Effects of Unilateral Facet Fixation and Facetectomy on Muscle Spindle Responsiveness During Simulated Spinal Manipulation in an Animal Model

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Abstract

Objectives: Manual therapy practitioners commonly assess lumbar intervertebral mobility before deciding treatment regimens. Changes in mechanoreceptor activity during the manipulative thrust are theorized to be an underlying mechanism of spinal manipulation (SM) efficacy. The objective of this study was to determine if facet fixation or facetectomy at a single lumbar level alters muscle spindle activity during 5 SM thrust durations in an animal model.

Methods: Spinal stiffness was determined using the slope of a force-displacement curve. Changes in the mean instantaneous frequency of spindle discharge were measured during simulated SM of the L_6 vertebra in the same 20 afferents for laminectomy-only and 19 laminectomy and facet screw conditions; only 5 also had data for the laminectomy and facetectomy condition. Neural responses were compared across conditions and 5 thrust durations (≤250 milliseconds) using linear-mixed models.

Results: Significant decreases in afferent activity between the laminectomy-only and laminectomy and facet screw conditions were seen during 75-millisecond ($P < .001$), 100-millisecond ($P = .04$), and 150-millisecond ($P = .02$) SM thrust durations. Significant increases in spindle activity between the laminectomy-only and laminectomy and facetectomy conditions were seen during the 75-millisecond ($P < .001$) and 100-millisecond ($P < .001$) thrust durations.

Conclusion: Intervertebral mobility at a single segmental level alters paraspinal sensory response during clinically relevant high-velocity, low-amplitude SM thrust durations (≤150 milliseconds). The relationship between intervertebral joint mobility and alterations of primary afferent activity during and after various manual therapy interventions may be used to help to identify patient subpopulations who respond to different types of manual therapy and better inform practitioners (eg, chiropractic and osteopathic) delivering the therapeutic intervention.

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Key Indexing Terms: *Manipulation Spinal; Muscle Spindle; Zygapophyseal Joint; Neurons Afferent; Chiropractic*

Intervertebral hypomobility can be described as an increase in spinal stiffness or a reduction in motion between adjacent spinal segments. Conversely, intervertebral hypermobility represents decreased spinal stiffness and increased intervertebral motion. Clinical diagnoses associated with spinal joint hypomobility include degenerative joint disease including facet degeneration, osteophyte formation, or increased tears in the innervated outer rim of the intervertebral disks that are often associated with low back pain (LBP).[1-8] Increased or excessive joint motion has been clinically associated with rheumatoid arthritis, joint hypermobility syndrome, spondylolisthesis, facet/disk degeneration, and LBP.[9-15]

Spinal manipulation, which typically is applied to improve aberrant vertebral motion, has been shown to be clinically effective in the treatment of both neck pain and LBP.[8,16-18] Therapeutic benefits have been ascribed to mechanically breaking adhesions in hypomobile zygapophyseal joints[19-22] and/or to the subsequent neurophysiologic consequences associated with improved vertebral joint motion.[23-25] Greater clinical efficacy may be found by identifying responsive subpopulations based on their spinal stiffness or intervertebral joint mobility.[8,26-28] In a randomized clinical trial, Fritz et al[8] categorized 131 patients with LBP with respect to the clinical determination of

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spinal joint hypomobility and hypermobility and found that spinal manipulation produced higher therapeutic success rates in participants with spinal joint hypomobility compared with those with spinal joint hypermobility. Participants with spinal joint hypomobility had treatment success rates of 74% after receiving spinal manipulation combined with stabilization exercises vs 25.6% after receiving stabilization exercises alone. In contrast, participants with spinal joint hypermobility had success rates of only 16.7% with spinal manipulation combined with stabilization exercises but 77.8% with stabilization exercises alone. The mechanisms responsible for this treatment effect are unknown, but alterations in sensorimotor processing due to intervertebral joint dysfunction may be a contributing factor.[24]

Patients with LBP have shown a variety of sensorimotor abnormalities including abnormal reflex responses indicated by reduced reflex gain and slowed reaction latencies,[29-32] impaired lumbosacral proprioceptive acuity,[33-37] dysfunction in trunk muscle response and control,[38-42] altered postural balance strategies,[30,43,44] and higher spinal loads during highly controlled exertions.[45] Many of these abnormalities are consistent with alterations in sensory feedback from the paraspinal tissues. Spindles in paraspinal muscles provide the central nervous system with sensory information regarding changes in muscle length and shortening velocity and thus are the proprioceptors most likely reporting changes in intervertebral position and aberrant vertebra movement. Pickar and Kang[46] and Ge and Pickar[47] have shown that very small displacements (0.5-1.0 mm) of lumbar vertebra evoke muscle spindle discharge from paraspinal muscles and that sustained vertebral positions can affect the accuracy of proprioceptive signaling.

The apparent relationship between intervertebral joint mobility and the clinical success of spinal manipulation for LBP, combined with increasing evidence for proprioceptive-related changes in individuals with LBP, led us to undertake a basic science investigation to determine the relationship between changes in lumbar spinal stiffness and mechanoreceptor activity from muscle spindles in the low back during a simulated high-velocity, low-amplitude spinal manipulation (HVLA-SM) in an animal preparation. The purpose of this study was to determine whether relative increases vs decreases in spinal stiffness can impact paraspinal sensory responses for 5 thrust durations of HVLA-SM directed at the same level as the dysfunction. This study aims to be an important first step in concurrently examining the effects of intervertebral dysfunction and peripheral afferent signaling during a commonly used and effective therapeutic intervention for LBP.

Methods

All experiments were reviewed and approved by our Institutional Animal Care and Use Committee. Electrophysiological activity in single primary afferent fibers from muscle spindles was obtained during HVLA-SM of the lumbar spine in 23 male cats weighing an average (SD) of 4.46 (0.31) kg. One afferent was investigated per cat because of the irreversible nature of the $L_{5/6}$ facetectomy surgical procedure.

General Procedures

The surgical procedures and device used to apply simulated spinal manipulations have previously been described in detail.[48,49] Briefly, anesthesia was induced using isoflurane and catheters placed in a carotid artery and an external jugular vein to monitor blood pressure and introduce fluids respectively. Deep anesthesia was then maintained throughout the experiment with nembutal (35 mg/kg, intravenously). The trachea was intubated, and the cat was ventilated mechanically. Arterial pH, P_{CO_2}, and P_{O_2} were monitored and maintained within the reference range (pH 7.32-7.43; P_{CO_2}, 32-37 mm Hg; P_{O_2}, >85 mm Hg). The right sciatic nerve was cut to reduce afferent input from the hindlimb. The lumbar spine was mechanically secured at the L_4 spinous process and the iliac crests using a Kopf spinal unit (David Kopf Instruments, Tujunga, CA). The L_5 laminae and caudal half of the L_4 laminae were removed to expose the L_6 dorsal rootlets. All intervertebral disks and facet joints remained intact. The dura mater was incised, and the L_6 dorsal root was cut close to the spinal cord. Thin filaments from the cut proximal dorsal rootlets were teased using forceps until impulse activity from a single afferent was identified. The L_6 spinal nerve innervates the fascicles of the multifidus and longissimus muscles attaching to the L_6 vertebra.[50] Action potentials were recorded using a PC-based data acquisition system (Spike 2; Cambridge Electronic Design, Cambridge, UK).

Calibrated nylon monofilaments (Stoelting, Wood Dale, IL) were applied to the exposed back muscle (longissimus or multifidus) to verify the location of the most sensitive portion of the afferent's receptive field. Afferents were identified as muscle spindles based on their increased discharge to succinylcholine (100-400 mg/kg; Butler Schein, Dublin, OH), decreased discharge to electrically induced muscle contraction, and sustained response to a fast vibratory stimulus.[51-53] Animals were euthanized at the end of the experiment by an intravenous overdose of pentobarbital.

Determination of Spinal Stiffness

Changes in spinal stiffness relative to a laminectomy-only control condition were created by unilateral (left) $L_{5/6}$ facet-fixation (to increase intervertebral stiffness) or $L_{5/6}$ facetectomy (to decrease intervertebral stiffness). A previous study using a similar feline model showed that the average spinal stiffness did not differ significantly before and after the laminectomy procedure itself.[54] Stiffness