Methods of Muscle Activation Onset Timing Recorded During Spinal Manipulation

Stuart J. Currie, DC,[a] Casey A. Myers, MS,[a] Ashok Krishnamurthy, PhD,[b] Brian A. Enebo, DC, PhD,[c] and Bradley S. Davidson, PhD[d]

Abstract

Objective: The purpose of this study was to determine electromyographic threshold parameters that most reliably characterize the muscular response to spinal manipulation and compare 2 methods that detect muscle activity onset delay: the double-threshold method and cross-correlation method.
Methods: Surface and indwelling electromyography were recorded during lumbar side-lying manipulations in 17 asymptomatic participants. Muscle activity onset delays in relation to the thrusting force were compared across methods and muscles using a generalized linear model.
Results: The threshold combinations that resulted in the lowest Detection Failures were the "8 SD–0 milliseconds" threshold (Detection Failures = 8) and the "8 SD–10 milliseconds" threshold (Detection Failures = 9). The average muscle activity onset delay for the double-threshold method across all participants was 149 ± 152 milliseconds for the multifidus and 252 ± 204 milliseconds for the erector spinae. The average onset delay for the cross-correlation method was 26 ± 101 for the multifidus and 67 ± 116 for the erector spinae. There were no statistical interactions, and a main effect of method demonstrated that the delays were higher when using the double-threshold method compared with cross-correlation.
Conclusions: The threshold parameters that best characterized activity onset delays were an 8-SD amplitude and a 10-millisecond duration threshold. The double-threshold method correlated well with visual supervision of muscle activity. The cross-correlation method provides several advantages in signal processing; however, supervision was required for some results, negating this advantage. These results help standardize methods when recording neuromuscular responses of spinal manipulation and improve comparisons within and across investigations. (J Manipulative Physiol Ther 2016;39:279-287)
Key Indexing Terms: *Manipulation; Spinal; Chiropractic; Reflex; Electromyography; Biomechanical Phenomena; Kinetics*

Spinal manipulation (SM) is a treatment used by doctors of chiropractic, doctors of osteopathy, and physical therapists to address a wide variety of musculoskeletal conditions.[1] Although high-velocity, low-amplitude (HVLA) SM is a recognized treatment of acute and chronic low back pain,[2] questions about the underlying biomechanical mechanisms of effective treatment remain unanswered. For example, the ideal amount of relative vertebral movement, the importance of a muscular reflex response, and the role of joint cavitation (audible release) all remain unclear.[3] By developing a better understanding of how these aspects contribute to pain relief through in vivo research, improvements can be made in the pairing of specific treatments with patient and clinical condition.

In vivo research on SM has largely focused on mechanical parameters such as external thrust force, vertebral movement, and cavitation, whereas few investigations have examined the neuromuscular response to the manipulation itself. This response consists of integrated communication between the sensory system (ie, mechanoreceptors) and the motor system (ie, muscles). Sensory system responses to SM include positive action potentials in spinal nerve roots,[4] increases in central nervous system excitability,[5] and decreased sensitivity to pain.[6] The motor system response to SM includes both

[a] Graduate Research Assistant, Department of Mechanical and Materials Engineering, University of Denver, Denver, CO.
[b] Assistant Professor, Department of Mathematics, Physics and Engineering, Mount Royal University, Calgary, AB, Canada.
[c] Clinician, University of Colorado Hospital, Integrative Medicine Program at University of Colorado Hospital, University of Colorado Denver School of Medicine, Aurora, CO.
[d] Assistant Professor, Department of Mechanical and Materials Engineering, University of Denver, Denver, CO.
Submit requests for reprints to: Bradley, S, Davidson, PhD, Assistant Professor, University of Denver, 2450 S Gaylord St, Denver, CO 80210. (e-mail: *Bradley.davidson@du.edu*).
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increased and decreased paraspinal muscle electromyographic (EMG) activity.[7–9] Mechanisms that may explain these effects are altered inflow of proprioceptive primary afferents (groups I and II) from the paraspinal tissues, mechanical compression of neural tissue, central nervous system sensitization, and altered motorneuron excitability.[10]

Two characteristics of the EMG response to SM are relevant for examination: *amplitude of the response* and *timing of the response*. Evidence of EMG amplitude changes after SM is conflicting,[11,12] which creates difficulty when interpreting the meaning and significance of amplitude changes in response to SM. A recent review of EMG and SM indicated that manipulation is associated with short-term changes in the amplitude response of the myoelectric signal, but that the response can be either an amplitude *increase or a decrease*, and may be specific to the proximity of the muscle to the force application and activity performed.[12] In addition, interpretation of the amplitude response across participants can be difficult as it is dependent on the type of muscle studied, the training level, and participant motivation.

Timing of the muscle response is quantified as the muscle activity onset following the application of the thrust force. Pickar and Kang[13] demonstrated that the frequency of muscle spindle firing increases in response to forces consistent with SM, which may incite timing changes in efferent motoneuron activity. The muscle activity onset delay measured after a manual posterior to anterior SM in the thoracic spine was 50 to 200 milliseconds, a range that suggests a muscle spindle pathway reflex.[8] In contrast, the muscle activity onset delay measured after an SM performed with a mechanical device applied directly to L1 and L3 spinal vertebra in a posterior to anterior direction was 2.4 to 18.1 milliseconds.[4]

Two common methods are available to calculate the muscle activity onset delay: double-threshold detection and cross-correlation. It is currently unclear which method is most appropriate for calculating onset delays in response to SM. Considering the wide range of onset delays reported in the literature (≈2-200 milliseconds), and that forces are applied by practitioners in variable settings, there is a need to facilitate comparison between investigations by standardizing methodologies. The double-threshold method, which is more commonly used, requires identification of an amplitude threshold and a duration threshold over which EMG activity is considered muscle "active."[14] The cross-correlation method uses the cross-correlation function to identify the temporal shift (or time lag) between 2 time-varying signals, and has been used in human movement and rehabilitation sciences to evaluate muscle activity.[15]

Specific details of how muscle activation onset delays are calculated within each investigation are sometimes sparse, and a comparison of methodologies does not exist. Therefore, the objectives of this investigation were as follows: (1) to determine the threshold parameters that most reliably characterize the muscular response to SM using the double-threshold method of EMG onset detection, and (2) to evaluate the advantages and disadvantages of the double-threshold method and cross-correlation methods when applied to HVLA SMs in healthy participants. This information will help develop methodological standards on which to compare the EMG responses in research on SM and assist interpretation and applications of EMG in research and clinical practice.

Table 1. *Mean ± SD Participant Anthropometric Information*

	Male (n = 9)	Female (n = 8)
Age (y)	31.6 ± 13.4	28.8 ± 5.2
Height (cm)	179.4 ± 7.7	165.0 ± 3.3
Weight (kg)	79.9 ± 6.4	59.0 ± 4.7
Dominant hand (right/left)	(8/1)	(6/2)

Methods

Participant Information

Seventeen participants with no history of low back pain during the previous 4 years (Table 1) visited the laboratory for 1 session lasting 3 hours in which lumbar muscle activity was collected during SM. Each participant was screened for contraindications to SM by performing an orthopedic and neurologic examination. Participants were excluded from the investigation if their current level of pain exceeded a 7 of 10 on a verbal pain scale, they experienced radicular pain below the knee during orthopedic testing, or neurologic examination revealed absent reflexes, decreased sensation, or weakness below the knee. Each participant provided written, informed consent in accordance with the Colorado Multiple Institutional Review Board prior to the start of the experimental session.

Application of SM

Two doctors of chiropractic, each with more than 10 years of clinical experience, performed HVLA SM at the L3 and sacroiliac spinal level with a hypothenar contact in the side-lying position. The order of manipulations was randomized, the time between manipulations was between 1 and 3 minutes, and only data from the manipulation at L3 were used in this analysis.

EMG and Thrust Force Instrumentation

Each participant was instrumented with surface EMG over the left erector spinae at the L2 level and indwelling EMG (50 mm, 25-gauge needle with a pair of 0.051 mm, insulated, hooked wires, and 200 mm tail with 5 mm bare-wire terminations) in the left multifidus at the L2 spinal level (Fig 1) according to the insertion protocol