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ORIGINAL CONTRIBUTION

Establishing the Content Validity of Palpatory Examination for the Assessment of the Lumbar Spine Using Ultrasonography: A Pilot Study

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Context: Practitioners of manipulative medicine have long sought to prove the intra- and interexaminer reliability of palpatory examinations in assessing somatic dysfunction. However, decades of research have yet to achieve the level of reproducibility needed to satisfy evidence-based criteria.

Objectives: To examine the content validity of segmental motion evaluations using ultrasonographic measurements and to investigate the implication of these results for understanding the effects of an osteopathic manipulative treatment technique—high-velocity, low-amplitude (HVLA)—applied to somatic dysfunction in the lumbar spine.

Methods: A repeated-measures design was used, with the ultrasonographer blinded to the findings for each participant. The study was divided into 2 phases: (1) palpatory and ultrasonographic examination with no treatment and (2) palpatory and ultrasonographic examination with HVLA treatment. During phase 1, measurements were taken of tissue depth corresponding to bony landmarks of the dysfunctional vertebrae. Dysfunction was identified by means of palpatory examination and captured in sequential (ie, test-retest) ultrasonographic images. Content validity of somatic dysfunction was addressed by comparing palpatory examination with ultrasonographic data. During phase 2, the same protocol for tissue depth measurements was applied to the pre- and posttreatment images for comparison.

Results: Twelve young, healthy, asymptomatic students with no contraindications to HVLA treatment were recruited at Kansas City University of Medicine and Biosciences. The test-retest reliability, as determined by a Pearson correlation coefficient, was 0.997. For all participants, objectively identified side of dysfunction correlated with palpatory evaluation of segmental motion. A within-subjects analysis of variance was performed on the raw data, corrected for lumbar lordosis, showing statistical significance for main effect for side of measurement ($P<.001$) and interaction of side and time ($P<.001$), and showed no statistically significant effect for time ($P=.259$).

Conclusion: Ultrasonography is a reliable instrument for the assessment of somatic dysfunction of the lumbar spine. The data also establish the content validity of palpatory examinations. In addition, this study provides the first objective evidence, to our knowledge, of the effect of a thrusting manipulative treatment on dysfunctional lumbar vertebrae.

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The concept of somatic dysfunction, or an alteration to the optimal mechanical state of the body with resultant effects to its functional capacity and surrounding structures,[1] is vitally important to practitioners of manipulative medicine. Somatic dysfunction is important because of its local effect on the body and its multifaceted effect on a patient's overall health.[2] The manipulative medicine research community has diligently sought an objective means to identify somatic dysfunction, focusing its effort on a standardized approach with independent verification. Without a consistent and reproducible diagnostic method, however, it is difficult to establish an evidence-based use of manipulative techniques to correct dysfunction.[3]

Somatic dysfunctions are commonly identified by palpatory examinations. Criteria used for palpatory evaluation

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of somatic dysfunction include assessing for changes in the texture of adjacent tissues, asymmetry in bony position, restricted range of motion, and tenderness to palpation.[1,3] Throughout the early history of the osteopathic medical profession, somatic dysfunction was identified by components specific to each physician's respective understanding, creating a wholly unreliable basis for osteopathic research.[2] Johnston et al[4] pioneered the use of standardized protocols to detect somatic dysfunction—consisting of "deep tapping" (a percussion style of palpation), tape markers, and a light cloth that mapped the location of somatic lesions—which provided one set of approaches to which investigations could be calibrated. However, despite this enhancement in reliability provided by standardization and later consensus training,[5] a majority of the published protocols have failed to report a level of reproducibility (ie, results that are statistically similar among investigators and across populations) that supports the use of palpatory examination in evidence-based clinical practice.[5]

Protocols were developed to remove aspects of variability from previous research through the use of instruments such as electromyography,[6,7] kinematic analyses,[8] myoelectric data,[9] and thermography.[10] Researchers sought to evaluate somatic dysfunction by using a more quantifiable method that incorporated these instruments as reference standards (also known as "gold standards") to measure the same phenomena investigated by means of palpatory examination. These studies[6-10] attempted to assess the validity—defined by Najm et al[11] as the accuracy of a measurement of the true state of a phenomenon—of aspects of manipulative medicine, placing a special emphasis on content validity.

Content validity is the extent to which a measure adequately and comprehensively measures what it claims to be measuring,[11] assessed by the incorporation of a reference standard, which is a measure accepted as the best available for the assessment of particular phenomena. Because previous studies of manipulative medicine lacked acceptable reference standards,[11] however, the full potential of this avenue of research has remained elusive. Fortunately, continuous advances in medical technology have provided new modalities to address and surmount this issue.

Ultrasonography represents one such advance in medical technology. Ultrasonography stands apart from invasive procedures (eg, surgery, histopathology, angiography)[11] or radiography; it allows for the direct visualization of underlying anatomy through a noninvasive technology that is free of radiation exposure. A study by Fryer et al[12]—which was, to our knowledge, the first to use ultrasonography for assessing palpatory examinations—compared readings of muscle thickness from paraspinal tissues that exhibited tenderness to palpation with nontender tissues.

Palpation remains a cornerstone of manipulative medical education curricula and a common technique used in clinical practice. The standard palpatory examination assesses for the asymmetrical change in position of the vertebra followed by motion testing for restriction of motion in 1 or more planes of motion.[1] Additional research is needed to confirm the reliability of palpatory examinations in identifying positional asymmetry. Such studies will begin to satisfy the requirements of evidence-based medicine and support the continued use of palpation examination in osteopathic medical education by demonstrating a reliable and reproducible way to assess motion restriction. Previous research,[5,11,13] however, has failed to demonstrate reliable evaluation of motion restriction. In the present study, we sought to examine the content validity of segmental motion evaluations by using ultrasonographic images and to investigate the implication of these results for understanding the effects of high-velocity, low-amplitude (HVLA) treatment applied to somatic dysfunction in the lumbar spine.

Methods

Participants were recruited from the freshman and sophomore classes of the student population at Kansas City University of Medicine and Biosciences' College of Osteopathic Medicine by announcement after daily lectures. We obtained approval from the university's Institutional Review Board. Exclusion criteria for the study included diagnosis of chronic back pain, spondylolisthesis, spondylosis, herniated nucleus pulposus, osteopenia, osteoporosis, osteophytic changes in the lumbar spine, and prior back surgery. For those who met the inclusion criteria, informed consent was obtained and demographic information was gathered from participants, including age, height, and weight.

All images in the present study depicted specific vertebral levels, as assessed by an ultrasonographer certified in cardiovascular and echo technology. The ultrasonographer ensured that soft tissue landmarks were uniform between subsequent images captured over time and, when scoring, the ultrasonographer measured the spinous process depth first, followed by the right and then left transverse process depths. The ultrasonographer relied on visual information, unaided by software, to correlate anatomic landmarks between images.

Phase 1: Pretreatment Examination and Imaging

For phase 1 of the current study, participants underwent palpatory examination by means of the lumbar rotoscoliosis test,[15,16] which assesses the rotational motion of a vertebral segment. This test consists of the application of an anterior force applied alternately on the most lateral aspect of both transverse processes of each vertebral segment, while restriction and freedom of motion in the prone position were noted (*Figure 1*). (A video of the pretreatment palpa-

Figure 1. *The physician performing palpatory examination using the lumbar rotoscoliosis test.*

Figure 2. *An example of the marking used for identification of transverse processes for repeat measurements.*

tory examination is available at http://www.jaoa.org/content/112/12/775/suppl/DC1.) A physician (K.D.T.) who was board certified in neuromusculoskeletal and osteopathic manipulative medicine performed the assessment. When a somatic dysfunction was identified, the physician marked the dysfunctional vertebra bilaterally (*Figure 2*) at its transverse processes for identification by the ultrasonographer, who was blinded to the specific diagnosis. Imaging was then performed at the particular level of dysfunction with the participant in the prone position by using the LOGIQ E9 Imaging System (GE Healthcare; Waukesha, Wisconsin), set to factory-established musculoskeletal imaging settings (*Figure 3*). The participant's body was maintained in a constant position for ultrasonographic examination and subsequent imaging.

After the initial imaging, participants were assisted from the examination table to a standing position. The participants immediately returned to the prone position on the examination table for a second (ie, retest) image capture at the marked level of dysfunction.

After both (ie, test and retest) images were captured, the ultrasonographer measured tissue depths as seen on the ultrasonographic images (*Figure 4*). Software included with the ultrasonographic imaging device was used to calculate the depth, in centimeters, from the superficial-most layer of skin to the most posterior aspect of the transverse processes of the dysfunctional lumbar vertebrae, bilaterally. The side demonstrating the shortest tissue depth was coded as the posterior transverse process, in accordance with the osteopathic postulates forming the foundation of palpatory examinations.[15,16] This same method was used to calculate the depth of the spinous process.

Statistical analyses were performed using IBM SPSS software (version 19; IBM Corporation, Armonk, New York). We computed test-retest reliability of ultrasonographic depth measurements by using Pearson product moment correlation. To assess content validity, the side of dysfunction identified at palpatory examination was compared with the most posterior side indicated by the ultra-

Figure 3. *The ultrasonographer holding a transducer at the level of somatic dysfunction.*

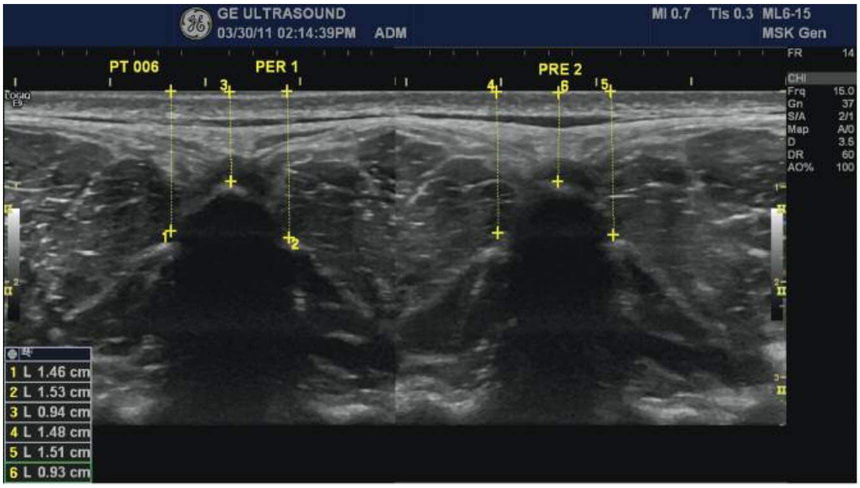

Figure 4. *Test-retest ultrasonographic images with markings for tissue depths, in centimeters. The first image (ie, test) was captured with the participant in a prone position on the examination table. After being assisted into a standing position, the participant was again placed in a prone position for a second (ie, retest) image capture.*

sonographic imaging. Means of the findings were calculated from test-retest findings.

Phase 2: Treatment and Posttreatment Imaging

In phase 2, the identified somatic dysfunction was treated using an HVLA technique.[17] This technique begins with the participant in the lateral recumbent position, with the side of the named dysfunction (ie, identified at the most posterior aspect of the transverse process) facing upward (*Figure 5*). The physician flexed the participant's knees and hips until motion was localized at the level of dysfunction (*Figure 6*). Next, the physician used the participant's arm in contact with the table as a lever to induce trunk rotation; motion was localized at the level of the dysfunctional vertebra (*Figure 7*). Once positioned, the participant crossed his or her arms and straightened the leg in contact with the table, while keeping the opposite thigh and leg flexed (*Figure 8*). Next, the physician placed his forearm closest to the participant's head between the participant's crossed arms and axilla, initiating contact with the participant's midaxillary region. With the patient properly positioned, the physician placed his forearm closest to the participant's feet on the posterior aspect of the innominate. The physician asked the participant to inhale and exhale. During exhalation, the physician used his arms to rotate the participant's pelvis and lumbar spine toward the physician while rotating the participant's cephalic torso away from the physician. At the end of exhalation, the physician applied an HVLA thrust with his forearm closest to the participant's feet (*Figure 8*), following the same rotation seen in *Figure 7*. At the conclusion of the intervention, the participant was returned to the prone position and the physician re-

Figure 5. *For initial set-up before high-velocity, low-amplitude technique, the physician placed the participant in a lateral recumbent position, on the side of the named dysfunction facing upward.*

Figure 6. *The physician induced rotation at the participant's upper extremity and flexing the participant's knees and hips until motion was localized at the level of dysfunction.*

Figure 7. *The final patient position before high-velocity, low-amplitude thrust was performed.*

examined the participant's lumbar spine by using the palpatory technique previously described. (A video of this procedure is available at http://www.jaoa.org/content/112/12/775/suppl/DC1.)

After HVLA treatment, ultrasonography was again performed (subsequently referred to as posttreatment imaging). The ultrasonographer adjusted the transducer until the anatomic landmarks in the posttreatment image converged with the landmarks in the pretreatment image. By using the same amount of force with the transducer, the ultrasonographer was able to use pre- and posttreatment images to calibrate transducer head placement. Ultrasonographic images were used to calculate the bilateral depths in centimeters from the superficial layer of skin to the most posterior aspect of the transverse processes and spinous process of the dysfunctional lumbar vertebrae before and after treatment (*Figure 9*). Once all measurements were obtained, the raw transverse process data were corrected for spinous process depth by subtracting the spinous process depth of the pre- and posttreatment images from their respective transverse process measurements to account for variation in the lordotic curvature of the lumbar spine.

Results

A convenience sample of 12 participants (5 men, 7 women) ranging in age from 22 to 30 years participated from January 2011 through February 2011. Posttreatment data were inadvertently deleted for 1 participant.

Phase 1

Test-retest measurements from the most superficial layer of skin to the transverse process, collected by means of ultrasonography before HVLA treatment, are provided in *Table 1*. The Pearson correlation between the calculated measurements from the 2 measurement sessions of the transverse process depths from the sequential ultrasonographic images was 0.997 ($P<.001$). Additionally, the findings of the segmental motion palpatory examination, compared with the objectively determined side of rotation measurements as previously described, revealed a concordance of 1.0 for the identification of side of rotation.

Phase 2

Raw data for transverse process depths, both before and after treatment, are summarized in *Table 2*. For the spinous process data (*Table 3*), no statistically significant differences were noted within individual participants as a function of time ($P=.47$). Between study participants, however, the posttreatment spinous process depth was noted to fluctuate inconsistently from the pretreatment depth measurements. To account for this degree of variability in

Figure 8. *The physician applied the high-velocity, low-amplitude technique.*

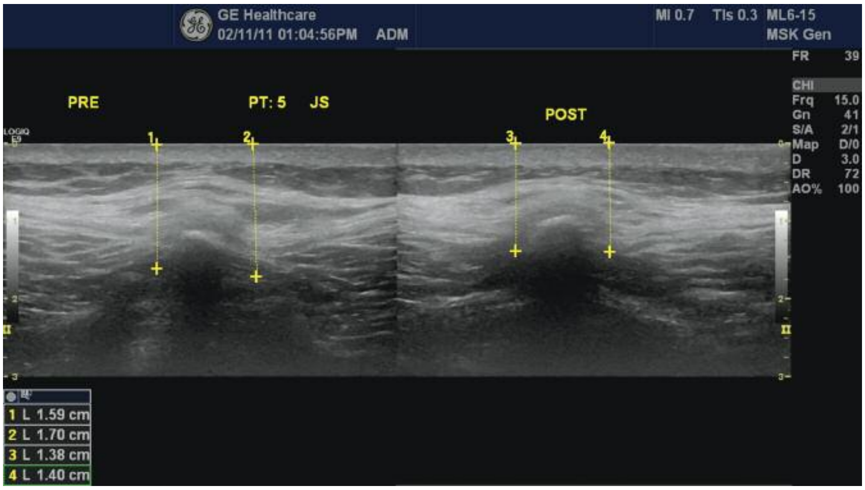

Figure 9. *Pre- and posttreatment ultrasonographic images of dysfunctional lumbar vertebrae, with tissue depths marked in centimeters.*

our transverse process data, the transverse process measurements were corrected for the lordotic curvature as previously described. A within-subjects analysis of variance compared the obtained measurements from the pre- and posttreatment images and left and right sides using data corrected for lordosis (*Table 2*). The analysis showed a statistically significant main effect for side ($F_{1,10}$=23.23, P<.001, partial η^2=0.699), a statistically significant interaction of side and time ($F_{1,10}$=29.74, P<.001, partial η^2=0.748), and no statistically significant effect for time. The interaction is illustrated in *Figure 10*.

Comment

The results indicate that ultrasonography can be a reliable method for the assessment and quantification of somatic dysfunction in the lumbar spine. Pearson correlation tests have a maximum value of 1.00, and our correlation of 0.997 indicates a very high degree of reliability for assessing tissue depth. Additionally, the correlation between palpatory examination of dysfunction and tissue depth measurements to identify the side of dysfunction revealed full concordance between the measures, providing support for the content validity of palpatory examination of segmental motion of the lumbar spine.

Phase 2 results indicated statistically significant side and side-by-time effects from data corrected for lordosis. The statistically significant results of the present study suggest that HVLA treatment improves segmental somatic dysfunctions as indicated by the return of restricted vertebra to a more symmetrical position as expressed by tissue depth measurements (*Figure 10*). Our data support the use of the lumbar rotoscoliosis test[15,16] in palpatory examination; a central tenet of the test is that dysfunctional vertebrae are held in an asymmetrical position of rotation. However, we also note that the measurement of tissue depth, when corrected for lordosis, showed a uniform presence of left-sided somatic dysfunctions. These findings may reflect either an unknown bias in measurement or a common biomechanical response such as the "common compensatory pattern" described by Zink and Lawson.[18]

Because the current study is, to our knowledge, the first attempt to use ultrasonography to assess the bony landmarks in palpatory examination, the possibility of a measurement bias cannot be excluded, particularly considering the magnitude of the depth being assessed. This potential for bias is compounded by the use of a single ultrasonographer

Table 1.
Pretreatment Test-Retest Data Measurements From Superficial Skin to Transverse Process Obtained During Palpatory Examination[a]

Patient No.	Age, y	Sex	BMI	First Image, cm			Second Image, cm		
				Right	Left	SP Depth[b]	Right	Left	SP Depth[b]
1	24	F	21.6	1.11	1.09	0.63	1.11	1.00	0.62
2	24	F	18.7	0.96	0.89	0.63	0.88	0.85	0.60
3	26	M	24.4	1.55	1.51	0.83	1.61	1.53	0.81
4	23	M	31.5	1.84	1.80	1.36	1.84	1.80	1.38
5	23	M	26.3	1.60	1.58	0.92	1.58	1.57	0.93
6	22	M	24.4	1.53	1.46	0.94	1.51	1.48	0.93
7	30	F	27.4	1.58	1.56	1.09	1.56	1.55	1.09
8	25	F	19.4	0.99	0.97	0.62	1.00	0.96	0.61
9	23	M	21.7	0.83	0.81	0.47	0.82	0.81	0.47
10	24	F	28.3	1.83	1.81	1.54	1.82	1.80	1.53
11	24	F	23.6	0.92	0.90	0.62	0.93	0.91	0.62
12	25	F	23.5	0.74	0.72	0.55	0.74	0.71	0.55

[a] All participants were rotated to the left side, as identified by means of palpatory examination. The first (ie, test) ultrasonographic image was captured when the participant was in prone position on the examination table, and the second (ie, retest) image was captured after participant stood up and then was re-placed in a prone position.

[b] Represents tissue depth to tip of spinous process (SP).

Abbreviation: BMI, body mass index.

Table 2.
Tissue Depth (cm) From Superficial Skin to Transverse Process, Before and After High-Velocity, Low-Amplitude Treatment, as Determined With Ultrasonography[a]

Patient No.	Age, y	Sex	BMI	Before Treatment[b] Right	Before Treatment[b] Left	After Treatment Right	After Treatment Left
1	24	F	21.6	1.11	1.05	0.97	1.15
2	24	F	18.7	0.92	0.87	0.88	0.90
3	26	M	24.4	1.58	1.52	1.53	1.51
4	23	M	31.5	1.84	1.80	1.78	1.79
5	23	M	26.3	1.59	1.58	1.58	1.58
6	22	M	24.4	1.52	1.47	1.41	1.42
7	30	F	27.4	1.57	1.56	1.74	1.73
8	25	F	19.4	1.00	0.97	0.82	0.81
9	23	M	21.7	0.83	0.81	0.88	0.88
10	24	F	28.3	1.83	1.81	NA	NA
11	24	F	23.6	0.93	0.91	0.77	0.79
12	25	F	23.5	0.74	0.72	0.81	0.81

[a] All participants were rotated on the left side, as identified by means of palpatory diagnosis.
[b] Pretreatment values were calculated as means from test-retest data, which are provided in *Table 1* and were obtained during the palpatory examination phase.

Abbreviations: BMI, body mass index; NA, not available.

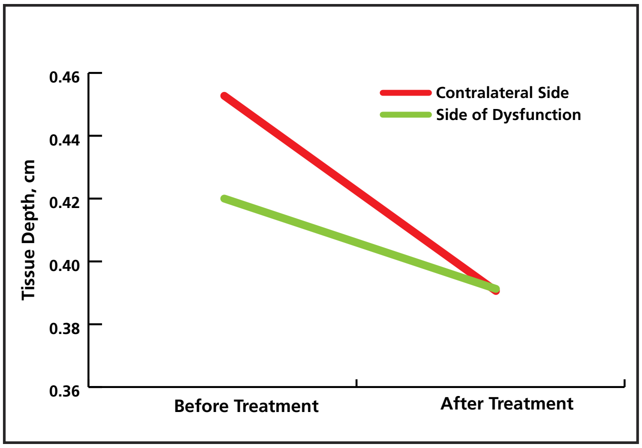

Figure 10. *Effect of high-velocity, low-amplitude technique on depth of transverse processes, in centimeters, corrected for lumbar lordosis. Measurements were obtained before and after treatment. The green line depicts the mean depth of the transverse process on the side of dysfunction and the red line depicts the mean depth of the transverse process on the opposite side. In the present study, all dysfunction was detected on the left side and thus for all participants the contralateral side was the right side.*

for the collection and analysis of the ultrasonographic images. In an attempt to minimize the risk of bias, the ultrasonographer approached the imaging and image scoring in a reproducible, stepwise manner. Future studies could allay this bias by using multiple examiners to assess interexaminer reliability for image measurements and by incorporating more advanced ultrasonographic imaging software to limit measurement variability.

One limitation of the current study was the inability to validate tissue location for imaging. We were unable to use volume navigation technology, which enables the ultrasonographer to use global positioning system markers to more precisely mark and calibrate tissue locations. Future studies could use this technology to more accurately duplicate measurements, thus removing some of the traditional obstacles to observing the relationship between vertebral positional changes and HVLA.

Conclusion

Through the implementation of ultrasonography, this study demonstrates a method for objectively identifying somatic dysfunction by reliably and quantitatively demonstrating the positional characteristics of rotation in the lumbar spine, and by establishing the content validity of palpatory examination for the identification of somatic

Table 3.
Comparison of Tissue Depth (cm) to Spinous Process Before and After High-Velocity, Low-Amplitude Treatment, With Transverse Process Data Corrected for Spinous Process Depth

Patient No.	Age, y	Sex	BMI	Before Treatment[a] SP Depth[b]	Before Treatment[a] Corrected Right	Before Treatment[a] Corrected Left	After Treatment SP Depth[b]	After Treatment Corrected Right	After Treatment Corrected Left
1	24	F	21.6	0.63	0.49	0.42	0.97	0.18	0.18
2	24	F	18.7	0.62	0.31	0.26	0.56	0.32	0.34
3	26	M	24.4	0.82	0.76	0.70	0.81	0.72	0.70
4	23	M	31.5	1.37	0.47	0.43	1.55	0.23	0.24
5	23	M	26.3	0.93	0.67	0.65	0.88	0.70	0.70
6	22	M	24.4	0.94	0.59	0.54	0.76	0.65	0.66
7	30	F	27.4	1.09	0.48	0.47	1.36	0.38	0.37
8	25	F	19.4	0.62	0.38	0.35	0.53	0.29	0.28
9	23	M	21.7	0.47	0.36	0.34	0.60	0.28	0.28
10	24	F	28.3	1.54	0.29	0.27	NA	NA	NA
11	24	F	23.6	0.62	0.31	0.29	0.50	0.27	0.29
12	25	F	23.5	0.55	0.19	0.17	0.53	0.28	0.28

[a] Pretreatment values were calculated as means from test-retest data, which are provided in *Table 1* and were obtained during the palpatory examination phase.
[b] Represents tissue depth to tip of spinous process (SP).

Abbreviations: BMI, body mass index; NA, not available.

dysfunction in the lumbar spine. This modality provides the manipulative medicine research community with a new means for palpatory examinations to meet evidence-based criteria.

The data from phase 2 of the present study suggest that a thrusting manipulative treatment technique can reduce segmental rotational dysfunction in the lumbar spine. This finding supports long-held postulates regarding the mechanism of this form of manipulative treatment.[2] Additional research is needed to confirm these findings for the lumbar spine. Long-term sequential imaging could be conducted to assess the longitudinal effects of HVLA treatment on dysfunctional vertebra of the lumbar spine. The use of volume-navigational ultrasonographic technology in future research would further enhance the validity of diagnostic imaging.

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References

1. Jones HJ. Somatic dysfunction. In: Ward RC, executive ed. *Foundations for Osteopathic Medicine.* 2nd ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2003:1153-1161.

2. Heath DM, Gevitz N. The research status of somatic dysfunction. In: Ward RC, executive ed. *Foundations for Osteopathic Medicine.* 2nd ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2003:1188-1193.

3. Potter L, McCarthy C, Oldham J. Intraexaminer reliability of identifying a dysfunctional segment in the thoracic and lumbar spine. *J Manipulative Physiol Ther.* 2006;29(3):203-207.

4. Johnston WL, Allan BR, Hendra JL, et al. Interexaminer study of palpation in detecting location of spinal segmental dysfunction. *J Am Osteopath Assoc.* 1983;82(11):839-845.

5. Degenhardt BF, Snider KT, Snider EJ, Johnson JC. Interobserver reliability of osteopathic palpatory diagnostic tests of the lumbar spine: improvements from consensus training. *J Am Osteopath Assoc.* 2005;105(10):465-473.

6. Fryer G, Mird M, Robbins B, Fossum C, Johnson JC. Resting electromyographic activity of deep thoracic transversospinalis muscle identified as abnormal with palpation. *J Am Osteopath Assoc.* 2010;110(2):61-68.

7. Fryer G, Morris T, Gibbons P, Briggs A. The electromyographic activity of thoracic paraspinal muscles identified as abnormal with palpation. *J Manipulative Physiol Ther.* 2006;29(6):437-447.

8. Johnston WL, Vorro J, Hubbard RP. Clinical/biomechanic correlates for cervical function, part I: kinematic study. *J Am Osteopath Assoc.* 1985;85(7):429-437.

9. Vorro J, Johnston WL. Clinical biomechanic correlates for cervical function, part II: a myoelectric study. *J Am Osteopath Assoc.* 1987;87(5):353-367.

10. Kelso AF, Grant RG, Johnston WL. Use of thermograms to support assessment of somatic dysfunction or effects of osteopathic manipulative treatment: a preliminary report. *J Am Osteopath Assoc.* 1982;82(3):182-188.

11. Najm WI, Seffinger MA, Mishra SI, et al. Content validity of manual spinal palpatory exams—a systematic review. *BMC Complement Altern Med.* 2003;3:1-14.

12. Fryer G, Morris T, Gibbons P. The relationship between palpation of thoracic tissues and deep paraspinal muscle thickness. *Int J Osteopath Med.* 2005;8(1):22-28.

13. Spring F, Gibbons P, Tehan P. Intra-examiner and inter-examiner reliability of a positional diagnostic screen for the lumbar spine. *J Osteopath Med.* 2001;4(2):47-55.

14. DiGiovanna EL. Somatic dysfunction. In: *An Osteopathic Approach to Diagnosis and Treatment.* 3rd ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2005:16-23.

15. DiGiovanna EL. Evaluation of the lumbar spine. In: *An Osteopathic Approach to Diagnosis and Treatment.* 3rd ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2005:237-242.

16. Kuchera WA. Lumbar region. In: Ward RC, ed. *Foundations for Osteopathic Medicine.* 2nd ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2003:727-750.

17. DiGiovanna EL, Erner BS, Scariati PD. Thrusting techniques for the lumbar spine. In: *An Osteopathic Approach to Diagnosis and Treatment.* 3rd ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2005:264-265.