ORIGINAL ARTICLES

NEURAL RESPONSES TO THE MECHANICAL PARAMETERS OF A HIGH-VELOCITY, LOW-AMPLITUDE SPINAL MANIPULATION: EFFECT OF PRELOAD PARAMETERS

William R. Reed, DC, PhD,[a] Cynthia R. Long, PhD,[b] Gregory N. Kawchuk, DC, PhD,[c] and Joel G. Pickar, DC, PhD[d]

ABSTRACT

Objective: The purpose of this study was to determine how the preload that precedes a high-velocity, low-amplitude spinal manipulation (HVLA-SM) affects muscle spindle input from lumbar paraspinal muscles both during and after the HVLA-SM.

Methods: Primary afferent activity from muscle spindles in lumbar paraspinal muscles were recorded from the L_6 dorsal root in anesthetized cats. High-velocity, low-amplitude spinal manipulation of the L_6 vertebra was preceded either by no preload or systematic changes in the preload magnitude, duration, and the presence or absence of a downward incisural point. Immediate effects of preload on muscle spindle responses to the HVLA-SM were determined by comparing mean instantaneous discharge frequencies (MIF) during the HVLA-SM's thrust phase with baseline. Longer lasting effects of preload on spindle responses to the HVLA-SM were determined by comparing MIF during slow ramp and hold movement of the L_6 vertebra before and after the HVLA-SM.

Results: The smaller compared with the larger preload magnitude and the longer compared with the shorter preload duration significantly increased (P = .02 and P = .04, respectively) muscle spindle responses during the HVLA-SM thrust. The absence of preload had the greatest effect on the change in MIF. Interactions between preload magnitude, duration, and downward incisural point often produced statistically significant but arguably physiologically modest changes in the passive signaling properties of the muscle spindle after the manipulation.

Conclusion: Because preload parameters in this animal model were shown to affect neural responses to an HVLA-SM, preload characteristics should be taken into consideration when judging this intervention's therapeutic benefit in both clinical efficacy studies and in clinical practice. (J Manipulative Physiol Ther 2014;37:68-78)

Key Indexing Terms: *Spinal Manipulation; Dosage Forms; Muscle Spindles; Neurophysiology; Spine; Cat; Chiropractic*

Spinal manipulation (SM) is a form of manual therapy that patients often seek for musculoskeletal problems.[1-3] By its very nature, SM is a mechanical intervention. Delivered as a high-velocity, low-amplitude (HVLA) technique (HVLA-SM), it is used by most chiropractors[4] as well as some osteopathic physicians and physical therapists.[5,6] The preponderance of evidence indicates that HVLA-SM reduces pain and improves functional health status,[7] but we know little of the mechanisms by which this occurs. Clinical improvements are thought to be initiated by the high-frequency peripheral sensory input evoked during the manipulation itself, improved spinal biomechanics, and sustained by a subsequent cascade of central neurophysiological changes.[8-11]

Delivering HVLA-SM to a patient involves a number of mechanical considerations including the magnitude and duration of any preload that precedes the manipulation, the

[a] Associate Professor, Palmer Center for Chiropractic Research, Palmer College of Chiropractic, Davenport, Iowa.
[b] Professor, Palmer Center for Chiropractic Research, Palmer College of Chiropractic, Davenport, Iowa.
[c] Associate Professor, Faculty of Rehabilitation Medicine, University of Alberta, Edmonton, Alberta, Canada.
[d] Professor Emeritus, Palmer Center for Chiropractic Research, Palmer College of Chiropractic, Davenport, Iowa.
Submit requests for reprints to: Joel G. Pickar, DC, PhD, Palmer Center for Chiropractic Research 741 Brady St, Davenport, IA 52803 (e-mail: jgpickar@live.com).
Paper submitted August 1, 2013; in revised form September 20, 2013; accepted September 20, 2013.
0161-4754/$36.00

http://dx.doi.org/10.1016/j.jmpt.2013.12.004

HVLA-SM's application rate, amplitude and direction, the type of leverage used, and the contact site on both the clinician and patient.[12-14] Analogous to the way in which a drug's chemical characteristics determine its pharmacokinetic and pharmacodynamic behavior, determining the way in which an HVLA-SM's mechanical characteristics influence neural and biomechanical responses should help identify the mechanical qualities that define HVLA-SM dosage. Currently, we know very little about the mechanical characteristics critical for the most effective application of SM. In clinical studies, descriptions of the HVLA-SM often lack adequate reporting for assessing how its mechanical characteristics relate to clinical outcomes.[15]

From neurophysiological studies using anesthetized animals where neural recordings from spinal tissues can be obtained directly, we know that as thrust durations approach those used clinically, the discharge frequency of muscle spindles in paraspinal muscles greatly increases.[16-19] The increase depends more upon the amplitude of the applied thrust displacement than the applied thrust force.[16-19] From biomechanical studies in humans, thrust force and duration appear to interact in changing spinal stiffness.[20] Increasing thrust force appears to increase intersegmental accelerations, whereas changing thrust duration has little effect on these accelerations.[21] However, paraspinal electromyographic responses to an HVLA-SM are affected by both thrust force and duration.[21] The relationship between any of these physiological responses and clinical outcomes is unknown.

In the current study, we were interested in how 1 mechanical consideration, the preload that often precedes delivery of an HVLA-SM, affects peripheral sensory input from lumbar paraspinal tissues both during and after the HVLA-SM. Preload characteristics of an HVLA-SM have been identified in several studies of chiropractic technique and appear to vary among chiropractors. Herzog's laboratory showed that preload forces range from 20 to 180 N, roughly comprising 9% to 32% of the thrust force[22,23] and lasting between 0.5 and 5 seconds.[24] Gudavalli[25] showed slightly wider variation in preload forces ranging from 20 to 275 N but lasting 0.2 to 0.4 seconds. In addition to preload amplitude and duration, a third mechanical feature of the preload has been identified in force-time tracings. A brief partial unloading (previously referred to in the literature as "downward incisural point" [DIP][26]) may occur just before the thrust where a clinician rapidly reduces the preload just before applying the thrust.[26] Biomechanically, this decrease is thought to be undesirable.

We used the neural output from 1 type of proprioceptor, the muscle spindle, in dorsal back muscles to determine the way in which an HVLA-SM's preload characteristics can influence primary afferent input. Muscle spindles lie parallel to extrafusal fibers and respond to muscle length and the rate of change in muscle length. As a result, spindles potentially supply information to the central nervous system regarding joint position.[27,28] Paraspinal muscle spindles behave thixotropically,[29] acting stiffer and becoming more responsive when the parent muscle is maintained at an elongated position but becoming slack and less responsive when the muscle is shortened following an elongated history. In paraspinal muscles, changes in muscle spindle responsiveness occur following very small, sustained changes in vertebral position and are graded with the magnitude of change in vertebral position.[30] The change in responsiveness is also graded with the duration over which the change in vertebral position is maintained.[31] The effect is maximal by approximately 4 seconds of lengthening history with a time constant of 1.1 second.[32] Therefore, we hypothesized that muscle spindle discharge during an HVLA-SM would be greater as either preload magnitude or preload duration became greater. Because the preload DIP would be expected to create slack in the spindle immediately prior the manipulative thrust, we hypothesized that an HVLA-SM would be less effective at stimulating muscle spindles during an HVLA-SM when the preload contained a DIP than when it did not contain a DIP. Therefore, the purpose of this study was to determine how the preload that precedes an HVLA-SM affects muscle spindle input from lumbar paraspinal muscles both during and after the HVLA-SM.

Methods

Electrophysiological responses from single muscle spindle afferents in lumbar paraspinal muscles were obtained before, during, and after a lumbar SM applied to 20 anesthetized (nembutal [35 mg/kg, intravenous {IV}]) cats of either sex weighing an average of 4.42 kg (SD, 0.72; range, 2.8-6.3 kg). Similar to previous studies,[16-18,30,33] 1 afferent was investigated per cat because following completion of all SMs, surgery of the intact spinal tissues was needed to confirm that afferent activity was from muscle spindles in the lumbar multifidus or longissimus muscles. Cats were euthanized at the completion of each experiment with a bolus injection (0.5 mL, IV) of Sleepaway (Fort Dodge, IA) followed by saturated potassium chloride (KCl [3 M] IV) to fibrillate the heart. All experiments were approved by the Palmer's Institutional Animal Care and Use Committee (no. 20070101).

The experimental preparation including the basis for the surgical approach,[34,35] the procedures used identifying primary afferent neurons as muscle spindles, and the equipment and methods used for applying an SM[34,35] has been presented previously and is recently available through an open-access journal.[16] Here, we present an overview of the approach, with detailed description of the choice of preload parameters, experimental design, and data analysis.

Muscle spindle activity from paraspinal muscles innervated by the L_6 spinal nerve was recorded in thin filaments of L_6 dorsal rootlets.[36] The laminectomy that exposed the L_6 rootlets kept the paraspinal muscles containing the muscle spindles intact because the L_6 dorsal root enters the