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The Role of Preload Forces in Spinal Manipulation: Experimental Investigation of Kinematic and Electromyographic Responses in Healthy Adults

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Abstract

Objectives: Previous studies have identified preload forces and an important feature of skillful execution of spinal manipulative therapy (SMT) as performed by manual therapists (eg, doctors of chiropractic and osteopathy). It has been suggested that applying a gradual force before the thrust increases the spinal unit stiffness, minimizing displacement during the thrust. Therefore, the main objective of this study was to assess the vertebral unit biomechanical and neuromuscular responses to a graded increase of preload forces.

Methods: Twenty-three participants underwent 4 different SMT force-time profiles delivered by a servo-controlled linear actuator motor and varying in their preload forces, respectively, set to 5, 50, 95, and 140 N in 1 experimental session. Kinematic markers were place on T6, T7, and T8 and electromyographic electrodes were applied over paraspinal muscles on both sides of the spine.

Results: Increasing preload forces led to an increase in neuromuscular responses of thoracic paraspinal muscles and vertebral segmental displacements during the preload phase of SMT. Increasing the preload force also yielded a significant decrease in sagittal vertebral displacement and paraspinal muscle activity during and immediately after the thrust phase of spinal manipulation. Changes observed during the SMT thrust phase could be explained by the proportional increase in preload force or the related changes in rate of force application. Although only healthy participants were tested in this study, preload forces may be an important parameter underlying SMT mechanism of action. Future studies should investigate the clinical implications of varying SMT dosages.

Conclusion: The present results suggest that neuromuscular and biomechanical responses to SMT may be modulated by preload through changes in the rate of force application. Overall, the present results suggest that preload and rate of force application may be important parameters underlying SMT mechanism of action. (J Manipulative Physiol Ther 2014;37:287-293)

Key Indexing Terms: *Spinal Manipulation; Dose Response Relationship; Force; Electromyography; Kinematics, Manipulation; Chiropractic*

The fundamental kinetic and kinematic parameters of spinal manipulative therapy (SMT) have been frequently studied, and parameters such as peak force, preload force, and time-to-peak force have been suggested as important features of SMT skillful execution. Chiropractic spinal manipulations are usually characterized by a high-velocity, low-amplitude (HVLA) thrust preceded by an initial gradual application of force commonly known as preload force.[1] Such progressive loading of spinal tissues (preload component of spinal manipulation) is believed to position the targeted vertebral segment near the limit of its physiological range of motion.[2,3] It has been suggested that gradually applying preload forces before the thrust increases the spinal unit (adjacent vertebrae together with connecting elements) stiffness, minimizing spinal displacement during the thrust phase of spinal manipulation.[4] A recent study indicates that a minimal preload force of 20 N increases paraspinal muscle activity until the thrust is applied.[5]

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Most studies where spinal manipulations are performed by chiropractors do not report specific instructions or parameters related to preload force application.[2,3,6-11] However, given the large array of manipulative techniques combined with the complexity and diversity of vertebral unit structures throughout the spine, one should expect preload values to vary across patients, clinicians, and studies.[2,3,6-13] Indeed, for the cervical spine, various spinal manipulation techniques (lateral break, rotation, Gonstead technique, Activator technique, and toggle) were associated with preload forces ranging from 1.9 to 39.5 N.[8] Prone thoracic manipulations frequently used in experimental studies are also associated with a wide range of preload forces varying from 23.8 to 310 N (mean value, 123.6 N).[2,3,6,7,9-11,13] In the lumbar spine, 2 studies from Triano et al[14,15] looked at the biomechanical features of HVLA spinal manipulation but did not report any values for the preload forces, whereas a study on human cadavers used a mechanical device to perform spinal manipulations with predetermined preload forces of 0, 5, 10, and 20 N to emulate different degrees of patient positioning.[14,16] Finally, 2 studies investigated sacroiliac joint manipulations biomechanical parameters and reported values between 20 and 180 N for the preload force.[11,17] These results clearly highlight the wide range of preload forces selected by clinicians as well as researchers.

A recently published study investigated how SMT preload forces affect muscle spindle input from lumbar paraspinal muscles both during and after the SMT thrust in anesthetized cats.[18] The results showed that, when peak force and time-to-peak force remain constant, mean instantaneous discharge frequencies increased during SMT thrust phase compared with baseline. The amplitude of this increase seems to depend upon both preload amplitude and duration with no preload condition resulting in the greatest increase.

Nonetheless, there has not been, to our knowledge, any systematic investigation of preload forces parameters or any attempt at determining the physiological impact of this specific spinal manipulation component in healthy humans. Thus, the main objective of this study was to assess, in humans, the vertebral unit biomechanical and neuromuscular responses to a graded increase of preload forces. Based on previous results,[5] it was hypothesized that increasing levels of preload forces would yield a graded increase in vertebral movement and electromyographic (EMG) activity during the preload phase of spinal manipulation. It was also hypothesized that biomechanical and EMG responses during and after the thrust phase would proportionally decrease with increasing preload forces.

Methods

Twenty-three healthy subjects aged between 20 and 38 years old were recruited (mean age, 24.4 years; ±3.3). Participants who presented thoracic or lumbar pain, previous history of back trauma or surgery, severe osteoarthritis, inflammatory arthritis or vascular problems, or any other condition that would limit the usage of SMT were excluded from the study after a general examination performed by an experienced chiropractor. Those who were included gave their informed written consent according to the protocol approved by the University Ethics Committee (No. CER-12-181-06.37).

Experimental Protocol

To demonstrate the operation of the apparatus and its main security features, each participant was first shown a demonstration of a simulated spinal manipulation performed by the apparatus. Each participant then lied down in a prone position on a chiropractic table. Electromyographic electrodes were applied over paraspinal muscles (right and left longissimus thoracis, T6 and T8 levels) following fiber orientation and kinematic markers were positioned on the spinous process of T6, T7, and T8. All participants underwent 4 different SMT force-time profiles characterized predetermined preload force for the first 750 milliseconds followed by an impulse phase of 125 milliseconds leading to a peak force of 300 N. The 4 SMT force-time profiles differed in their preload forces (not duration), respectively, set to 5, 50, 95, and 140 N. A 5-minute pause was taken between each trial, and the various preload conditions were randomized across participants to avoid any sequence effect.

Apparatus

Electromyographic activity was recorded using a Delsys Surface EMG electrode with a common mode rejection ratio of 92 dB at 60 Hz, an input impedance of 1015 Ω (Model DE2.1; Delsys, Inc, Boston, MA). Electrodes were applied over the thoracic spine erector spinae muscles on each side of the spine, approximately 2 cm from the T6 and T8 spinal processes. Thus, 2 electrodes were placed on both right and left sides of T6. The reference electrode was positioned on the left acromion of each participant. For each electrode, (1) the desired body part (region) was gently shaved, (2) then the skin was gently abraded with fine-grade sandpaper (Red Dot Trace Prep; 3 M, St Paul, MN) and finally (3) skin was wiped with alcohol swabs. These 3 steps were systematically done for each electrode for each participant to reduce skin impedance. Data were sampled at 1000 Hz with a 12-bit A/D converter (PCI 6024E; National Instruments, Austin, TX). The data were collected by LabView (National Instruments) and processed by Matlab (MathWorks, Natick, MA). A motion analysis system (Optotrak Certus; Northern Digital, Waterloo, Ontario, Canada) was used to perform the kinematic data acquisition. Kinematic markers were