THE EFFECT OF AGE ON THE MECHANICAL PROPERTIES OF PORCINE INTERVERTEBRAL DISCS FOLLOWING A CYCLIC LOADING PROTOCOL

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INTRODUCTION

The North American working population is aging. American workers over 55 comprised 19% of the labour force in 2010 [1] and the proportion of Canadian workers over 55 increased by 21.7% between 1997 and 2010 [2]. Occupational injuries sustained by American workers 65 and older resulting in a lost-time claim increased by 6.4% between 2007 and 2008 [3]. The low back was the body location ranked highest in number of injuries sustained among Ontario workers in 2013, accounting for 17% percent of all lost time claims, with the leading demographic group 50-54 year old males [4]. A mechanistic understanding of the age-related responses to loading in spinal tissues is essential to the prevention of low back injury throughout the aging process. Known age-related changes to the intervertebral discs (IVDs) of the spine include; the denaturation of collagen fibres [5], reduction/altered distribution of proteoglycans [6] and an increased propensity to form microstructural clefts in response to tensile loading when compared to more juvenile samples [7]. The formation of clefts is a known mechanism of initiation and propagation of an IVD herniation [8]. The aim of this investigation was to quantify the effect of age on the mechanical properties of annulus fibrosis tissue following exposure to cyclic loading.

METHODS

A total of 8 (4 mature, 4 young) cervical functional spinal units (FSUs) were obtained fresh-frozen from mature (aged ~3 years) and immature (aged ~6 months) porcine spines. The FSUs included two adjacent vertebral bodies with the intervening disc and were tested in a modified servohydraulic testing system (Model 8872, Instron Canada, Burlington, ON, CAN). To counteract post-mortem swelling, specimens were loaded with 300 N of compression for 15 min while the zero moment posture about the flexion/extension axis was determined. Following the preconditioning phase, specimens were loaded with 1400 N of compression and cyclically loaded at 1 Hz to a range of motion 8.5 degrees in flexion and extension around the midpoint of each specimen's neutral zone for 3000 cycles.

Following the cyclic loading protocol, specimens underwent further biaxial mechanical testing to determine how age impacts the mechanical properties of the annulus following loading exposure. A total of 12 (6 mature, 6 young) anterio-lateral annular specimens were excised from the intermediate layers of the IVD with an average (SD) thickness of 0.9 (0.2) mm and comprised of 3-5 annular layers. The specimens were tested in a humidity and temperature-controlled environment of 30 (1.4) degrees Celsius and 94.3 (1.5) % humidity to prevent dehydration. Specimens were dissected to dimensions of approximately 5 mm x 5 mm and mounted into a biaxial tensile (BioTester 5000, CellScale, Waterloo Instruments Inc., Waterloo, ON, CAN) testing system by puncturing the edges with sharpened tungsten wires. Following the mounting procedure, specimens were preloaded in the axial and circumferential directions with 10-15 mN, followed by preconditioning of 5 cycles of 10% actuator stretch at a rate of 1%/s and subsequently loaded to 20% actuator stretch for 100 cycles at a rate of 2%/s.

Dependent measures of interest included neutral zone range (degrees) and neutral zone stiffness (Nm/degree) both pre and post loading protocol for intact FSUs. Additionally, peak stress (MPa) in the circumferential and axial directions for excised annular samples during cycles 1, 50 and 100 were examined.

RESULTS AND DISCUSSION

Of the 8 FSU specimens tested; sagittal plane radiographs indicated that 2 of the specimens (1 young, 1 mature) sustained a herniation due to the loading protocol. There was a significant effect of age on neutral zone range (p=0.0448) where mature specimens had a smaller range before and after the loading protocol compared to the younger specimens (Figure 1). There was a main effect of age on neutral zone stiffness (p=0.0446) where mature FSUs had greater stiffness compared to younger specimens (Figure 2). There was no main effect of the loading protocol on neutral zone range or neutral zone stiffness.

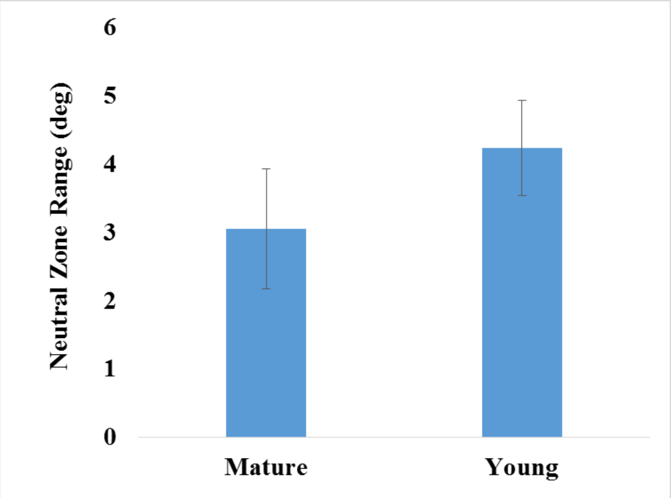

Figure 1: Neutral zone range by age across time point

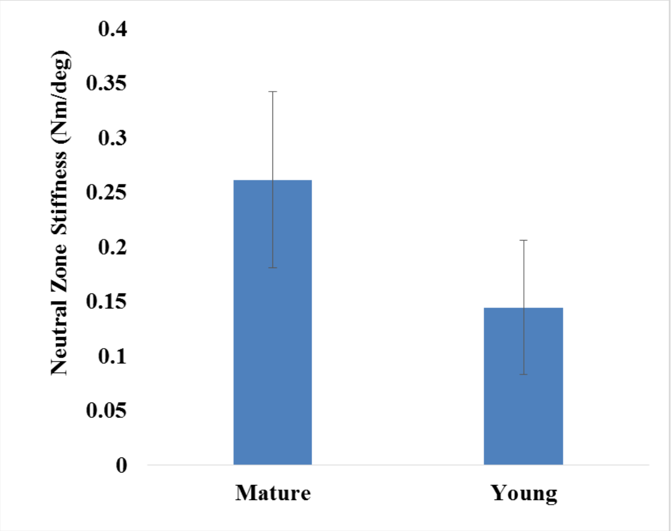

Figure 2: Neutral zone stiffness by age across time

Decreased specimen flexibility among the mature FSUs is consistent with previous work [9]. There was no main effect of age or cycle on the peak stress. While not statistically significant, Figure 3 depicts a trend consistent in both loading directions of higher peak stress in the mature specimens compared to the young specimens with an overall reduction in peak stress with a more cycles.

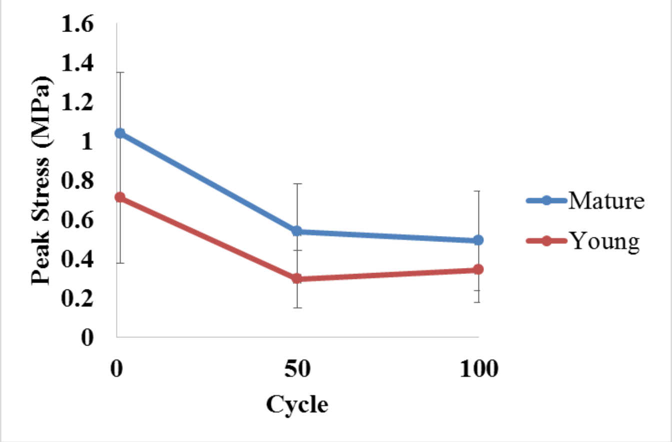

Figure 3: Peak stress in the circumferential direction by age and cycle

Ongoing work continues on samples excised from the posterio-lateral location of the annulus and on mature and young annular samples in the absence of cyclic loading in order to isolate any innate differences due to aging alone. The results from this work will provide insight into differences in the responses to loading due to age. The biological changes and the cumulative exposures that occur throughout the aging process are important to understanding the mechanisms of injury given an aging workforce.

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