# Ultrasound Shear Wave Elastography to Assess Osteopathic Manipulative Treatment on the Iliocostalis Lumborum Muscle

## A Feasibility Study

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***Objectives***—To investigate the feasibility of ultrasound shear wave elastography (SWE) in assessing iliocostalis lumborum muscle changes after osteopathic manipulative treatment (OMT).

***Methods***—Using a linear array ultrasound transducer (4–9 MHz), we prospectively measured the shear wave velocity (SWV) of bilateral iliocostalis lumborum muscles in 20 patients with low back somatic dysfunction and in 9 age-matched healthy volunteers. The SWV was measured in muscle relaxation and contraction in all participants and immediately before and after OMT in patients. We developed a muscle SWV rate $[SWV_{contraction} - SWV_{relaxation})/SWV_{relaxation}]$ and an SWV improvement index $[(SWV_{pre\text{-}OMT} - SWV_{post\text{-}OMT})/SWV_{pre\text{-}OMT}]$ for quantifying muscle contractibility and changes in muscle stiffness after OMT. Statistical analyses included an unpaired *t* test to analyze the difference in the muscle SWV between muscle relaxation and contraction and between somatic dysfunction and nonsomatic dysfunction in patients and healthy volunteers, a paired *t* test to examine the difference in the SWV and SWV rate before and after OMT, the intraclass correlation coefficient to test intraobserver and interobserver reliability, and Spearman rank correlation to analyze the correlation of changes in the SWV with manual osteopathic assessments.

***Results***—The mean ages of the patients with low back somatic dysfunction and the healthy volunteers were 28 and 26 years, respectively. The muscle SWV significantly differed between somatic dysfunction and nonsomatic dysfunction in patients and healthy volunteers, between muscle relaxation and contraction, and before and after OMT ($P < .001$). The SWV improvement index moderately correlated with manual osteopathic assessments ($r = 0.68$). The interobserver and intraobserver reliability for performing SWE was good (intraclass correlation coefficient, >0.8).

***Conclusions***—Our results suggest that SWE is feasible for quantifying the change in muscle stiffness and contractibility after OMT.

***Key Words***—musculoskeletal disorder; osteopathic manipulative treatment; shear wave elastography; somatic dysfunction; ultrasound

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**Abbreviations**

*ICC, intraclass correlation coefficient; MSK, musculoskeletal; OMT, osteopathic manipulative treatment; SWE, shear wave elastography; SWV, shear wave velocity; TART, tissue texture abnormality, asymmetry, altered restriction of motion, and tenderness; US, ultrasound*

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Acute and chronic musculoskeletal (MSK) conditions with palpatory findings of somatic dysfunctions are often manually evaluated by osteopathic physicians. In osteopathic medicine, somatic dysfunction is defined as "impaired or altered function of related components of the somatic (body framework) system: skeletal, arthrodial, and myofascial structures, and related vascular, lymphatic, and neural elements."[1] Somatic dysfunction is associated with disorders of muscles, tendons, and the skeleton with common clinical manifestations of pain (low back or other locations), reduced muscle movement, and decreased limb/spine mobility in patients with MSK conditions. Common causes of the development of muscle somatic dysfunction include, but are not limited to, acute trauma, chronic injury, degeneration, and inflammation.[1–3] The criteria for diagnosing somatic dysfunction in osteopathic medicine are described as TART, an acronym that stands for tissue texture abnormality (T), asymmetry (A), altered restriction of motion (R), and tenderness (T).[2] Patients with somatic dysfunction and MSK problems are often negatively affected by physical limitations to their normal activities, which may in time lead to short- or long-term disabilities. Published reports approximate that nearly half of all Americans (126.6 million people) have an MSK condition.[3,4] The societal and economic costs of MSK problems are estimated to be approximately $874 billion per year, and this amount is rising.[5]

Somatic dysfunction can be treated by a manual therapeutic approach known as osteopathic manipulative treatment (OMT), by which the physician's hands are used to correct the dysfunction in the targeted tissue. Osteopathic physicians who perform OMT commonly observe that tissues with somatic dysfunction are associated with palpable stiffness of the musculature in the region of concern and that such muscle stiffness changes after OMT.[6–8] Osteopathic manipulative medicine has the advantage of treating the whole patient (body, mind, and spirit). Osteopathic manipulative treatment is considered more cost-effective than pharmaceutical or invasive interventions.[9] Osteopathic physicians are more likely to provide care using OMT for low back pain associated with MSK conditions than their allopathic medical counterparts.[10] One of the challenges that plagues the osteopathic profession has been the limited number of objective research studies to evaluate the efficacy of OMT in the clinical setting.[2] Many of the published studies comparing methods for assessing the efficacy of OMT were of insufficient quality and quantity to gain wide acceptance from the scientific community.[11,12]

Noninvasive assessment methods include conventional radiography, computed tomography, and magnetic resonance imaging. Although magnetic resonance imaging can provide good resolution and anatomic information on muscles and joints,[13–15] its routine application is limited because of poor patient tolerance, lack of portability, contraindications, and high cost.[16,17] Surface electromyography is another noninvasive method in which the electrical activity of muscles can be measured on the skin surface, but this often has a limited correlation with deep-tissue properties.[18] Therefore, the aforementioned techniques are not ideal methods for quantifying the muscle response to OMT in a clinical setting.

Ultrasound (US) shear wave elastography (SWE) has been successfully used to assess muscle mechanical properties (stiffness) in physiologic[19,20] and pathologic conditions such as Parkinson disease and poststroke spasticity.[21–23] These developments suggest that a US analysis of muscle properties may be useful in the evaluation of muscle alterations after OMT. To overcome unmet clinical needs of quantitative measurements in osteopathic manipulative medicine, we aimed to assess the feasibility of SWE for evaluating the efficacy of OMT.

## Materials and Methods

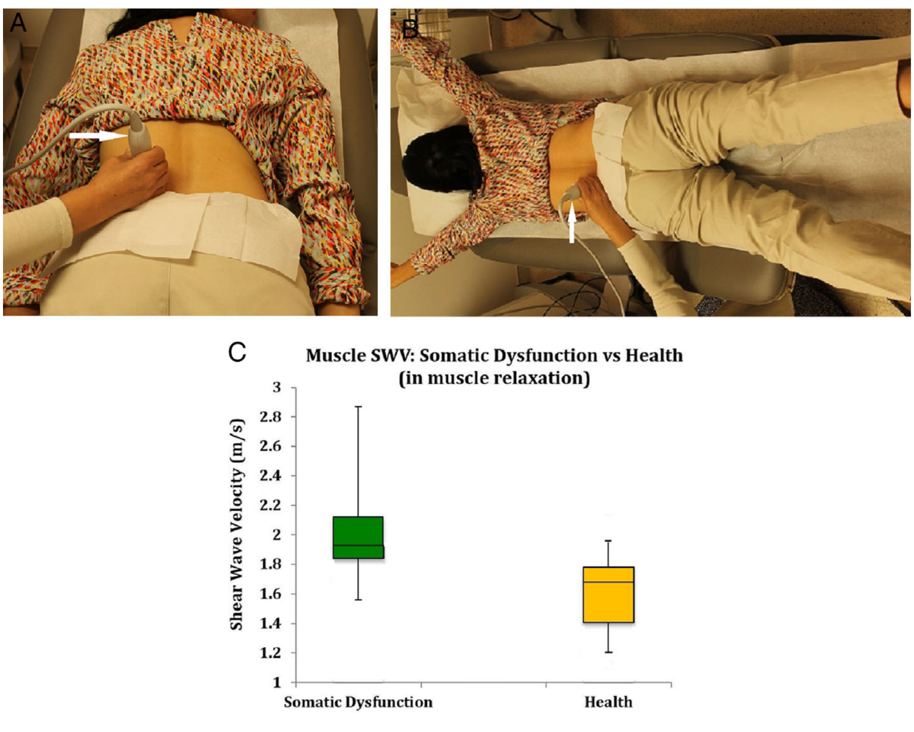
The Institutional Review Board at the university approved the study (No. 2017-0023), and all participants provided written informed consent before the outset. We randomly recruited patients who underwent OMT for low back pain. Inclusion criteria of the study were as follows: (1) age of 20 years and older; (2) consentable status; (3) ability to tolerate an osteopathic palpatory examination, a US scan, and OMT; (4) absence of cardiovascular or respiratory disease; (5) no lumbar spine surgery within a year before the US examination; and (6) the ability to extend back muscles (iliocostalis lumborum). We also recruited age-matched healthy volunteers who had no history of pain, injury, surgery, or identified low back somatic dysfunction as a control group. Absence of low back somatic dysfunction was determined by a licensed osteopathic physician (J.C.) using manual osteopathic TART assessments.

### *Shear Wave Elastography*

Shear wave elastography was performed on the low back of the participants while they were in the prone position (Figure 1). A licensed osteopathic physician targeted the iliocostalis lumborum muscles at the level between lumbar vertebrae 1 and 5 (L1–L5; Figure 1) to determine somatic dysfunction in the localized area. An Acuson S3000 US system (Siemens Medical Solutions, Mountain View, CA) equipped with a 9L4 linear array transducer (bandwidth of 4–9 MHz) was used to acquire shear wave velocity (SWV; meters per second) measurements of bilateral iliocostalis lumborum muscles. Technical considerations in performing muscle SWE included the following: (1) placing the transducer along a longitudinal section of muscle fibers because an anisotropic effect on the muscle is less in longitudinal than in transverse sections of the muscle[24]; (2) ensuring light pressure on the skin and underlying muscle, since any excessive pressure on the muscle may lead to overestimation of muscle stiffness; (3) maintaining good contact of the transducer to ensure that the sound beam was constantly perpendicular to the skin to minimize out-of-plane motion from the operator and patient; (4) using a shear wave quality map to verify the quality of the SWE process (Figure 2A); a homogeneous green area on the digital map indicated high-quality shear wave processing[22]; (5) using a standardized size (2.65 × 1.0 cm) of the region of interest to estimate the muscle SWV (Figure 2B); and (6) using a temporary skin marker to ensure the same site for SWV measurements before and after OMT.

The SWV was measured in iliocostalis lumborum muscle relaxation when the participant was in a neutral prone position (Figure 1A). The SWV was also measured in maximum muscle contraction when the participant was performing the Superman spine extension (trunk and leg extension) to produce a lumbar spine posture (15°–30° arch; Figure 1B).[25] The muscle SWV in bilateral iliocostalis lumborum muscles was measured at a depth between 2 and 4 cm from the skin throughout the study. The mean and standard deviation of the muscle

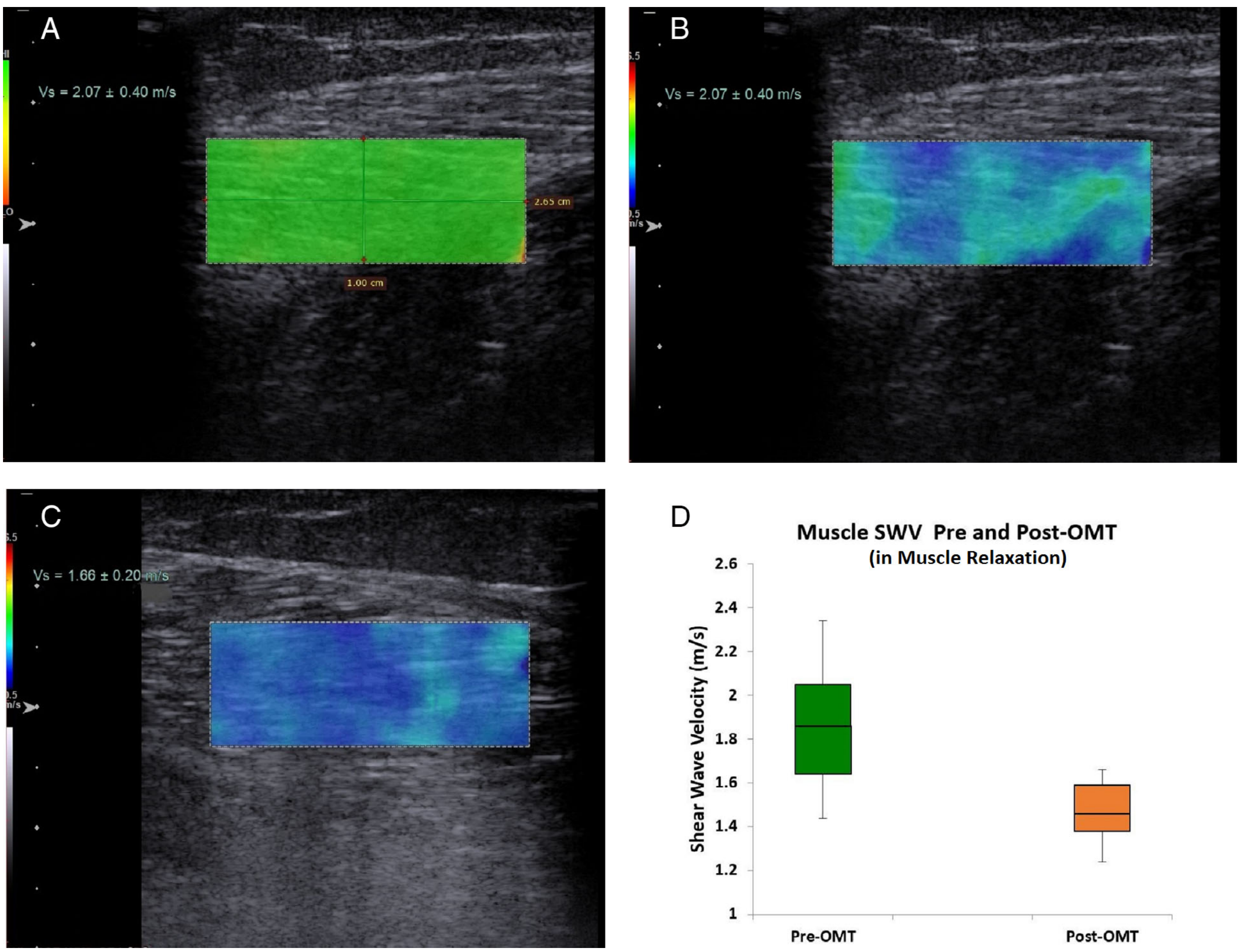
**Figure 1.** The SWV of the iliocostalis lumborum muscle was measured in the region of L1–L5. The US transducer (arrow) was placed on the skin in a longitudinal section of the iliocostalis lumborum muscle between L1 and L5. The muscle SWV was measured in iliocostalis lumborum muscle relaxation when the participant was in a neutral prone position **A**, and measured again in maximum muscle contraction when the participant was performing the Superman spine extension **B**. Box-and-whisker plots **C**, show a significant difference in the mean SWV in muscle relaxation between the muscle with somatic dysfunction (green box) and the muscle in healthy volunteers (yellow box; *P* < .01).



SWV in the entire region of interest (2.65 × 1.0 cm) was measured twice in muscle relaxation (Figure 2) and twice in maximum muscle contraction (Figure 3) in the patients and healthy volunteers. The muscle SWV was also measured immediately before and after OMT in patients with somatic dysfunction (Figure 3). A single observer performed SWE on the same muscle twice in 10 participants to test intraobserver repeatability. Two observers performed SWE in the same 10 participants separately to test interobserver reproducibility.

Shear wave elastography measures the velocity of shear wave propagation in the target tissue, and the SWV is positively correlated with the stiffness of the target tissue. The SWV is high in stiff tissue and low in soft tissue and is high in muscle contraction and low in muscle relaxation.[19] With SWV data being measured and collected, an SWV improvement index was developed to assess the percentage of change in the SWV measured after OMT compared with that measured before OMT. The SWV improvement index was defined as $(SWV_{pre\text{-}OMT} - SWV_{post\text{-}OMT})/SWV_{pre\text{-}OMT}$. A high SWV improvement index indicates a substantial change in the identified muscle responding to OMT. In addition, the SWV rate was defined as

**Figure 2.** Shear wave elastography was performed on a 30-year-old man with low back pain with the diagnosis of somatic dysfunction in the right lumbar region. Homogeneous green appears in the entire region of interest in the shear wave quality map **A**, indicating high-quality SWE processing. In back muscle relaxation, the SWV of the right iliocostalis lumborum muscle measured 2.07 ± 0.40 m/s **B**, and 1.66 ± 0.02 m/s **C**, before and after OMT, respectively. The color bars in (**A–C**) indicate the quality of the SWV from high (red) to low (blue). Box-and-whisker plots **D**, show a significant difference in the mean SWV in muscle relaxation before (green box) and after (orange box) OMT in 20 enrolled patients with low back somatic dysfunction ($P = .009$).



$(SWV_{contraction} - SWV_{relaxation})/SWV_{relaxation}$ to assess the relationship of the muscle SWV measurements between muscle relaxation (Figure 2) and contraction (Figure 3), representing muscle contractility during a maximum back extension. Essentially, a high SWV rate indicates a muscle with strong contractibility, whereas a low SWV rate indicates a muscle with weak contractibility (Figure 3C).

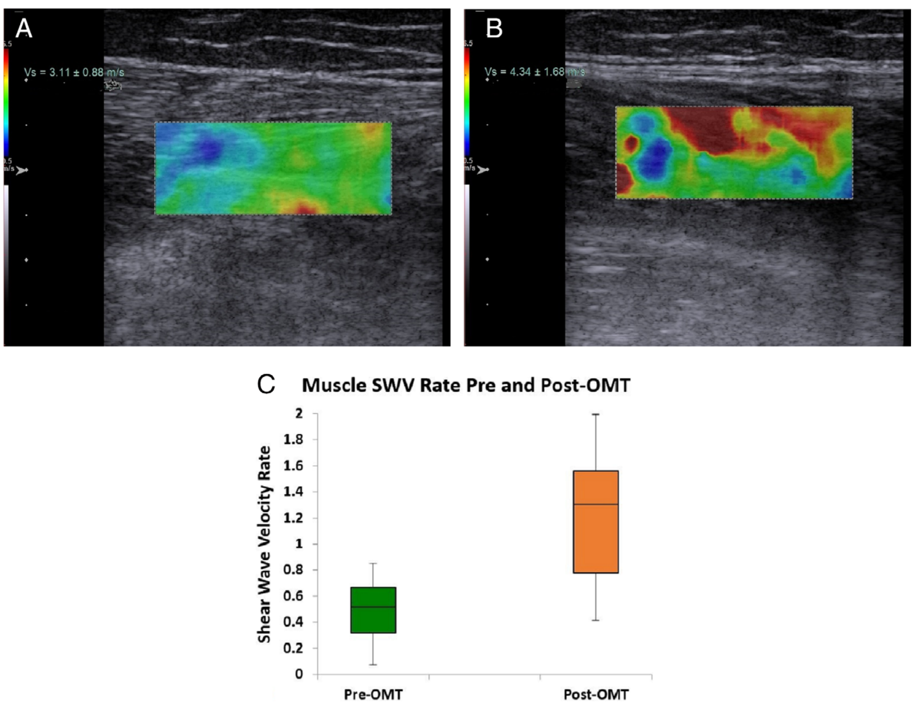
### *Osteopathic Assessments and OMT*

Osteopathic assessments were performed by manual osteopathic TART assessments that included 12 TART parameters (Table 1). A positive TART parameter was scored as 1, and a negative TART parameter was scored as 0 before OMT. A partial resolution of each positive TART parameter was scored as 0.5, and complete resolution of each positive TART parameter was scored as 0 after OMT. The total TART score was the sum of scores of all 12 TART parameters. An osteopathic improvement index, defined as TART improvement index = (total TART $score_{pre\text{-}OMT}$ − total TART $score_{post\text{-}OMT}$)/total TART $score_{pre\text{-}OMT}$, was developed to evaluate the OMT effect.

**Table 1.** Total TART Score for Assessing Muscle Somatic Dysfunction

| TART No. | TART Criteria | TART Parameters |
|---|---|---|
| 1 | Tissue changes | Red reflex |
| 2 | | Skin drag |
| 3 | | Temperature: hot |
| 4 | | Temperature: cold |
| 5 | Asymmetry | Decreased muscle tone |
| 6 | | Increased muscle tone |
| 7 | | Paraspinal fullness |
| 8 | Restriction of motion | Rotation |
| 9 | | Flexion |
| 10 | | Extension |
| 11 | | Restricted motion |
| 12 | Tenderness | Tenderness |
| Total | | |

**Figure 3.** Shear wave elastography was performed on the same patient with low back somatic dysfunction as in Figure 2. Color bars in **A** and **B**, indicate the quality of the SWV from high (red) to low (blue). The SWV of the right iliocostalis lumborum muscle was measured in maximum back muscle extension (contraction) before (**A**; 3.11 ± 0.88 m/s) and after (**B**; 4.34 ± 1.68 m/s) OMT. According to the developed SWV rate to assess muscle contractibility, the SWV rates of the right iliocostalis lumborum muscle for this patient were 0.5 and 1.61 before and after OMT, respectively. Box-and-whisker plots **C**, show a significant increase in the muscle SWV rate after OMT (orange box) compared with the rate before OMT (green box) in 20 enrolled patients with low back somatic dysfunction ($P < .001$).



Osteopathic manipulative treatment can be described as the therapeutic application of manually guided forces to improve physiologic function, including the muscular, bony, and fascial structures that affect neural, vascular, and lymphatic elements to support homeostasis that has been altered by somatic dysfunction.[6,7] Osteopathic manipulative treatment involves an eclectic range of manual techniques, such as soft tissue stretching, joint manipulation, resisted isometric “muscle energy” stretches, fascial relaxation or unwinding, counter strain, and visceral techniques. It is commonly applied to multiple regions with combinations of several techniques.[10]

The OMT in this study was targeted to the iliocostalis lumborum muscle, which is a part of the ilicostalis column of muscles and a common area affected by somatic dysfunctions in MSK conditions. The OMT techniques based on the individual somatic dysfunctions assessed by the osteopathic physician used in this study included articulatory, balanced ligamentous tension, facilitated positional release, high-velocity/low-amplitude, muscle energy, myofascial release, and still techniques. The iliocostalis lumborum provides resistance when the body bends forward and provides the force necessary to bring the body back into an upright position. Its bilateral action is responsible for the extension and hyperextension of the spine. Along with the small multifidus muscles, the iliocostalis lumborum can also act to support and stabilize the lumbar spine.[26,27]

### *Statistical Analyses*

All variables were expressed at the mean and standard deviation. The mean SWV of the iliocostalis lumborum muscles between the sites with and without somatic dysfunction in patients, between patients with somatic dysfunction and healthy controls, between the muscle without somatic dysfunction in patients and the muscle in healthy controls, and between muscle relaxation and contraction was examined by an unpaired $t$ test. The mean muscle SWV and SWV rate measured before and after OMT were tested by a 2-tailed paired $t$ test. A single observer performed SWE on the same participants twice with an interval of 1 minute for testing intraobserver repeatability. Two observers performed SWE on the same participants separately for testing interobserver reproducibility. Interobserver and intraobserver variations in performing SWE were analyzed with the intraclass correlation coefficient (ICC). The correlation of the SWV improvement index with the osteopathic TART improvement index was analyzed by Spearman rank correlation to assess the feasibility of SWE for evaluating the efficacy of OMT. $P < .05$ was considered statistically significant. All statistical analyses were conducted with SPSS version 25.4 software (IBM Corporation, Armonk, NY).

## Results

Ultrasound SWE was performed on 20 patients (10 men and 10 women) with the diagnosis of low back somatic dysfunction and 9 age-matched healthy volunteers (5 men and 4 women) from September 2018 to May 2019. There was no significant difference in the mean age (29 versus 27 years) or body mass index (27.8 ± 3.1 versus 28.2 ± 1.9 kg/m$^2$) between men and women or between patients with somatic dysfunction and healthy volunteers (mean age, 28 versus 26 years; body mass index, 28.0 ± 2.5 versus 27.5 ± 1.6 kg/m$^2$; all $P > .05$).

A significant difference in the mean SWV was found between muscles with and without somatic dysfunction in 20 patients (1.83 ± 0.28 versus 1.60 ± 0.3 m/s; $P < .01$), between somatic dysfunctional muscles and healthy muscles (1.83 ± 0.28 versus 1.63 ± 0.27 m/s; $P < .01$) as well as between muscle relaxation and contraction ($P < .001$). The difference in the mean SWV between the muscles without somatic dysfunction in patients and the muscles in healthy controls was not significant ($P > .05$; Figure 1C). The mean SWV and SWV rate before and after OMT differed significantly ($P < .05$; Table 2). The mean SWV in the relaxed muscles significantly decreased after OMT (Figure 2D). The

**Table 2.** Shear Wave Velocities and Osteopathic Assessments for Somatic Dysfunction Before and After OMT

| Parameter | Before OMT | After OMT | *P* | Improvement Index |
|---|---|---|---|---|
| Total TART score | 6.55 ± 2.18 | 2.03 ± 1.68 | <.001 | 0.73 |
| SWV: relaxation, m/s | 1.83 ± 0.28 | 1.58 ± 0.3 | .009 | 0.27 |
| SWV: contraction, m/s | 3.27 ± 0.69 | 4.14 ± 0.88 | .001 | 0.55 |
| SWV rate | 0.82 ± 0.55 | 1.74 ± 0.79 | <.001 | 0.96 |

SWV rate significantly increased after OMT (Figure 3C). The ICC for testing interobserver repeatability was high at 0.80 ($P < .001$). The ICCs for testing intraobserver reproducibility were even higher at 0.97 for observer 1 and 0.96 for observer 2 ($P < .001$; Table 3). There was a moderate correlation between the SWV improvement index and the osteopathic improvement index after OMT (Spearman $r = 0.68$; $P < .01$).

## Discussion

We have observed the capability of US SWE for determining low back somatic dysfunction by comparing the mean SWV measured in the muscles with somatic dysfunction with that measured in the muscles without somatic dysfunction in patients and healthy controls. We have also demonstrated the feasibility of SWE for quantifying changes in stiffness and contractibility of the dysfunctional iliocostalis lumborum muscle after OMT by measuring the mean muscle SWV and calculating the developed SWV improvement index and SWV rate. To our knowledge, this is the first report on using SWE to quantify the effects of OMT on muscle mechanical properties (stiffness) and contractibility.

In comparison with muscles without somatic dysfunction in the enrolled patients and healthy controls, SWV values were remarkably high in muscles with somatic dysfunction as muscle elasticity decreased (stiff) because of muscle spasms, restriction of motion, or intrinsic disease. Muscles that are elastic (not stiff) normally will have a low SWV value.[28,29] In this study, SWV values in the dysfunctional muscles (Figure 2B) were significantly lower after OMT (Figure 2C). Explanations for this change include, but are not limited to, consequences of resolution of muscle spasms, improvement of local blood and lymphatic circulations, and a decrease of motion restriction by osteopathic manipulative techniques. After a significant decrease of the muscle stiffness at the site of somatic dysfunction, the contractility of the iliocostalis lumborum muscle increased significantly, indicating improvement in active muscle movement. These changes in SWE parameters after OMT indicate OMT treatment effects, not only on muscle tissue mechanical properties (stiffness) but also on muscle function (contractibility). In addition, the change in the iliocostalis lumborum muscle SWV calculated by the SWV improvement index moderately correlated with the improvement in somatic dysfunction assessed by osteopathic palpatory methods (TART) after OMT (Spearman $r = 0.68$).[30] Importantly, we have demonstrated good interobserver and intraobserver reliability of performing SWE in iliocostalis lumborum muscles with somatic dysfunction (ICC, 0.8–0.97; $P < .001$).

The effectiveness of OMT is commonly evaluated by conventional TART assessments by manual palpation subjectively. In this study, we have demonstrated that palpable muscle stiffness can be quantified by muscle elasticity changes in SWV values. Asymmetry can be measured by a significant difference in the SWV between the site of somatic dysfunction and the site free of somatic dysfunction if the somatic dysfunction is unilateral. Restriction of motion can be evaluated by the SWV ratio, which represents muscle contractibility. Nevertheless, the changes in SWE parameters that correlate with TART assessments may be used to evaluate the effectiveness of OMT.

Limitations in this study included the small sample size, the lack of testing the reliability of intraobserver and interobserver osteopathic manipulative examination of low back somatic dysfunction, and the lack of evaluating the effectiveness of OMT on low backs with varying severities of somatic dysfunction in different age groups. Furthermore, the acuity or chronicity of somatic dysfunction was not known among the participants.

In conclusion, the results of this study suggest that US SWE is feasible for assessing the effects of OMT in adults with iliocostalis lumborum muscle somatic dysfunction. Additional research is needed to further investigate the role of SWE in the evaluation

**Table 3.** Intraobserver and Interobserver Reliability Tests

| | | 95% Confidence Interval | | *F* Test With True Value 0 | |
|---|---|---|---|---|---|
| **Average Measure** | **ICC** | **Lower Bound** | **Upper Bound** | **Value** | ***P*** |
| Observer 1–observer 1 | 0.974 | 0.951 | 0.986 | 38.507 | <.001 |
| Observer 2–observer 2 | 0.961 | 0.926 | 0.979 | 25.527 | <.001 |
| Observer 1–observer 2 | 0.797 | 0.616 | 0.892 | 4.919 | <.001 |

**of OMT in different anatomic locations and across all age groups.**

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