Effect of Spinal Manipulation Thrust Duration on Trunk Mechanical Activation Thresholds of Nociceptive-Specific Lateral Thalamic Neurons

William R. Reed, DC, PhD,[a] Randall Sozio, BS, LATG,[b] Joel G. Pickar, DC, PhD,[c] and Stephen M. Onifer, PhD[a]

Abstract

Objective: The objective of this preliminary study was to determine if high-velocity, low-amplitude spinal manipulation (HVLA-SM) thrust duration alters mechanical trunk activation thresholds of nociceptive-specific (NS) lateral thalamic neurons.

Methods: Extracellular recordings were obtained from 18 NS neurons located in 2 lateral thalamic nuclei (ventrolateral [n = 12] and posterior [n = 6]) in normal anesthetized Wistar rats. Response thresholds to electronic von Frey anesthesiometer (rigid tip) mechanical trunk stimuli applied in 3 lumbar directions (dorsal-ventral, 45° caudal, and 45° cranial) were determined before and immediately after the delivery of 3 HVLA-SM thrust durations (time control 0, 100, and 400 milliseconds). Mean changes in mechanical trunk activation thresholds were compared using a mixed model analysis of variance.

Results: High-velocity, low-amplitude spinal manipulation duration did not significantly alter NS lateral thalamic neurons' mechanical trunk responses to any of the 3 directions tested with the anesthesiometer.

Conclusions: This study is the first to examine the effect of HVLA-SM thrust duration on NS lateral thalamic mechanical response thresholds. High-velocity, low-amplitude spinal manipulation thrust duration did not affect mechanical trunk thresholds. (J Manipulative Physiol Ther 2014;37:552-560)

Key Indexing Terms: *Manipulation; Spinal; Thalamus; Nociceptive Neuron; Lumbar Vertebrae; Chiropractic*

Spinal manipulation has been shown to be effective in treating neck and low back pain.[1-3] Not only are the neurophysiological mechanisms by which this occurs unknown, but a lack of knowledge also exists regarding the effects of clinician-controlled mechanical application parameters of spinal manipulation on neural response. Clinician-controlled mechanical parameters that could potentially impact clinical outcomes of spinal manipulation include the following: magnitude and/or duration of preload, thrust magnitude, thrust duration and the consequent thrust rate, contact point, and/or loading direction relative to patient position.[4,5] Basic and clinical studies aimed at determining the relationship between these various mechanical delivery parameters of spinal manipulation and their effects on neurophysiological, biomechanical, and/or patient outcome measures are just beginning to be reported in the literature.[4-14] Once delineated, these findings could markedly improve and eventually optimize the utilization and effectiveness of spinal manipulation.

Numerous studies show that high-velocity, low-amplitude spinal manipulation (HVLA-SM) immediately increases mechanical pressure pain thresholds (ie, decreases sensitivity) in both symptomatic and asymptomatic individuals.[15-24] These hypoalgesic effects occur both unilaterally and bilaterally as well as proximally and distally to the manipulation site. Evidence from animal models[25-29] demonstrates that manual therapy applied to rats affects mechanical withdrawal thresholds in areas of the body

[a] Associate Professor, Palmer Center for Chiropractic Research, Davenport, IA.
[b] Research Associate, Palmer Center for Chiropractic Research, Davenport, IA.
[c] Professor Emeritus, Palmer Center for Chiropractic Research, Davenport, IA.
Submit requests for reprints to: William R Reed, DC, PhD, 741 Brady St, Davenport, IA 52803.
(e-mail: *william.reed@palmer.edu*).
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distant to those being treated, which is consistent with reported clinical findings. Collectively, this clinical and experimental evidence suggests that HVLA-SM alters central processing of sensory input.

Gillette[30] speculated that as many as 40 types of mechanoceptive endings (innocuous as well as nociceptive) in cutaneous and deep paraspinal tissues could be stimulated by spinal manipulation due to their mechanical activation thresholds being below the magnitude of mechanical force applied during a spinal manipulation. Although convergence and modulation of sensory input are known to occur at the level of the spinal cord,[31] neuroimaging studies in humans and animals have also demonstrated decreased activation in supraspinal structures involved in pain processing after manual therapy intervention.[32-34]

The thalamus is a subcortical structure of research interest to manual therapy due to the fact that most ascending somatosensory input converges in it and output from it has the capacity to influence descending projections to nociceptive pathways in the spinal cord dorsal horn.[35-37] It receives axonal projections from the spinal cord that relay innocuous (dorsal column pathway) and nociceptive (spinothalamic pathway) input from peripheral receptors.[35] These receptors are presumably stimulated by spinal manipulation and theoretically are thought to impact central mechanisms including thalamic neurons.[30,38-40] Moreover, there is anatomical evidence of direct projections between the thalamus and subcortical descending pain modulating structures such as the periaqueductal gray (PAG).[41-44] Just recently, reciprocal short latency (~5 milliseconds) interactions between the thalamus and PAG have been shown in humans to be associated with pain relief.[44] Increasing electrophysiological and neuroreceptor activation evidence implicates thalamic participation in an endogenous analgesic system, which is considered responsible (at least in part) for acupuncture-induced analgesia.[37,45-47] Because acupuncture and spinal manipulative interventions both mechanically stimulate receptors in superficial and deep peripheral tissues, they may share a common mechanism of action via the thalamus.

Experimental efforts to better understand the neural effects of spinal manipulation at different levels of central ascending and descending nociceptive processing are needed to help elucidate the mechanisms responsible for its near immediate hypoalgesic effects. Furthermore, identifying which (if any) of the clinician-controlled mechanical parameters of a spinal manipulation can affect convergent ascending central processing will provide critical insight into the central mechanisms and clinical variables responsible for the positive clinical outcomes of spinal manipulation. Toward addressing these areas, a preliminary study was conducted to determine whether HVLA-SM thrust duration alters mechanical trunk activation thresholds of adult rat nociceptive-specific (NS) neurons in lateral thalamic nuclei.

Methods

All methods were approved by the Palmer Institutional Animal Care and Use Committee. Animals were housed individually and exposed to a 12-hour light/dark cycle with food and water ad libitum. For electrophysiological recordings, 9 adult male Wistar rats (320-460 g; Harlan, Indianapolis, IN) were anesthetized with an intraperitoneal injection of 50% urethane (1.2 g/kg) and maintained with supplement doses (5% urethane) administered intravenously as needed.[48,49] Anesthetic state III-3 was maintained by monitoring pinch withdrawal, corneal reflex, respiration rate, and vibrissae movements.[50] The jugular vein was catheterized for intravenous infusion. The trachea was intubated for P_{CO_2} monitoring. Oxygen concentration, heart rate, and respiration were monitored by a MouseOx system (Starr Life Sciences Corp, Oakmont, PA). Body temperature was monitored with a rectal thermistor and maintained at 37°C with a circulating-water heating pad. The rat's head was secured in a stereotaxic device (Kopf Instruments, Tujunga, CA) with its dorsal surface positioned horizontally. A small hole was made in the skull and expanded with bone rongeurs. The exposed dura was opened, and the extracellular recording electrode was advanced into the thalamus.

Electrophysiology

Activity in lateral thalamic neurons was recorded extracellularly with 1,1′-dioctabecyl-3,3,3′,3′-tetramethylindocarbocyanine perchlorate (DiI; Invitrogen, Carlsbad, CA)–coated tungsten microelectrodes (FHC, Bowdoin, ME) having 6 to 8 MΩ impedance as previously described.[49,51,52] Thalamic electrode tracks were made in parallel rows, 500 μm apart, and were located between −2.04 and −3.30 mm caudal to bregma and 1.2 and 3.8 mm lateral to midline.[49,53] Recording began at 4 mm below the surface of the cortex and ended at 7.5 mm. Lateral thalamic nuclei through which the DiI-labeled electrode passed in each rat included ventrolateral (VL), ventroposterior lateral (VPL), ventroposterior medial (VPM), posterior (Po), and laterodorsal ventrolateral (LDVL), and laterodorsal dorsomedial (LDDM) (Fig 1). The electrode was slowly advanced at a rate of 1 to 5 μm per step using a motorized micromanipulator (Neurostar, Tubingen, Germany) until spontaneous single unit activity was isolated. Neurons with cutaneous receptive fields on the dorsolateral trunk were tested with graded mechanical stimuli (gentle stroking with a nylon brush and noxious pinch with a serrated forceps). Neurons failing to respond to innocuous stroking but responding to trunk pinch were classified as NS neurons. Activity in single thalamic NS neurons was passed through a high impedance probe (HIP511; Grass, West Warwick, RI), amplified (P511K; Grass), recorded, and evaluated off-line using a PC-based data acquisition system (Spike 2; Cambridge Electronic Design, Cambridge, England).