as Fig. 2). Specimens with major endplate fractures exhibited high levels of broadband excitation, following hypothesized fracture initiation.

REFERENCES


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