

THE EFFECT OF PROLONGED VIBRATION EXPOSURE ON THE TENSILE MECHANICAL PROPERTIES OF SINGLE LAYERS OF THE ANNULUS FIBROSUS

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INTRODUCTION

Disc herniation is an injury to the annulus fibrosus (AF) of the intervertebral disc. It is characterized by the posterior migration of the nucleus pulposus through the AF tissue. The migration progresses through clefts in the layers of the AF that have formed as a result of cyclic tension in the posterior annular layers. Exposure to vibration may increase the risk of herniation. In particular, vibration has been shown to reduce proteoglycan synthesis in the AF [1, 2], which in turn may reduce the strength of the tissue, making it more susceptible to cleft formation. Further, cyclic loading has resulted in decreased strength in ligament tissue [3] and could plausibly have a similar effect on AF tissue. The purpose of this investigation was to determine any differences between the mechanical properties of single AF layers harvested from discs that were exposed to prolonged axial vibration versus control discs.

METHODS

Thirty-two single layer AF tissues were harvested from porcine intervertebral discs obtained from the cervical spine levels C34 and C56. Sixteen of these tissues were harvested from discs subjected to two hours of vibration and the remaining 16 tissues from control discs. The intervertebral discs that were vibrated were subjected to 1400N of axial compressive load that was cyclically loaded to +/- 10% load (140N) at a rate of 5Hz. The control discs were subjected to 1400N of static axial compressive load for two hours.

The 32 single layer tissues were obtained from the anterior and posterior AF as well as from both superficial and deep sections. Each tissue sample was mounted in a custom biaxial tensile testing system (BioTester 5000, CellScale, Waterloo Instruments Inc, Ontario, Canada), such that strain

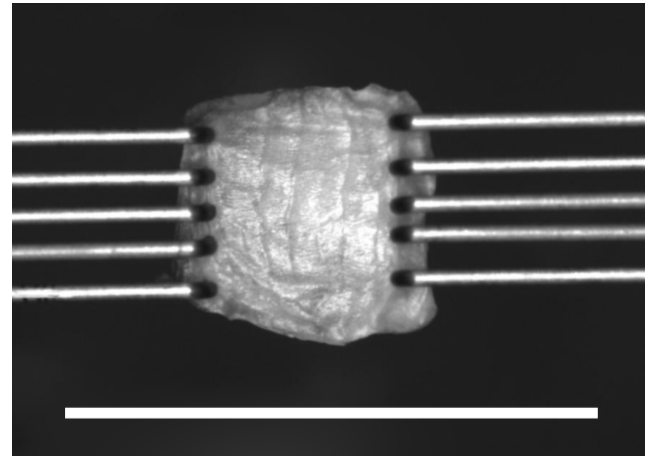


Figure 1: Single layer annulus fibrosus tissue mounted via rakes in strain-control testing apparatus. Note the vertically aligned collagen fibres. White horizontal bar represents 10 mm.

was applied perpendicular to the orientation of the collagen fibres (Figure 1). Tissues were preconditioned with three repeats of 10% strain at a rate of 1% strain/sec and subsequently strained at 2% strain/sec until failure. Variables of interest obtained from the stress-strain curve were maximum stress, strain at maximum stress, elastic modulus, length of toe region (% strain), and stress at the end of the toe region. A 4-way ANOVA was used to determine the effect of condition (2 levels: vibrated versus control); cervical level (2 levels: C34 versus C56); tissue depth (2 levels: superficial versus deep); and tissue location (2 levels: anterior versus posterior). A significance level of 0.05 was used.

RESULTS AND DISCUSSION

The tissues harvested from discs that were subjected to vibration did not demonstrate differences in the elastic modulus, maximum stress, and strain at maximum stress (Table 1). Vibrated tissues did,

however, have significantly larger toe regions, with a mean toe region of 50% strain (S.D. 33%) as compared to control tissues which had a mean toe region of 31% strain (S.D. 15%) ($p = 0.027$). The stress at the end of the toe region was not significantly different between the control and vibrated tissues (Table 2).

No significant effect of spinal level, tissue depth, or tissue location was observed.

It is generally accepted that the toe region of the stress-strain curve of connective tissues occurs as a result of collagen fibre uncrimping. However, due to the perpendicular orientation of these tissues, it is unlikely that the toe region seen here can be explained by such fibre reorientation. Rather, it is more likely that the toe region represents strain in the matrix that connects collagen fibres to one another in parallel. A larger toe region may therefore represent initial damage in this matrix. This initial damage may eventually result in the ability for the nucleus pulposus to migrate through each layer of the AF with greater ease and therefore increase the risk of disc herniation. Further, an increased toe region may be indicative of increased

laxity and altered joint mechanics in the intervertebral disc as a whole.

CONCLUSIONS

This study suggests that prolonged axial vibration may potentially result in the initiation of injury to the AF, specifically to the inter-collagen matrix. This damage has the potential to transcribe into an increased risk of sustaining disc herniation by allowing the nucleus pulposus to migrate through the layers of the AF with greater ease.

Further research is required to assess the effect of vibration on the complete intact intervertebral disc and to determine if vibration does increase the risk of disc herniation.

REFERENCES

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Table 1: Average (standard deviation) values collapsed across cervical level (C34 and C56), tissue depth, and tissue location for the control tissues and the vibrated tissues. For each variable between control and vibrated tissues, the p-value was greater than 0.05 (not statistically significant).

	Elastic Modulus (MPa)	Maximum Stress (MPa)	Strain at Max Stress (%)
Control (n=16)	3.41 (2.61)	1.44 (1.26)	117 (50)
Vibrated (n=16)	2.91 (2.06)	1.62 (1.63)	115 (43)

Table 2: Average (standard deviation) values obtained from toe region of the stress-strain graph collapsed across cervical level (C34 and C56), tissue depth, and tissue location for the control tissues and the vibrated tissues. Only the toe region length was significantly different between the control and vibrated tissues ($p=0.027$).

	Toe Region Length (% Strain)	Stress at End of Toe Region (MPa)
Control (n=16)	31 (15)	0.33 (0.24)
Vibrated (n=16)	50 (33)	0.59 (0.63)