Ring Apophysys Fractures Under Simulated Activities of Daily Living: a Cervine Model

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INTRODUCTION:

Ring apophysis fractures (RAFs) are avulsion type fractures to the posterior aspect of the lumbar vertebral body, which initiate at the ring apophysis and propagate either anteriorly or through the vertebral endplate. These fractures result in low back pain, limited mobility, and often present along with intervertebral disc herniation. A dominant risk factor of RAFs is incomplete ossification of the ring apophysis (complete ossification occurs at approximately age eighteen), causing this type of injury to be associated most frequently with otherwise healthy, active young people [1]. As many patients presenting with RAFs cannot recall a single traumatic event prior to the onset of symptoms, it is presumed that these fractures may be initiated by normal activities of daily living (ADLs), during which the most common movement for the lumbar spine is flexion of less than 15° [2]. We hypothesize that application of low-load, low-angle cyclic flexion in an ex-vivo model (absent of bone remodeling) will induce RAFs resulting in both biomechanical and radiographical symptoms. This hypothesis was tested by applying cyclic flexion to 5-vertebra motion segments obtained from white tailed deer (O. virginianus), of a similar degree of skeletal maturity to adolescent humans.

METHODS:

Six cervine [3-4] lumbar vertebral motion segments (L1-L5) (male, 2.67 ± 0.52 years) were prepared (Nolt’s Custom Meat Cutting, Lowville, NY) and potted as in [3]. Initial imaging was completed to rule out any bone pathologies; x-rays (MultiX X-Ray System, Siemens, Berlin, Germany), DXA (dual-scan (Phoenix Nanotom, General Electric, Wunstorf, Germany) were collected. No specimens had observable disc damage or osteophyte formation as indicated from the µCT scans. The bone mineral density (BMD) was 1.182 ± 0.155 g/cm² which is comparable to the BMD of healthy human bone. A Six cervine [3-4] lumbar vertebral motion segments (L1-L5) (male, 2.67 ± 0.52 years) were prepared (Nolt’s Custom Meat Cutting, Lowville, NY) and ex-vivo from white tailed deer (O. virginianus), of a similar degree of skeletal maturity to adolescent humans.

RESULTS:

The peak load decreased non-linearly (see Figure) throughout the cyclic loading, suggesting that both disc relaxation and vertebral damage occurred. Articular facet failure was observed during cyclic loading for all motion segments; some specimens failed as early as 1,400 cycles. The location of the RAF corresponded to the articular facet level failure during cyclic loading. During monotonic compression to further failure, the average failure load was 240 ± 146N, which is substantially smaller than previously-reported failure loads using fixed end conditions [5]. This suggests that the pinned end loading conditions used here are more physiologically realistic than fixed end loading and should be used to create physiologically realistic fractures.

DISCUSSION:

This work shows that ring apophysis fractures can occur during low-angle low-load repetitive flexion in an ex-vivo model (2-3 year old deer) mimicking the degree of skeletal maturity of patients who typically present with this type of injury. The difference in fracture type, in contrast to similar studies with fixed-end conditions [5], suggests that cyclic flexion, rather than monotonic compression, is an initiator of RAFs. The smooth change in load-displacement curves and hysteresis loops suggests that the fractures occurred without trauma. RAFs (three Type I and three Type II) were created in all specimens. Future work will include identification of additional potential risk factors for RAFs, including common parameters used to describe trabecular geometry and the presence of pre-existing intervertebral disc damage.

SIGNIFICANCE:

These results show that ring apophysis fractures can occur during ADLs, suggesting that health care providers need to consider small movement ADLs in fracture risk assessment. Furthermore, prevention education and patient specific exercise regimens could be developed to prevent RAFs.

REFERENCES:


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Figure: Schematic of test set-up, hysteresis loops before and after fracture, and Ring Apophysis Fracture µCT scan.