Neuromusculoskeletal Medicine (OMT) Original Article

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Quantitative ultrasound to assess efficacy of treatment for neck somatic dysfunctions: a feasibility study

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Abstract

Context: Neck pain is a common complaint in healthcare clinics. Although the pathogenesis of neck pain is often multifactorial, trapezius muscle dysfunction has been commonly linked to neck pain. Osteopathic manipulative treatment (OMT) has been demonstrated to be an effective treatment modality in treating trapezius muscle dysfunction and neck pain. However, there is a current lack of objective, quantitative measures to assess the effectiveness of OMT. Through previous research, ultrasound technology has been shown to be promising in its ability to quantify tissue changes both pre- and post-OMT.

Objectives: The objectives of this study are to evaluate the feasibility of shear wave elastography (SWE) in assessing upper trapezius muscles with pain and hypertonicity, as well as the changes in these muscles post-OMT for cervical somatic dysfunctions.

Methods: After obtaining approval from the Rocky Vista University Institutional Review Board and written informed consent from participants, SWE and osteopathic assessments were performed on 22 adult participants with and without cervical spine somatic dysfunction. Participants with positive osteopathic assessments of tissue texture, asymmetry, restricted motion, and/or tenderness (TART) were treated utilizing OMT. Shear wave velocity (SWV, m/s) and shear wave velocity rate [SWVR = ($SWV_{contraction} - SWV_{relaxation}$)/ $SWV_{relaxation}$] of the upper trapezius muscles with and without pain and hypertonicity, and before and after OMT, were examined utilizing a two-tailed *t*-test.

Results: SWV in muscle contraction and SWVR were significantly lower in muscles with pain compared to muscles without pain ($p \leq 0.01$). SWV in muscle contraction was also significantly lower in hypertonic muscles compared to normotonic muscles ($p < 0.01$). Following OMT, SWV in muscle contraction and SWVR in muscles with pain and hypertonic increased significantly ($p \leq 0.01$). Overall TART score of all muscles with somatic dysfunction (SD) after OMT significantly decreased ($p < 0.01$). SWV in muscle contraction and SWVR in hypertonic muscles were also significantly increased ($p \leq 0.03$), with an improvement index of 0.11 and 0.20.

Conclusions: This study's results demonstrate the feasibility of utilizing SWE to evaluate somatic dysfunctions of the upper trapezius musculature and the efficacy of OMT for neck somatic dysfunctions.

Keywords: muscle; osteopathic assessment; osteopathic manipulative treatment; shear wave elastography; ultrasound.

Neck pain is a common complaint affecting up to 45.5% of office workers [1–3]. Risk factors for neck pain include duration of sitting, workplace design, and computer work [4, 5]. Physical exercise has been shown to alleviate and possibly prevent neck pain in sedentary adults [6]. Although the pathophysiology of neck pain is often multifactorial, trapezius muscle dysfunction is commonly linked [4, 5]. Trapezius muscle activity has been shown to be altered in patients with neck pain [7]. In a study of 38 office workers, scapular postural correction strategies were shown to address dysfunctions in trapezius muscle activity, illustrating the role of the upper trapezius muscle in the management of neck pain [7]. Myofascial trigger points (MTPs) within the trapezius muscle, characterized with ultrasound technology, have also been implicated in patients with neck pain [8].

From an osteopathic physician's perspective, one tool to evaluate neck pain is the Osteopathic Structural Exam (OSE) [9]. The OSE includes a palpatory examination to determine the physical characteristics of musculoskeletal pathologies,

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such as neck pain [10]. These characteristics include tissue texture abnormalities, asymmetry, restricted motion, and/or tenderness (TART). TART findings are utilized to identify the presence of somatic dysfunction (SD). SD is defined as impaired or altered function of the skeletal, arthrodial, and myofascial structures, as well as their related vascular, lymphatic, and neural elements [11]. SD is commonly associated with pain and muscle hypertonicity due to frequent involvement of nociceptive reflexes [12, 13]. Following the identification of an SD, osteopathic manipulative treatment (OMT) is commonly performed as an intervention [14, 15]. Following treatment, the SD is reassessed, evaluating for treatment effect [16]. In the setting of managing acute neck pain, OMT has been shown to be as efficacious as parenteral nonsteroidal anti-inflammatory medications [17]. Factors suggesting improvement or resolution of the SD include decreased pain sensation and increased range of motion of the affected tissues [18–20]. However, these improvements are largely subjective and prone to variability among patients as well as osteopathic practitioners [21, 22]. Currently, more research is needed to develop quantitative and objective measures for categorizing SD and OMT effectiveness [23, 24].

A method that has been shown to accurately quantify SD is quantitative ultrasound [8, 25, 26]. Quantitative ultrasound is a noninvasive imaging modality that assesses the biomechanical properties of tissues [25–28]. Specifically, ultrasound shear wave elastography (SWE) can be utilized to evaluate tissue stiffness, or elasticity, a major contributor to SD [25, 26]. SWE records shear wave velocity (SWV), the speed at which a shear wave propagates through tissues, measured in meters per second [25, 26]. Shear waves propagate through stiffer tissues faster than more elastic tissues [25, 26]. Thus, greater SWVs are associated with stiffer tissues [25, 26]. A study conducted with 20 adults demonstrated a positive correlation between SWV and SD, with higher SWV associated with higher TART scores [25]. SWE has also been shown to be capable of detecting changes in tissues with previous SD after OMT [20, 26]. SWV has been found to decrease following OMT [26].

The ability to objectively diagnose SD and monitor OMT efficacy could facilitate more standardization in diagnosis as well as lead to improvements in osteopathic training. While previous studies have indicated that SWE is effective at evaluating SD affecting the low back musculature [25, 26], the aims of this study are to evaluate the feasibility of SWE in assessing upper trapezius muscles with pain and hypertonicity, as well as the changes in these muscles post-OMT for cervical somatic dysfunctions.

Methods

The Institutional Review Board at Rocky Vista University approved this study (IRB #2017-0023), and all participants provided written informed consent. The study took place from February 2021 through July 2021.

Participants

A total of 22 adult volunteers were recruited (16 females and 6 males; mean age, 27 years; age range, 23–34 years) from the Rocky Vista University College of Osteopathic Medicine Southern Utah Campus and residents of Ivins, Utah. Recruitment was completed through emails, social media outreach, and fliers on the university campus as well as the surrounding community. Potential participants were questioned regarding any history of neck pain and then forwarded additional information on the purpose of the study. Compensation in the form of incentive cards were provided to offset the cost of traveling to the ultrasound laboratory. Once recruited, participants were scheduled for a survey (Supplementary Material) followed by a pre-OMT ultrasound assessment, then a 30 min OMT session performed by an osteopathic physician, and finally a post-OMT ultrasound assessment. All participants answered a health questionnaire regarding their neck musculoskeletal pathologies. Sixteen participants identified as having neck pain, while six did not (Table 1). Neck pain was graded by the participant before and after OMT utilizing a scale of 0–10, 10 indicating the highest level of pain. The inclusion criteria were as follows: (1) participants must be 20 years of age or older; (2) participants must understand the participatory risks and benefits in addition to providing written informed consent; (3) participants must be able to tolerate the OSE, ultrasonography scan, and OMT; (4) participants must have no history of neuromuscular disorders or autoimmune diseases; (5) participants must not have a history of cervical or other spinal surgery, or trauma within the last 6 months; and (6) participants must be able to self-contract the upper trapezius muscles.

Ultrasound shear wave elastography

SWE was performed prior to OSE (Figure 1) and immediately following a single OMT session (Figure 2). SWV measurements were obtained utilizing an ACUSON Sequoia (Siemens Healthineers, Issaquah, WA, USA) 10L4 linear array transducer (bandwidth of 4–10 MHz). Technical considerations of performing SWE included: (1) placing the transducer along a longitudinal section of muscle fibers to avoid anisotropic effects;

Table 1: Participant demographics and neck pain metrics presented with data ranges.

Average age (range), years	27 (23–34)
Average BMI (range), kg/m^2	24 (16–42)
Number of males	6
Number of females	16
Number with neck pain	16
Average duration of neck pain, months	18 (0.25–204)
Average severity of neck pain	4.8 (1–8)

BMI, body mass index.

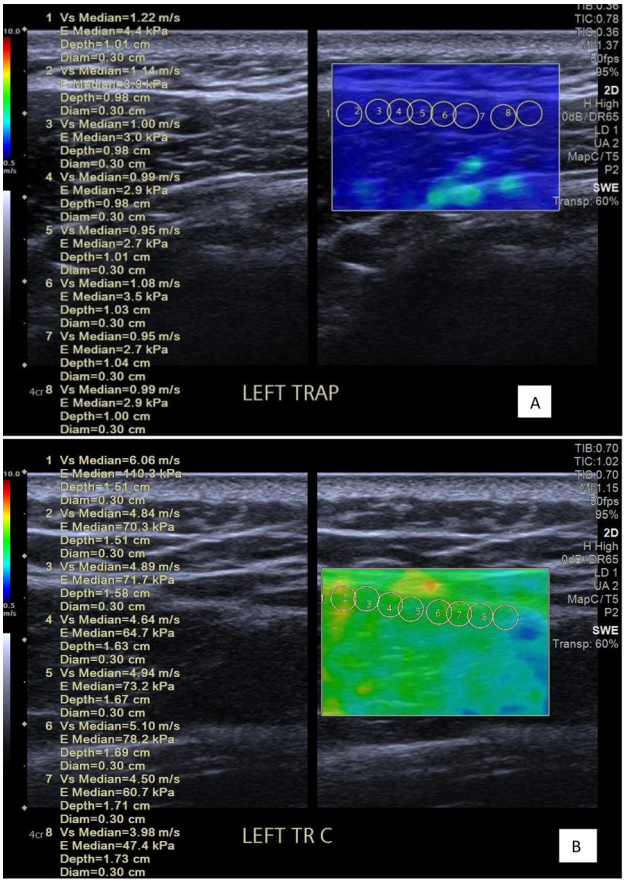

Figure 1: Point shear wave elastography (SWE) is performed to record eight shear wave velocity (SWV) measurements within the left trapezius muscle, in (A) muscle relaxation (mean SWV, 1.04 m/s) and (B) muscle contraction (mean SWV, 4.87 m/s).

(2) ensuring light contact to the skin to avoid overestimation of muscle stiffness; (3) maintaining consistent contact of the transducer; (4) ensuring that the sound beam was perpendicular to the skin to minimize out-of-plane motion from the operator and patient; and (5) SWV measurements were collected in the upper trapezius musculature at a point between the lateral edge of the acromion and spinous process of C7.

The ultrasound operator was blinded to the results of the pre-treatment survey, OSE, and OMT techniques performed. Standard ultrasonography machine settings for B-mode and SWE of the upper trapezius musculature included a scanning frequency of 7 MHz, image depth of 4 cm, tissue harmonic imaging, dynamic range of 65, mechanical index of 1.38, and the size of the region of interest (ROI, circle with 3 mm diameter). The same settings were utilized to scan the upper trapezius muscle in relaxed and contracted positions, and pre- and post-OMT. SWV in muscular relaxation was measured with the participant in a neutral prone position (Figure 3). SWV during muscular contraction was obtained with the patient in a prone position and instructed to retract and elevate their shoulders (Figure 3). Two images were taken in each position, and the mean and standard deviation SWV of the two images were calculated in relaxation and contraction. Shear wave velocity rate (SWVR), which represents muscle contractility as the change in muscle stiffness in contraction compared with that in muscle relaxation, was calculated utilizing the formula SWVR = ($SWV_{contraction}$ − $SWV_{relaxation}$)/$SWV_{relaxation}$ [29]. A high SWVR indicates a muscle with strong contractility, whereas a low SWVR indicates a muscle with weak contractility [26].

SWV of the upper trapezius muscle both pre-OMT and post-OMT were then utilized to calculate the Shear Wave Velocity Improvement Index (SWVII). The SWVII equation: ($SWV_{pre\text{-}OMT}$ − $SWV_{post\text{-}OMT}$)/($SWV_{pre\text{-}OMT}$) effectively quantifies the change in SWV after OMT. A higher SWVII indicates a greater change in the upper trapezius muscle in response to OMT [26].

Osteopathic assessment and OMT

Once the pre-OMT ultrasound images were obtained, participants were assessed by one of two osteopathic physicians, who were blinded to the pre-OMT ultrasound images as well as the participant's medical history. Two osteopathic physicians performed OMT in this study to increase the availability for scheduling participants. The osteopathic physicians performed an OSE with emphasis on the cervical (C1-7) and mid-upper thoracic (T1-4) spine and musculature. Utilizing the TART assessment, the physician then diagnosed neck SD, performed OMT aimed at correcting the diagnosed SD, and then reassessed TART for treatment effectiveness. Each participant was assessed and treated by the same physician.

The TART assessment included 11 parameters (Table 2) and was evaluated before and after OMT. Before OMT, a positive parameter was scored as 1, whereas a negative parameter was scored as 0. After OMT for each positive parameter, a partial resolution was scored as 0.5, and a complete resolution was scored as 0; a new or unimproved finding was scored as 1. The TART score was the sum of scores of all parameters. A TART improvement index, defined as [(total $TART\ score_{pre\text{-}OMT}$) – (total $TART\ score_{post\text{-}OMT}$)]/ (total $TART\ score_{pre\text{-}OMT}$), was utilized to evaluate overall improvement in TART following treatment [26].

Following the TART assessment and SD diagnosis, the osteopathic physician performed OMT on each subject, and the trapezius was rescanned to assess for changes. The osteopathic treatments in this study were targeted toward the neck, mid-upper thoracic region, and upper extremities. The average number of body regions treated was 2.6. An emphasis was given to the upper trapezius muscle due to its role in the pathogenesis of neck pain [30]. The osteopathic techniques utilized in this study included an articulatory technique, balanced ligamentous technique, facilitated positional release, counter-strain, high-velocity-low-amplitude, muscle energy technique, myofascial release, and osteopathic cranial manipulative medicine. The physicians were free to select any combination of these techniques to achieve the best results within the 30 min appointment time. The most frequently utilized techniques were the muscle energy technique, myofascial release, and counter-strain. The average number of modalities utilized was 4.3.

Statistical analyses

All variables were expressed as a mean and standard deviation. The mean SWV of the upper trapezius muscles with and without pain, as well as muscles with and without hypertonicity, were calculated utilizing a two-tailed *t*-test. The difference between painful or hypertonic muscles before and after treatment was determined utilizing a paired two-sample *t*-test. A single observer performed SWE on all participants. A p value <0.05 was

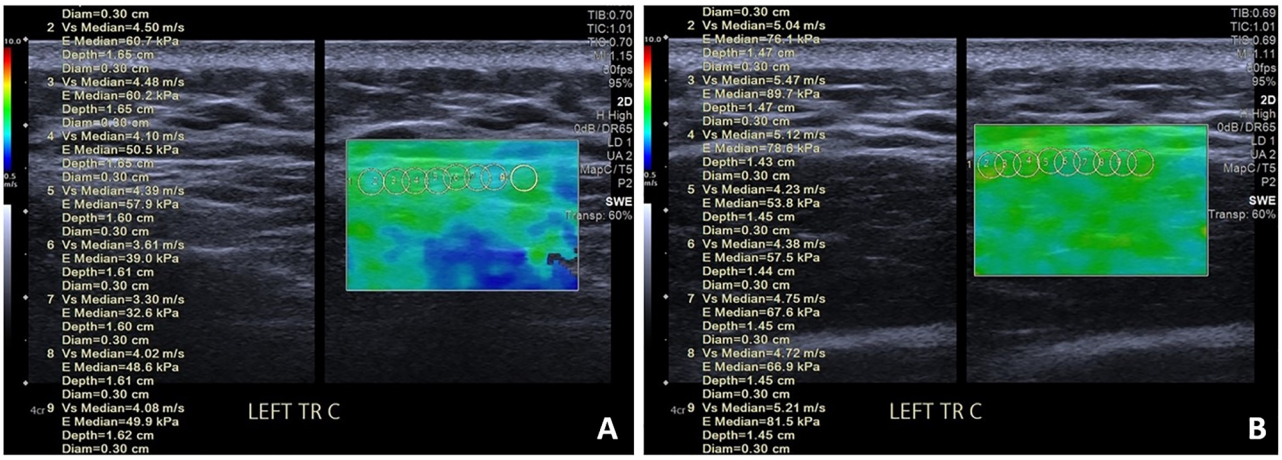

Figure 2: Point shear wave elastography (SWE) is performed to record eight shear wave velocity (SWV) measurements within the upper trapezius muscle. (A) Pre-OMT (mean SWV, 4.06 m/s) and (B) post-OMT (mean SWV, 4.87 m/s).

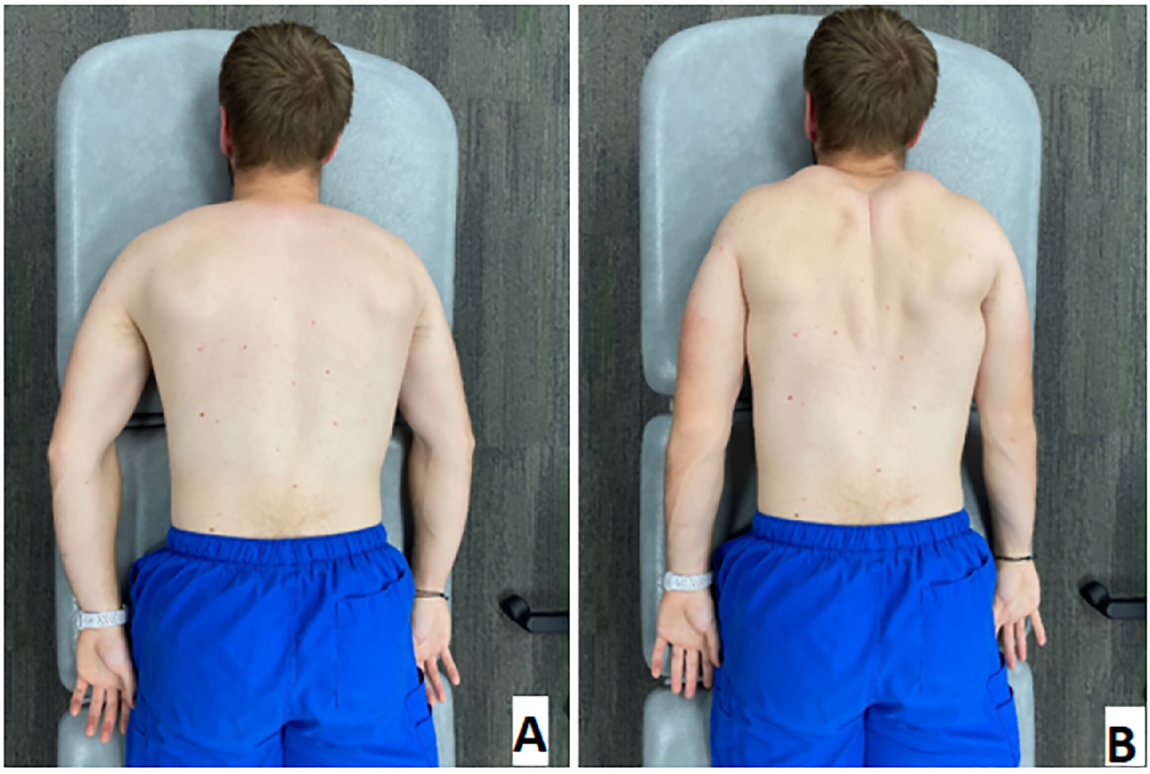

Figure 3: Participant scanning positions. Shear wave velocity (SWV) of the upper trapezius muscle is measured in (A) muscular relaxation and (B) muscular contraction both before and after OMT.

considered statistically signficant. Analysis was conducted utilizing GraphPad software and SPSS (version 27.0, IBM, Armonk, NY).

Results

SWE was performed on 22 subjects. Pretreatment surveys reporting pain in the right, left, or bilateral trapezius placed the muscle in the with-pain group, whereas no reported pain placed the muscle in the without-pain group. Among the 22 subjects, 16 participants were categorized as with neck pain and six without pain. The average reported severity of the pain was 4.8/10, with the average duration of pain being 18 months ranging from several days to 24 months (Table 1). Trapezius muscles with pain had an average contraction

Table 2: Parameters of TART assessment.

	TART criteria	TART parameters
1.	Tissue change	Red reflex
2.		Skin drag
3.		Warmth
4.	Asymmetry	Decreased muscle tone
5.		Increased muscle tone
6.		Hypertonicity (trapezius)
7.	Restriction of motion	Flexion
8.		Extension
9.		Rotation
10.		Restriction of motion
11.	Tenderness	Tenderness

TART, texture, asymmetry, restricted motion, and/or tenderness.

Table 3: Average SWV and SWVRs for muscles in contraction and relaxation.

	Contraction	Relaxation	SWV rate
No pain	5.47 ± 1.68	1.78 ± 0.58	2.42 ± 0.77
Pain	3.95 ± 0.96	1.56 ± 0.36	1.67 ± 0.89
p-Value	<0.01	<0.01	0.01
Normotonic	5.61 ± 1.40	2.01 ± 1.40	1.96 ± 1.11
Hypertonic	4.04 ± 1.13	1.61 ± 0.79	1.84 ± 1.11
p-Value	<0.01	0.53	0.77

SWV, shear wave velocity; SWVR, shear wave velocity rate.

shear wave velocity (CSWV) of 3.95 ± 0.96, an average relaxation shear wave velocity (RSWV) of 1.56 ± 0.36, and an average SWVR of 1.67 ± 0.89. Trapezius muscles without pain had an average CSWV of 5.47 ± 1.68, an average RSWV of 1.78 ± 0.58, and an average SWVR of 2.42 ± 0.77. The differences between CSWV and SWVR were significant, with p values of <0.01 and equaling 0.01 respectfully. The differences between RSWV in this group were found not to be significant, with a p value of 0.13 (Table 3).

Following TART evaluation, 12 trapezius muscles were identified as hypertonic, whereas 32 were without hypertonicity. Hypertonic trapezius muscles had an average CSWV of 4.04 ± 1.13, an average RSWV of 1.61 ± 0.79, and an average SWVR of 1.84 ± 1.11. Nonhypertonic trapezius muscles had an average CSWV of 5.61 ± 1.40, an average RSWV of 2.01 ± 1.43, and an average SWVR of 1.96 ± 1.11. Trapezius muscles with hypertonicity were found to have significantly lower CSWV, with a p value of <0.01. No difference was observed in RSWV or SWVR, with p values of 0.53 and 0.77 respectively, for these groups (Table 3).

The data were further subdivided into pre-OMT and post-OMT groups. In the pre-OMT group, muscles with pain had an average CSWV of 3.95 ± 0.96, an average RSWV of 1.56 ± 0.37, and an average SWVR of 1.67 ± 0.89. In the post-OMT group, muscles with pain had an average CSWV of 4.85 ± 1.10, an average RSWV of 1.52 ± 0.36, and an average SWVR of 2.30 ± 0.92 (Table 4). Again, in the pre-OMT group, hypertonic muscles had an average CSWV of 4.04 ± 1.13, an average RSWV of 1.50 ± 0.37, and an average SWVR of 1.84 ± 1.11. In the post-OMT group, hypertonic muscles had an average CSWV of 4.79 ± 0.97, an average RSWV of 1.46 ± 0.30, and an average SWVR of 2.37 ± 0.83 (Table 4). In muscles with pain, both CSWV and SWVR were statistically different when comparing pre-OMT and post-OMT data, with p values of <0.01. Relaxation SWV differences in muscles with pain pre-OMT and post-OMT were not statistically significant, with a p value of 0.53 (Table 4). In muscles with hypertonicity, both CSWV and SWVR were statistically different between pre- and post-OMT, with p values of <0.01 and 0.01 respectfully. However, RSWV differences in muscles with hypertonicity pre- and post-OMT were again found to be nonsignificant, with a p value of 0.44 (Table 4).

Table 4: Average SWV and SWVRs pre- and post-OMT in painful and hypertonic muscles.

	Pre-OMT	Post-OMT	p-Value
Muscles with pain			
Contraction	3.95 ± 0.96	4.85 ± 1.10	<0.01
Relaxation	1.56 ± 0.37	1.52 ± 0.36	0.53
SWVR	1.67 ± 0.89	2.30 ± 0.92	<0.01
Hypertonic muscles			
Contraction	4.04 ± 1.13	4.79 ± 0.97	<0.01
Relaxation	1.50 ± 0.37	1.46 ± 0.30	0.44
SWVR	1.84 ± 1.11	2.37 ± 0.83	0.01

OMT, osteopathic manipulative treatment; SWV, shear wave velocity; SWVR, shear wave velocity rate.

Table 5: Average SWV and SWV rate pre- and post-OMT in all participants.

	Pre-OMT	Post-OMT	p-Value	Improvement index
Average tart score	4.81 ± 1.86	3.26 ± 1.30	<0.01	0.32
Contraction SWV	4.41 ± 1.36	4.92 ± 1.11	0.01	0.11
Relaxation SWV	1.62 ± 0.44	1.58 ± 0.39	0.7	0.025
SWV rate	1.87 ± 1.10	2.34 ± 0.91	0.03	0.20

OMT, osteopathic manipulative treatment; SWV, shear wave velocity; SWVR, shear wave velocity rate; TART, texture, asymmetry, restricted motion, and/or tenderness.

Total TART scores for all muscles decreased from 4.81 ± 1.86 pre-OMT, to 3.26 ± 1.30 post-OMT. This decrease was significant, with a p value of <0.01. The overall TART improvement index was 0.32. The average CSWV of all muscles pre-OMT was 4.41 ± 1.36, whereas the average CSWV of all muscles post-OMT was 4.92 ± 1.11. This increase was

significant, with a p value of 0.01. Conversely, the average RSWVs of all muscles pre-OMT and post-OMT were 1.62 ± 0.44 and 1.58 ± 0.39 respectfully. This increase was not statistically significant, with a p value of 0.7. SWVR followed a similar trend. The average SWVR of all muscles pre-OMT was 1.87 ± 1.10, while average SWVR of all muscles post-OMT was 2.34 ± 0.91. This increase was significant, with a p value of 0.03. SWVR was found to have the greatest SWVII at 0.20, followed by CSWV at 0.11, and finally by RSWV at 0.25 (Table 5).

Discussion

This study demonstrates the capability of SWE to detect differences in biomechanical properties within trapezius muscles through the observed statistically significant differences in SWVR and CSWV. Painful and hypertonic muscles were found to have statistically significant decreases in CSWV. This suggests that for assessing pathologic changes within muscles, SWV measured in muscle contraction might be more sensitive than SWV measured in muscle relaxation. Muscular pain and hypertonicity have previously been shown to reduce maximal voluntary contraction [31, 32]. The CSWV data obtained in this study support this claim. The significant decrease in SWVR between painful and non-painful muscles can also be explained by this principal. SWVR is a proxy for muscle contractility, thus it would stand to reason that painful muscles exhibit lower contractility. Although previous studies focused on examining muscles during relaxation, the results of this study indicate that examining CSWV and SWVR may provide more insight into a muscle's properties, thus potentially increasing SWE's sensitivity to changes in musculature.

When comparing pre- and post-OMT data, a significant increase in SWVR and CSWV post-OMT was observed. This relationship was identified in both painful and hypertonic muscles. An increase in CSWV and SWVR post-OMT is expected because of OMT's documented improvements on muscle mobility and contractility [19]. These results coincide with a significant decrease in TART score, as well as greater SWVII of CSWV and SWVR. The observed effect in this study suggests that OMT improved dysfunctional muscles by improving the overall contractility of the musculature. Explanations for these changes may include but are not limited to a resolution of muscle spasms, increased recruitment of muscle fibers in contraction, and improved lymphatic and vasculature function. These results are similar to previous studies examining SWE and lumbar spine dysfunctions, which also report an increase in muscle stiffness in contraction, as well as increased SWVR post-OMT [26].

The difference between this study and previous studies is that there was no observed decrease in RSWV in muscles before and after OMT [26]. This may have been the result of differences in study design from previous studies. For example, in previous studies, patients reported back pain to be present for 6 months to 72 months, whereas this study had a greater distribution of neck pain duration, ranging from several days to years, possibly leading to a more accurate representation of the effects of OMT on chronic pain [25, 26, 33]. This discrepancy could also be explained by the differences in TART scores; previous studies observed higher average TART scores compared to this study. This also may be an indication that acute SDs may not be detected by ultrasound during relaxation. Another possible reason for the lack of significance is because of the nature of neck pain. The intention of this study was to correlate cervical spine dysfunction with SWE; therefore, TART assessment was primarily focused on the cervical spine. Ultrasound scanning was performed on the upper trapezius muscle because it was one of the most common muscles associated with cervical SD and pain [8, 30]. However, neck pain is often multifactorial, involving more structures than just the trapezius muscle. Future studies must be performed to accurately correlate neck SD and SWV.

Limitations

This study has a few limitations. First, the sample size was small. Due to time constraints, 22 subjects were selected as participants. Future studies should focus on recruitment of a larger, more heterogenous participant population. Second, ultrasound images were not obtained at the exact same body site as the TART findings. Ultrasound scanning was obtained from a standardized location; however, the TART findings were obtained anywhere along the cervical spine. Although scanning location and TART findings were geographically close, this could have contributed to this study not identifying a significant difference in RSWV pre- and post-OMT. Third, only the upper trapezius muscle was scanned. Although the upper trapezius muscle is commonly implicated in neck SDs, these are often complex, comprising multiple musculoskeletal structures. Fourth, this study did not include a follow-up appointment to assess the longitudinal effects of OMT. TART findings and SWV were assessed immediately after OMT, and no follow-up appointment was made.

Conclusions

SWE of the upper trapezius muscle is capable of quantifying neck SD. This is evidenced by its ability to detect changes in TART findings within dysfunctional tissues. SWE was also shown to quantify changes to tissues after OMT. The results of this study as well as previous studies provide more evidence-based validation of the osteopathic profession and OMT.

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Conflicts of interests: None reported.
Informed consent: All participants in this study provided written informed consent prior to participation.
Ethical approval: The Institutional Review Board at Rocky Vista University approved this study (IRB #2017-0023).

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