Biomechanical and Somatosympathetic Responses to Spinal Manipulation in an In Vivo Model of Cervical Intervertebral Disc Degeneration

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Introduction. Cervical disc degeneration is a common finding among patients presenting for spinal manipulative care. Few biomechanical studies have examined the kinematics of the degenerated cervical spine or its response to spinal manipulation. The objective of this prospective *in vivo* experimental animal study was to determine the effects of intervertebral disc (IVD) degeneration on the dynamic dorsoventral (DV) cervical spine stiffness and subsequent neuromechanical responses to spinal manipulation.

Methods. Adolescent merino wethers (n=24, mean 50.1 kg) were mechanically tested *in vivo* using a previously validated technique to quantify DV stiffness. Twelve sheep randomly received induced anular injury via scalpel wound a minimum of four months earlier that resulted in degeneration of the C4-C5 intervertebral disc. Twelve age and weight-matched animals served as controls having cervical spine exposure surgery only without anular contact. Dynamic swept-sine mechanical loads were applied (~5% body weight) from 0.5 to 19.7 Hz (pseudo-chirp sweep) to the C6 spinous process under load control and with the animals lying prone on an operating table. DV cervical spine stiffness (load/deformation, N/mm) at C6 was determined from six trials in each animal at 32 distinct loading frequencies.

Tri-axial accelerometers were rigidly attached to steel pins implanted into the spinous process of C4 and C5, four needle electromyographic (nEMG) electrodes were inserted adjacent, and following surgical exposure, bipolar platinum electrodes were cradled around the left C5 spinal nerve root and nearby sympathetic chain. Spinal manipulative thrusts were delivered to C4 with an Impulse Adjusting Instrument and three trials of repeated (6 Hz) impulsive (~100 N, 2 ms) thrusts were administered by a clinician blinded to the groups. Dynamic cervical spine stiffness, vertebral accelerations, nEMG, spinal nerve root and sympathetic responses were compared between animals with cervical disc degeneration and controls using a one-way ANOVA with repeated measures. Post-hoc analysis with Bonferroni correction was used when significant differences were observed.

Results. Histological analyses confirmed anular disruption and degradation in the disc degeneration group. Dynamic DV spinal stiffness ranged from 4.33 N/mm (1.8 Hz) to 7.69 N/mm (10 Hz) for animals with disc degeneration and 3.62 N/mm (1.8 Hz) to 6.00 N/mm (13.1 Hz) for control animals, respectively. Dorsoventral stiffness at C6 was significantly increased at 31 of 32 mechanical excitation frequencies ($p<.05$) among animals with cervical disc lesions (all frequencies mean = 7.32 N/mm) compared with control animals (all frequencies mean = 5.47 N/mm). In response to spinal manipulation, vertebral accelerations were significantly reduced in four of six axes in the animals with disc degeneration ($p<.05$) while a significant reduction in nEMG response was observed. Marked spinal nerve root and sympathetic responses occurred during manipulation, however, there was no difference in these responses among the groups with and without disc lesions.

Conclusion. In vivo dorsoventral vertebral motions of the cervical spine are significantly reduced in animals with degenerated discs which in turn influences neuromechanical responses to spinal manipulation. These biomechanical findings may be useful in understanding the biomechanical consequences of cervical IVD pathology and their contribution in patients undergoing spinal manipulative care.