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The Spine Journal 5 (2005) 650–659

THE SPINE JOURNAL

Clinical Studies

Evaluation of the effect of postural perturbation on motoneuronal activity following various methods of lumbar spinal manipulation

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Received 24 June 2004; accepted 6 August 2005

Abstract

BACKGROUND AND CONTEXT: One basic physiologic response to spinal manipulation (SM) is a transient decrease in motoneuronal activity, as assessed by the Hoffmann reflex (H-reflex) technique. However, questions of appropriate control procedures when using the H-reflex technique to study the basic physiologic mechanisms of SM still exist. The identification of appropriate control procedures may allow us to better differentiate among the specific and nonspecific aspects of SM.
PURPOSE: The purpose of the research was to determine the contributions of postural perturbations on the attenuation of motoneuronal activity following spinal manipulative thrusts and spinal joint preload procedures applied to the lumbar spine.
STUDY DESIGN/SETTING: H/M_{max} ratios, recorded from the gastrocnemius muscle, were measured before and after lumbar spinal procedures. The experimental designs for the laboratory data collection protocols were repeated measures and between-subjects.
PATIENT SAMPLE: The subjects were asymptomatic, young, healthy volunteers.
OUTCOME MEASURE: H/M_{max} ratios recorded from the gastrocnemius muscle.
METHODS: In Experiment 1, the administration of prone lumbar procedures involved either manual assist to more fully shear the lumbar zygapophyseal joints or no manual assist. One set of subjects (n=17) received assisted joint preload force and manipulation, whereas a second set of subjects (n=17) received unassisted joint preload force and manipulation. In a second laboratory experiment, one set of subjects (n=10) received a L5-S1 side-posture SM, whereas a second set of subjects (n=10) were just positioned into side-posture.
RESULTS: There was a H/M_{max} ratio attenuation of 18.2% after assisted spinal manipulation, whereas H/M_{max} ratio attenuation was only 9.5% after unassisted spinal manipulation. Decreases of H/M_{max} ratios by 8.5% and 7.5% were observed after assisted and unassisted joint preload forces, respectively. The amount of H/M_{max} ratio attenuation was significantly greater immediately after the L5-S1 SM procedure (28.4%) as compared with a side-posture positioning maneuver (15.3%).
CONCLUSION: SM may provide procedure-specific sensory input that appears to vary, based upon the various types of vertebral loading applied to the lumbar spine.

Keywords: Spinal manipulation; Lumbar spine; Tibial nerve H-reflex; Chiropractic

Introduction

Spinal manipulation (SM) is a commonly employed nonoperative treatment modality in the management of patients with neck, low back, or pelvic pain. One basic physiologic response to SM is a transient decrease in motoneuronal activity, as assessed by the Hoffmann reflex (H-reflex) technique [1–4]. However, questions of appropriate control procedures when using the H-reflex technique to study the basic physiologic mechanisms of SM still exist. SM of the lumbar spine typically involves changes in whole

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FDA device/drug status: not applicable.

Support in part was received by a grant from the Foundation for Chiropractic Education and Research. Nothing of value received from a commercial entity related to this research.

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1529-9430/05/$ – see front matter
doi:10.1016/j.spinee.2005.08.007

body orientation during side-posture procedures. A postural perturbation is one of many factors that may affect the amplitude of the H-reflex response [5,6]. The H/M_{max} ratio is a valid index of motoneuronal activity when the recording and stimulating environments are the same before and after an experimental perturbation [5]. Although the previous data on the effects of SM on the transient decrease in motoneuronal activity document the consistency of the recording and stimulating environments from pre to post SM [1–4], the inclusion of appropriate control procedures may allow us to better differentiate among the specific and nonspecific aspects of SM.

Other research indicates that a cervical SM does not lead to changes in the activity of the lumbar motoneuron pool as assessed by the tibial nerve H-reflex response [7]. SM delivered to the lumbar spine with the subject in side-posture leads to a short-term attenuation of tibial nerve H-reflex responses without a concomitant change after paraspinal massage therapy [2]. Motor evoked potentials in the gastrocnemius muscle from transcranial magnetic stimulation were significantly facilitated from 20 to 60 seconds after a L5-S1 SM, without a concomitant change after a side-posture positioning (control) maneuver [8]. These current data tend to support the hypothesis that SM imparts a specific effect on lumbar motoneuronal activity. Thus, the hypothesis that SM may produce the same result as a nonspecific perturbation, such as a ‘‘startle’’ maneuver, was not supported by these reports.

The exact physiologic mechanism underlying SM-induced inhibition of motoneuronal activity is unknown. SM may produce an inhibitory reflex response that is segmental in origin [9,10]. Group Ia, Ib, II, and IV afferents respond in a graded fashion to the velocity, magnitude, and direction of vertebral loading applied to the lumbar spine [10]. Importantly, stimulations of Group Ib, III, and IV muscle afferents exert an inhibitory effect on alpha motoneurons [10,11]. The transient nature of SM inhibition of motoneuronal activity may involve decreased excitatory inputs from the muscle spindle afferents which is consistent with two well-defined physiologic mechanisms: muscle spindle aftereffects and post-activation depression of Ia afferents (cf. current discussion and Dishman and Bulbulian [1]). Thus, SM, and similar types of perturbation, may alter sensorimotor behavior of the lumbar spine [10,12].

Other manual therapies that do not employ high-velocity, low-amplitude (HVLA) manipulative thrusts are also commonly used as a conservative treatment technique in the management of patients with neck, low back, or pelvic pain. The independent contribution of manual joint preload application to the transient attenuation of lumbar motoneuronal activity after a side-posture L5-S1 SM procedure was previously addressed [1]. Healthy subjects, with no low back pain (n=7) were evaluated for baseline tibial nerve H-reflex responses, and then subjected to bilateral manual spinal joint preload procedures in side-posture. Then, after a 1-hour wash-out period, these same subjects were administered a bilateral L5-S1 SM (HVLA) procedure in side-posture. Other than the manipulative thrusts, the bilateral joint preload procedure did not differ from the bilateral SM procedure. Although there were no significant differences between SM and joint preload alone, the H/M_{max} ratios, collapsed across procedures, were significantly reduced with respect to baseline pre-values from 10 to 50 seconds post-procedures [1]. The same ordering of procedures, joint preload first then SM, for a small number of subjects, may have limited their ability to detect differences between the procedures or may have indicated that effects of joint preload and SM were additive. In addition, and perhaps more importantly, the nonspecific contribution of the side-posture body positioning perturbation on the SM-induced attenuation of motoneuronal activity was not addressed. What role might body positioning perturbation play in the observed effect of HVLA SM on motoneuron excitability?

The overall purpose of the current research was to determine the contributions of postural perturbations on the attenuation of motoneuronal activity after HVLA manipulative thrusts as compared with spinal joint preload procedures applied to the lumbar spine. The investigators developed experimental protocols that used a constant prone patient positioning for the administration of spinal procedures to the lumbar spine and the collection of tibial nerve H-reflex responses. The experimental protocols also altered the direction of applied force vectors by performing the prone lumbar procedures with or without the so-called ‘‘pelvic assist’’. The ‘‘pelvic assist’’ essentially entails the lifting of the pelvis via an anterior iliac crest contact, in an attempt to more fully shear the lumbar zygapophyseal joints. Comparisons of tibial nerve H-reflex responses before and after HVLA manipulative thrusts and low-velocity, spinal joint preload procedures in the prone position, assisted and unassisted, allowed us to address the effects of various aspects of different vertebral loading applied to the lumbar spine, independent of postural perturbations. In a second experiment, a comparison of tibial nerve H-reflex responses before and after a side-posture positioning maneuver and a side-posture HVLA SM was addressed in an attempt to better differentiate among the specific and nonspecific (ie, postural perturbation) aspects of the manipulative thrust on the lumbar spine.

Methods

Experiment 1

Participants. The subjects were 34 healthy, young volunteers recruited from a college student population. Inclusion criteria included no low back pain within the past 3 months and no history of radiculopathy or neuropathy of the lower limbs. One set of subjects (n=17, 11 males and 6 females) received mobilization and manipulation with assist (25.8±1.67 years; 170.7±10.48 cm; 78.2±17.78 kg), whereas a second set of subjects (n=17, 14 males and 3 females) received mobilization and manipulation without assist (29.3±5.71 years; 174.1±6.36 cm; 80.6±14.57 kg). All subjects were neurologically screened by one clinician before the initiation of the experiments to exclude subjects with radiculopathy or peripheral neuropathy. The evaluation included a manual motor evaluation, deep tendon reflexes, and sensory dermatome examinations. The local ethics committee reviewed and approved all experimental procedures. All subjects signed an informed consent form.

Experimental design. All spinal procedures were delivered with the subjects prone on a treatment table and in one test session. Within each set of subjects, the order of joint preload and manipulation procedures delivered in a test session was alternated to minimize a possible order effect on the data. There was a 20-minute wash-out period between each of the spinal procedures delivered in a test session. Before each spinal procedure, 10 maximal H-reflexes were recorded as pre-baseline values. The stimulation rate for evoking baseline responses was 0.10 Hz. Immediately after the spinal procedure, maximal H-reflexes were measured at 10-second intervals within the first 60 seconds to determine the acute time course of post-procedures effects on motoneuronal activity. Ten maximal H-reflexes were also recorded at 5 and 10 minutes post spinal procedure at a stimulation rate of 0.10 Hz.

General protocol for assessing motoneuronal activity. At the beginning of the test session, the standard H/M recruitment curve was generated by increasing stimulus intensity from 0 to 150 volts in 5-volt increments. The typical M-wave recruitment curve is S-shaped, whereas the typical H-reflex recruitment curve is an inverted ‘‘U’’. Electromyographic (EMG) amplitudes, peak-to-peak EMG values, of the H-reflex and M-wave responses were recorded to construct the standard H/M recruitment curve.

The maximal M-wave response was defined as the plateau in recruitment curve (EMG amplitude) that occurs in response to three successive 5-volt increments of stimulus intensity. After recording three maximal M-wave responses, the stimulus intensity was adjusted in 2-volt increments until the amplitude of the H-reflex response was maximal. The purpose of this procedure was to more accurately define the stimulus intensity needed to evoke a maximal H-reflex response for all subjects. This optimal stimulus intensity for evoking maximal H-reflex responses was not adjusted for the remainder of the test session.

At the completion of the test session, three maximal M-wave responses were recorded again. The consistency of maximal M-wave responses at the beginning and end of each test session ensured that recording and stimulation environments were constant throughout the test session for each subject [13].

Tibial nerve H-reflex methodology. The tibial nerve H-reflex methodology outlined by Hugon [14] was used with the essential components described here. The subjects rested prone on a treatment table with their feet resting on foot plates. The foot plates were rotated to maintain 90° angles at the ankle joint in order to control for the effects of muscle length on H-reflex responses. Postural effects on H-reflex responses were accounted for by having the subjects rest their head face down on the treatment table with their arms placed down by their sides onto arm rests. The arms were bent at 90° angles at the elbow joint, whereas the head piece adjustment allowed for the subject to rest comfortably face down. The subjects were visually observed for gross changes in arousal states. The right tibial nerve was stimulated in the popliteal fossa using a 1-ms square wave pulse delivered by a Grass S-88 stimulator in series with a stimulus isolation unit (Grass SIU5).

The cathode stimulating electrode was positioned within the popliteal fossa at the optimal location for evoking a H-reflex response in the right gastrocnemius muscle. The optimal location for evoking the H-reflex response is defined as the site within the popliteal fossa at which a slightly suprathreshold stimulus for evoking a H-reflex response does not simultaneously evoke a M-wave response. The anode stimulating electrode was placed 10 cm proximal to the cathode on the posterior thigh.

The EMG recordings of the evoked H-reflex response in the gastrocnemius muscle were measured with bipolar, surface Ag/AgCl electrodes. The positioning of the EMG recording electrodes was in accordance with the Braddom and Johnson [15] methodology. The Braddom and Johnson [15] methodology reduced intersubject variability with respect to electrode placement. The EMG signal was bandpass filtered (10 Hz–10 kHz) and amplified using the Grass P511 EMG system.

The evoked EMG responses were collected using an analog-to-digital converter (12-bit resolution) interfaced to a computer. Sampling rate was 5 kHz per channel. The deliverance of the peripheral nerve stimulus was controlled through the computer's digital output port interface. LabView software (National Instruments Corp., Austin, TX) was used to write algorithms for data acquisition and data analysis. EMG amplitudes of M-wave and H-reflex responses were detected online and stored in a data output file for statistical analyses.

Spinal procedures: assisted and unassisted manipulation. The L5-S1 SM procedures consisted of a HVLA impulsive force to the right side of the spine with the subject lying prone on the treatment table. The impulsive force applied to the spine in these procedures was applied pragmatically, and was consistent with a typical therapeutic application of the procedure. Although the procedure was applied without an instrument for displacement and velocity measurement, previous reports indicate that these procedures are typically applied in a time course of approximately 200 ms [16], with linear vertebral displacements of less than 10 mm [17]. With crossed hands, the clinician provided manual contact upon the tissues overlying the zygapophyseal joint. The right-handed Cartesian orthogonal coordinate system of movement has been previously used as a reference to describe our spinal procedures [18]. These procedures have been thoroughly described by the authors in previous reports [1]. However, in an effort to more clearly describe the spinal procedures for the clinician, the authors have elected to use a more pragmatic approach to the description of the manual procedures performed in this study.

Unassisted manipulation involved slightly increasing manual tension by providing axial distraction to the spine. Once tissue preload tension was maximized, a HVLA impulsive force was applied to the L5-S1 zygapophyseal joints with the primary force vector applied in a posterior to anterior direction. Assisted manipulation also involved slightly increasing manual axial distraction to the spine, coupled with a rotational force application which further increased the mechanical load upon the soft tissues. Once tissue preload tension was maximized, a HVLA impulsive force was applied to the L5-S1 zygapophyseal joints with the primary force vector applied in the posterior to anterior direction, with a secondary axial rotation force also applied. As such, ''assist'' referred to the axial rotation force that was achieved by manually contacting the right anterior superior iliac spine and applied an anterior to posterior shear force.

Spinal procedures: assisted and unassisted joint preload. The subjects were lying prone on the treatment table. With crossed hands, the clinician provided a manual contact with a very slow velocity of application to the L5-S1 zygapophyseal joints of the right side of the spine. However, no high-velocity thrust was applied after maximizing tissue preload. The force vectors associated with increasing manual tension during the joint preload procedures were the same as defined above for assisted and unassisted manipulation. For unassisted joint preload, the primary force vector was also posterior to anterior. For assisted joint preload procedures, the primary force vector applied to the lumbar spine was posterior to anterior with a secondary vector consisting of rotation. Other than the manipulative thrust, the joint preload procedures did not differ from the manipulation procedures.

Nonforceful, low-velocity (nonimpulse) manual excursion of the zygapophyseal joint to the passive endpoint range of motion is considered the essential element of joint preload procedures. Thus, the primary difference between manipulation and joint preload procedures was the impulsive, high-velocity thrust applied at the end range of passive joint excursion. The intention of the joint preload procedure was to accurately replicate the manipulation ''set-up,'' except for the application of the HVLA thrust.

Statistical analyses. The dependent variable was the H/M_{max} ratio. The data sets were analyzed separately to address the differences between manipulation and mobilization, regardless of the direction of the force vectors, ie, with assist versus without assist. For each data set, a procedure by time repeated measures analysis of variance (ANOVA) was used to reveal the effects of mobilization and manipulation on H/M_{max} ratios. The Dunnett's procedure for a priori contrasts was used to detect any differences in H/M_{max} ratios between baseline values and post-procedure time points. A split-plot ANOVA model (Technique by Procedure$\times$Time) with repeated measures on procedure and time was used to explore potential differences in manual techniques delivered to the lumbar spine. Technique referred to either with assist or without assist, thereby allowing us to address the effects of axial rotation on H/M_{max} ratios. All analyses were conducted using SPSS for Windows. The level of significance was .05 for all statistical analyses.

Experiment 2

Participants. Twenty healthy, young volunteers were recruited from a college student population (see Experiment 1 inclusion and exclusion criteria). One set of subjects (n=10, 9 males and 1 female) received a L5-S1 side-posture spinal manipulation (24.7$\pm$3.56 years; 177.4$\pm$8.88 cm; 80.7$\pm$15.29 kg), whereas a second set of subjects (n=10, 7 males and 3 females) were just positioned into side-posture (29.3$\pm$5.71 years; 174.1$\pm$6.36 cm; 80.6$\pm$14.57 kg). All subjects were neurologically screened by one clinician before the initiation of the experiments to exclude subjects with radiculopathy or peripheral neuropathy. The local ethics committee reviewed and approved all experimental procedures. All subjects signed an informed consent form.

Experimental design. The susceptibility of motoneurons to inhibition is dependent upon size of the pre-baseline H/M_{max} ratio [19]. Baseline H/M_{max} ratios of 25% to 45% are typically used to study decreases in motoneuron activity after a conditioning stimulus, eg, SM procedures, as there is rapid decrease in the amount of motoneuronal inhibition for larger baseline values [19–21]. Thus, all subjects' baseline H/M_{max} ratios were required to be within the aforementioned range for inclusion in the study.

The time line for evoking H-reflex responses was the same for both groups of subjects. Before each spinal procedure, 10 maximal H-reflexes were recorded as pre-baseline values. The stimulation rate for evoking baseline responses was 0.10 Hz. Immediately after the spinal procedure, maximal H-reflexes were measured at 10-second intervals within the first 60 seconds to determine the acute time course of post-procedures effects on motoneuronal activity. Ten maximal H-reflexes were also recorded at 5 and 10 minutes post spinal procedure at a stimulation rate of 0.10 Hz.

Assessment of motoneuronal activity and tibial nerve H-reflex methodology. The same procedures as described above for Experiment 1 were replicated for Experiment 2.

Lumbosacral SM procedure. As previously described [1], the L5-S1 SM procedure consisted of a HVLA manipulation to the right side of the spine with the subject positioned into side-posture. The clinician provided a manual contact upon the tissues overlying the zygapophyseal joint. Manual contact over the paraspinal soft tissues was slightly increased by providing axial distraction to the spine, coupled with a posterior to anterior and rotation force, thereby increasing the mechanical load upon the soft tissues. Once soft-tissue preload was maximized, a HVLA impulsive thrust was applied. The primary force vector applied to the zygapophyseal joint was posterior to anterior, with a secondary vector consisting of rotation. After the HVLA thrust, the subject was returned to the prone testing position for the acquisition of the tibial nerve H-reflex responses, post SM.

Lumbosacral positioning procedure. Lumbosacral positioning procedure was performed by having the clinician assist the subject into the side-posture position. However, the clinician did not apply lower limb flexion or truncal torque. In an effort to eliminate the effects of the manual application of force and velocity to the zygapophyseal joints, only a minimal manual contact, without manual tension, was made with the spine. No other components of the SM procedure were applied. In effect, the positioning procedure was nothing more than a minimal hand contact to the paraspinal skin of the subject. The subject was simply returned to the prone H-reflex testing position following this minimal manual contact procedure. Minimal manual handling and positioning of the subject allowed for us to account for nonspecific effects of SM procedures on motoneuron activity [22].

Statistical analyses. The dependent variable was the H/M_{max} ratio. A split-plot ANOVA model (Group×Time) with repeated measures on time was used to reveal the effects of a side-posture L5-S1 SM procedure and side-posture positioning on H/M_{max} ratios. The Dunnett's procedure for a priori contrasts was used to detect any differences in H/M_{max} ratios between baseline values and post-procedure time points. All analyses were conducted using SPSS for Windows. The level of significance was .05 for all statistical analyses.

Results

Experiment 1

H/M_{max} ratios were significantly attenuated immediately after the spinal procedures involving assisted joint preload and manipulation, as compared with the pre-baseline values (Fig. 1; $F[6,96]=43.45$; $p<.05$). The time by spinal procedure interaction term was significant ($F[6,96]=13.89$; partial eta squared=.465; $p<.05$). The analysis of simple

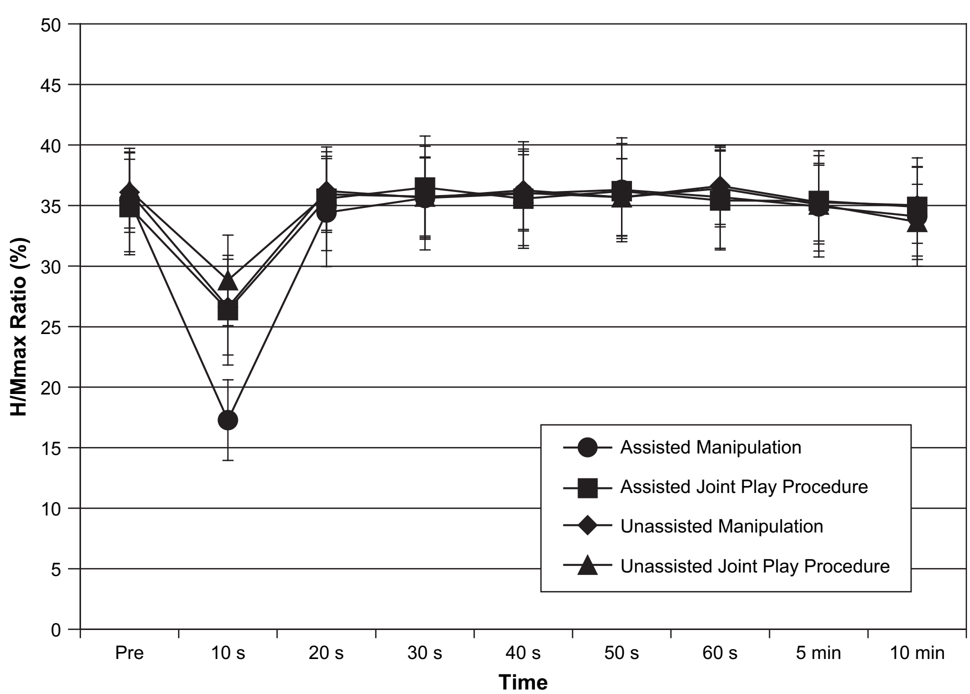

Fig. 1. Changes in H/M_{max} ratios after the administration of assisted and unassisted manipulation and assisted and unassisted joint-preload procedures. One set of subjects received assisted joint preload and assisted manipulation, whereas a second set of subjects received unassisted joint preload and unassisted manipulation. Pre represents the baseline H/M_{max} ratios, ie, before the spinal procedure. Error bars are standard errors of the means.

main effect of procedure at each time point detected that the amount of H/M_{max} ratio attenuation was significantly greater immediately after assisted manipulation as compared with assisted joint preload procedures (10 seconds time point; $F[1,16]=18.46$; partial eta squared=.536; $p<.05$).

H/M_{max} ratios were significantly attenuated immediately after the spinal procedures involving unassisted joint preload and manipulation, as compared with the pre-baseline values (Fig. 1; $F[6,96]=28.92$; $p<.05$). However, the time by spinal procedure interaction term was not significant ($F[6,96]=1.49$; $p>.05$). This statistical finding indicates that the amount of H/M_{max} ratio attenuation at the 10 seconds time point after unassisted manipulation was not different from unassisted joint preload procedures.

In summary, there was a H/M_{max} ratio attenuation of 18.2% after assisted spinal manipulation, whereas H/M_{max} ratio attenuation was only 9.5% after unassisted spinal manipulation. Decreases of H/M_{max} ratios by 8.5% and 7.5% were observed after assisted and unassisted joint preload procedures, respectively. The technique by procedure by time interaction term was significant ($F[6,192]=4.99$; partial eta squared=.135; $p<.05$). This statistical finding revealed that the amount of H/M_{max} ratio attenuation was greatest for assisted spinal manipulation as compared with the other three spinal procedures. Figure 1 summarizes the data as a function of techniques, procedures, and time.

For both sets of subjects, the maximal M-wave responses recorded at the beginning and the end of the test session were not different. These data indicate that the EMG recording environment was maintained throughout the test session. Within each set of subjects, a procedure by order ANOVA model revealed that baseline H/M_{max} ratios were constant throughout the test session. These data imply that differential carry-over effects from the first spinal procedure to the second spinal procedure were not occurring in our experimental design. Submaximal M-wave responses recorded on the data sweeps with the maximal H-reflex responses were constant on all trials. (On the majority of H-reflex trials, there is a small submaximal M-wave response that occurs at latency of 5 ms and precedes the H-reflex response. The peak-to-peak EMG amplitude of this submaximal M-wave response, expressed relative to maximal M-wave response, is typically used to document the consistency of stimulus intensity across experimental conditions.) These data indicate that the stimulation of the tibial nerve was constant on all trials. Collectively, these control data findings indicate that the recording and stimulating environments were maintained throughout the test session. Thus, the significant decreases in H/M_{max} ratios observed in this study reflected attenuation of motoneuronal activity.

Experiment 2

The Group×Time interaction term was significant (Fig. 2; $F[8,144]=4.33$; partial eta squared=.194; $p<.05$). The analysis of simple main effect of group at each time point detected that the amount of H/M_{max} ratio attenuation was significantly greater immediately after the L5-S1 side-posture HVLA SM procedure as compared with the

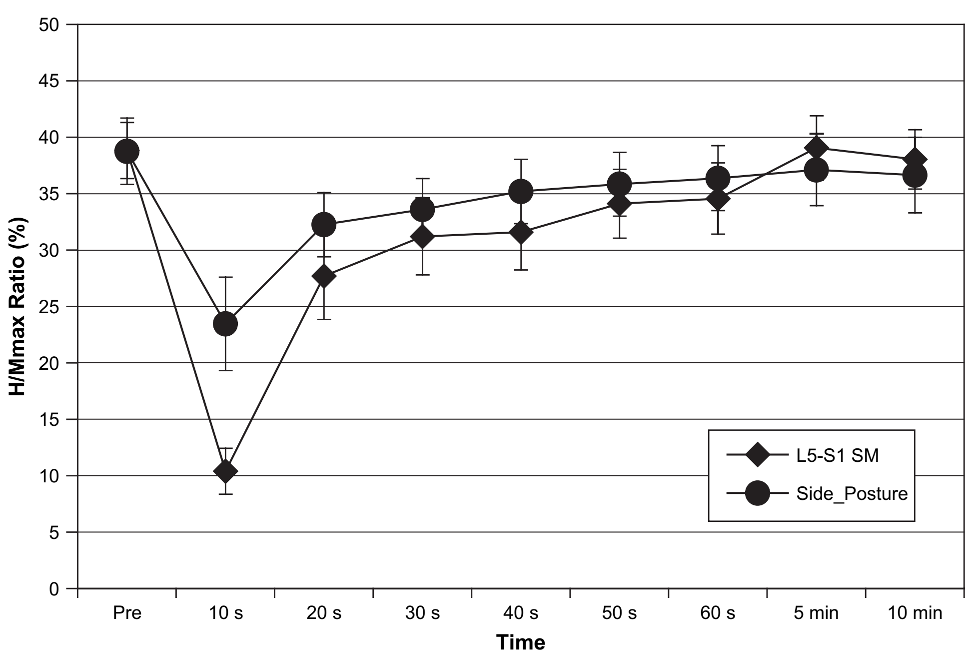

Fig. 2. Changes in H/M_{max} ratios after the administration of a side-posture spinal manipulation or a side-posture positioning maneuver (Experiment 2). One set of subjects received a side-posture spinal manipulation, whereas a second set of subjects received a side-posture positioning maneuver. Pre represents the baseline H/M_{max} ratios, ie, before the spinal procedure. Error bars are standard errors of the means.

side-posture positioning maneuver (10 seconds time point; $F[1,18]=8.06$; partial eta squared=.309; $p<.05$).

There were significant decreases in H/M_{max} ratios from 10 to 50 seconds after the L5-S1 SM procedure (Fig. 2; $F[6, 108]=32.61$; $p<.05$). The side-posture positioning maneuver also significantly decreased the H/M_{max} ratios from 10 to 30 seconds, post-procedure (Fig. 2; $F[6, 108]=9.38$; $p<.05$). The treatment effect of the L5-S1 SM procedure on decreases in H/M_{max} ratios accounted for 64% of measurement variance (partial eta squared=.644), whereas the treatment effect of the side-posture positioning maneuver on decreases in H/M_{max} ratios accounted for only 34% of measurement variance (partial eta squared=.342).

As described above for Experiment 1, the control data findings indicated that the recording and stimulating environments were maintained throughout the test session. Thus, the significant decreases in H/M_{max} ratios observed in Experiment 2 reflected attenuation of motoneuronal activity.

Discussion

Comparisons of tibial nerve H-reflex responses before and after assisted and unassisted HVLA manipulative thrusts and low-velocity, joint preload procedures in the prone position substantiated the hypothesis that SM may provide a procedure-specific sensory input that differs from nonspecific perturbation. The inhibition of the tibial nerve H-reflex response appears to have a dependence on the various types of manipulation-induced vertebral loading applied to the lumbar spine. The comparison of tibial nerve H-reflex responses before and after a side-posture positioning maneuver and a side-posture HVLA SM substantiated the hypothesis that the specific aspects of the manipulative thrust lead to a greater attenuation of the H/M_{max} ratio as compared with the nonspecific aspect related solely to the postural perturbation. The control data indicated that the H/M_{max} ratio was a valid index of motoneuronal activity, because the recording and stimulating environments were the same before and after an experimental perturbation.

These data indicate that the specific aspects of the HVLA manipulative thrust occur with an acute time course, 10 seconds post-SM. This transient nature of SM inhibition of motoneuronal activity occurs with a similar time course as for other basic physiologic responses (cf. below). In our experiments, the perturbation (ie, the spinal procedure) was applied to the trunk, whereas the effects of the perturbation were measured by recording the H-reflex response in a peripheral muscle, the calf muscle. As such, the stimulus-response relationship between the spinal perturbation and tibial nerve H-reflex response is defined as either heteronymous inhibition or heteronymous conditioning effects. There is sufficient evidence to suggest heteronymous inhibition of motoneurons by altering Ia afferent discharges rates from postural, synergistic, and antagonistic muscles [21,23–29]. The transient effects of SM on motoneuronal activity occur with a similar time course as other heteronymous conditioning effects reported in the literature [24,30].

Documentation of a heteronymous relationship between the afferent discharges from the trunk and tibial nerve H-reflex response tends to offer support for the hypothesis that a basic physiologic response to SM is a transient decrease in motoneuronal activity. A heteronymous inhibition of tibial nerve H-reflex response during trunk flexion has been previously reported [31]. In addition, electrical, mechanical, and chemical stimuli applied to paraspinal tissues evoke reflex activity in leg muscles supplied by the same spinal cord segment [32]. These data provide evidence for the convergence of afferent discharges from the ligament–muscular system of the spine onto alpha motoneurons of segmentally related peripheral muscles.

The exact physiologic mechanism underlying SM-induced inhibition of motoneuronal activity is unknown. SM may produce an inhibitory reflex response that is segmental in origin [9,10]. In support of an inhibitory segmental reflex response, Indahl et al. [9], using a porcine model, reported that distension of the zygapophyseal joint by injection of physiologic saline reduced the amplitudes of motor unit action potentials recorded from the paraspinal musculature. These data suggest that mechanical perturbations, such as SM, may initiate afferent discharges from mechanoreceptors and free nerve endings in the annulus fibrosus, zygapophyseal joint capsule, and ligaments of the spine that synapse on inhibitory interneurons, which in turn inhibit motoneurons [9]. Although recent data substantiate intersegmental reflex pathways between lumbar paraspinal tissues, the effect of these intersegmental reflex pathways on motoneuronal activity requires further clarification [32].

Experimental models of applying a spinal manipulative-like load to cervical and lumbar vertebrae are now available to study changes in afferent activity after an impulsive thrust [33,34]. The mechanoreceptors of the lumbar spine may make a major contribution to the overall inhibitory effect of SM on motoneuronal activity, because their discharge characteristics are reported to be dependent upon the force and direction of the applied loads [10,35,36]. Group III and IV muscle afferents from receptive fields within and near the facet joint capsule increase their discharge rates in graded fashion to the direction of the mechanical load applied to the lumbar facet joint [36]. Ib afferents from Golgi tendon organs increase their discharge rates to a greater extent in response to an impulse thrust as compared with static load applications to the lumbar spine [34,37]. Individual Golgi tendon organs respond preferentially to the direction of vertebral loading [37]. Importantly, the stimulation of Group Ib, III, and IV muscle afferents exerts an inhibitory effect on alpha motoneurons [10,11].

Spinal manipulative-like loads also modify the discharge rates of Ia afferents from muscle spindles in the lumbar spine. Discharge rates of Ia afferents increased more in response to an impulse thrust than to static loading of the lumbar spine [37]. Individual muscle spindles responded preferentially to the direction of vertebral loading [37]. Most importantly, after the impulse thrust, the discharge of Ia afferents was silent from 0.1 to 4.3 seconds and the resting discharge rates of Ia afferents did not return to control values from a time course of 100 ms to 21 seconds [37]. As such, the transient nature of SM inhibition of motoneuronal activity may involve decreased excitatory inputs from the muscle spindle afferents, ie, aftereffects.

Aftereffects refer to changes in sensory discharge rates, predominantly in Ia afferents, that occur in response to an alteration in a muscle's history of activation and length changes [38]. This basic receptor property of muscle spindles has been demonstrated in the lumbar spine [10]. The time course of aftereffects is from a standard of 2 seconds up to 400 seconds, with maximum effects persisting for 50 seconds [30,38,39]. With respect to inhibition of motoneuronal activity, the specific aspects of the HVLA thrust at 10 seconds post and the nonspecific aspects of the HVLA thrust, which persist until 50 seconds post, are consistent with these previous reports on muscle spindle aftereffects.

Depression of Ia-motoneuron synapse after a previous activation of the stretch reflex arc is a well-documented physiological phenomenon known as post-activation depression [40]. The recovery of the Ia-motoneuron synapse from post-activation depression occurs gradually over the time course of 16 seconds [40]. HVLA thrust is equivalent to rapidly applying a mechanical strain to the trunk. Mechanical strain of the ligament–muscular system of the spine evokes reflex activation of paraspinal muscles [41,42]. Most relevant, the force application of a HVLA thrust evoked reflex activation of muscles targeted by the SM [43,44]. In support of post-activation depression, reflex activation of SM-targeted thoracic musculature led to a subsequent alleviation of hypertonicity, as detected with surface EMG recordings, in one symptomatic patient with thoracic back spasms [44]. These data, in concert with data on heteronymous conditioning effects, lend support to the hypothesis that post-activation depression may contribute to the decreased convergence of Ia afferent discharges from ligament–muscular system of the spine onto alpha motoneurons of segmentally related peripheral muscles.

Regardless of the exact mechanism, the current data and previous reports (cf. Introduction) on the effects of SM on motoneuronal activity document a transient inhibition. The inhibition of the tibial nerve H-reflex response appears to be dependent upon the velocity and direction of vertebral loading applied to the lumbar spine. The inclusion of appropriate control procedures allowed us to better differentiate among the specific and nonspecific aspects of SM. As such, the data obtained in the current research may assist the design of future research wherein the physiologic effects of various manual techniques may be relatively compared. Similar to our H/M_{max} ratio data, ''gapping'' of lumbar zygapophyseal joints was greater after side-posture adjusting (HVLA SM) as compared with side-posture positioning [45,46].

Based upon the current research, the interpretation of H/M_{max} ratios as a clinical outcomes instrument is inappropriate. However, the interpretation of H/M_{max} ratios as a physiologic response to a therapeutic-based manual procedure is appropriate. The inclusion of three experimental groups (HVLA SM, joint preload, and side-posture positioning) in future investigations may provide additional insights on the relative contributions of body positioning and mobilization procedures to the transient decrease in motoneuronal activity after a HVLA thrust. Our research group is currently conducting experiments to further address the specific and nonspecific aspects of a HVLA thrust to the lumbar spine with the subject in side-posture. Randomized clinical trials of high methodological quality provide moderate evidence of short-term efficacy for SM in the treatment of acute low back pain, as well as SM combined with mobilization for chronic low back pain [47]. Although additional quality research endeavors using randomized clinical trials are needed to further address the efficacy of SM, an understanding of the basic physiologic mechanisms underlying SM may help identify a distinct population of patients who have a high probability of benefiting from HVLA manipulative thrusts and other spinal procedures.

The possible clinical relevance of these data at this juncture can only be speculative. However, it is feasible that the sensory afferent input provided by HVLA SM may in some manner intervene or alter dorsal horn processing of other sensory stimuli, such as nociception. The time course of these inhibitory effects is quite transient. However, when SM is performed on a serial basis, the sensory input may be integrated differently. Serial SM and its effect on motoneuron excitability are currently being evaluated in our laboratory. It has been proposed that perhaps SM intercedes in the so-called ''pain-spasm-pain'' cycle. Although this supposition would appear to be a logical extrapolation of these data, one cannot definitely draw these conclusions by these data alone. The presence of, and the physiologic mechanisms of the pain-spasm-pain cycle are not conclusive. In theory, the attenuation of motoneuron excitability, even if transient, may alter the process in which sensory stimuli effects motor output. Clearly, these putative roles for the inhibitory effects of SM are hypothetical at this time.

In conclusion, SM may provide a unique sensory input that appears to be dependent on the type of manipulative thrusts and vertebral loading applied to the lumbar spine. These data indicate that body perturbation, or positioning, is not the main contributor to this reliable and consistent attenuation of motoneuronal activity that occurs as a consequence of SM. Clinical implications of the transient nature of SM inhibition of motoneuronal activity await further clarification; however, the authors are currently conducting experiments in chronic low back pain patients in order to further define any possible putative clinical role that inhibition of motoneuron excitability may play.

Acknowledgments

The authors thank Mr. Matthew Cowley for his technical assistance with data collection.

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Two Hundred Forty Years Ago in Spine

In 1765, John Morgan [1] issued the first publication about medical education in the United States. Morgan was born in Philadelphia and received his medical education at Edinburgh. The work commemorated the founding, in 1765, of the Medical Department of the University of Pennsylvania, which was founded in 1740. This was the first American medical school and Morgan held the first chair of medicine.

Reference

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