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ORIGINAL CONTRIBUTION

Measuring Thoracic Excursion: Reliability of the Cloth Tape Measure Technique

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Objective: To assess the reliability of using a cloth tape measure to determine thoracic respiratory excursion as a measurement of chest expansion or mobility.

Methods: Physicians and residents experienced in osteopathic manipulative treatment measured thoracic excursion with a cloth tape measure held around the circumference of healthy male subjects' chests at two levels. Upper thoracic excursion measurements were taken at the level of the fifth thoracic spinous process and the third intercostal space at the midclavicular line. Lower thoracic excursion measurements were taken at the level of the 10th thoracic spinous process and the xiphoid process. At peak inhalation and exhalation, three examiners measured thoracic excursion at both levels. In the first session (n=5), examiners measured the same subject inhalation and exhalation. In the second session (n=4), examiners measured separate respiratory cycles. For each session, interexaminer intraclass correlation coefficients (ICCs) were calculated for thoracic excursion, inhalation, and exhalation in the upper and lower positions using a two-way random-effects analysis of variance model.

Results: Intraclass correlation coefficients for thoracic excursion ranged from 0.81 to 0.91 (95% confidence interval, 0.69-0.99) at both measurement levels in both sessions. When inhalation and exhalation were considered separately, interexaminer ICCs were 0.99 and greater. Standard deviations for measurements of each subject's thoracic excursion at both levels ranged from 0.5 cm to 0.8 cm with a mean of 0.6 cm.

Conclusion: The method of using a tape measure to assess thoracic excursion was highly reliable in men, resulting in ICCs of substantial reliability. The SDs at each level of measurement indicate that this method may be most useful in measuring changes in thoracic excursion that are expected to be 0.6 cm or greater.

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Improved mobility of patients is a fundamental objective in osteopathic medicine. A major goal of osteopathic manipulative treatment (OMT) is to normalize patient mobility. Assessment of mobility is crucial in determining the effectiveness and appropriateness of OMT for specific conditions, and osteopathic physicians typically reevaluate mobility and restriction after treatment. Although measurements of mobility are important in osteopathic medical research, most assessments of mobility have been subjective and qualitative in nature.[1,2]

Osteopathic physicians need to validate quantitative measures of mobility in a way that is meaningful to osteopathic medical theory and practice. However, the most critical aspects of mobility to measure for any given condition may not be clear to osteopathic physicians. We believe that, at minimum, measurements should assess the desired effect of the osteopathic manipulative (OM) procedure being administered.

Thoracic respiratory excursion is one such measurement of mobility. It is useful in diagnosing and evaluating ankylosing spondylitis, asthma, chronic obstructive pulmonary disease (COPD), and thoracic scoliosis.[3-7] It can also be used to assess the effects of OMT in patients with these conditions. Johnston[8] and Swabb at al[9] examined the interexaminer reliability of thoracic excursion during palpatory-skills training for osteopathic physicians. Both of these studies reported achieving substantial interexaminer reliability. However, these studies were published as meeting abstracts only, so the exact methods and statistical analyses were not described sufficiently to permit clinical application and comparison of findings.[8,9]

Previous Trial of Tape-Measure Technique

A previous clinical study that involved two authors of the present study (S.E.B., K.N.J.)[10] briefly described the use of tape-measure assessments of thoracic excursion to measure the effects of OM procedures in patients. In that study, 10 patients with chronic stable asthma were enrolled in a trial of pretest-posttest crossover design in which the effects of four recognized OM procedures were compared with sham manipulative treatment. The OM and sham procedures were administered 1 week apart. Thoracic excursion was used as a pretest and posttest measurement of respiratory mobility. Upper and lower thoracic excursion increased in the patients after the OM procedures but not after the sham procedures.[10] Mean

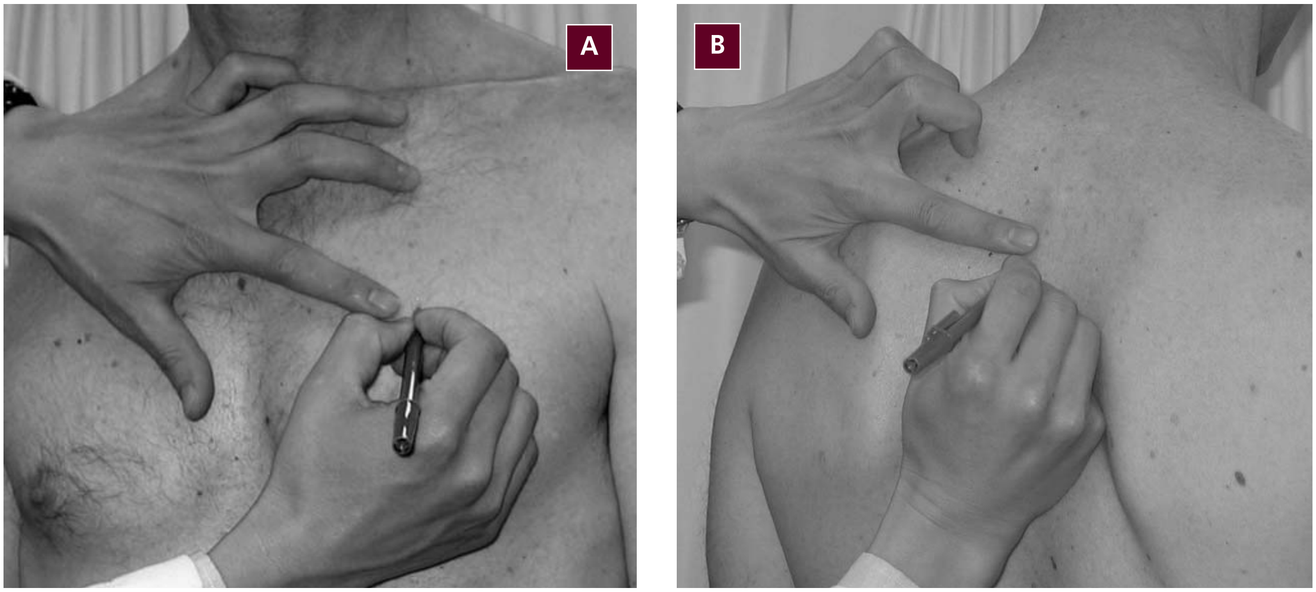

Figure 1. *Anatomic markers for measures of upper thoracic excursion using a cloth tape measure: (A) third intercostal space at the midclavicular line, and (B) fifth thoracic spinous process.*

upper thoracic excursion increased by 0.9 cm while mean lower thoracic excursion increased by 0.8 cm.[10]

We had a number of concerns about the methodology used in the 2002 study. The tape-measure method of assessing thoracic excursion at two levels was new at the time of the study. A search of the osteopathic medical literature using the United States National Library of Medicine's PubMed database and the OSTMED Osteopathic Literature Database found no reliable method for measuring thoracic excursion against which this new method could be compared. Thus, an important question was left unanswered: were the 0.8-cm and 0.9-cm increases in thoracic excursion larger than the measurement error associated with this new method?

The purpose of the present study was to assess the reliability of measuring thoracic excursion at two levels with a cloth tape measure—a method that is inexpensive, straightforward, easy to learn and apply, and appropriate for use in clinical settings. This technique is described more completely in the present study than in the previous study,[10] allowing other examiners to apply it more readily.

Methods

The present study was approved by the institutional review board at Lutheran Medical Center in Brooklyn, NY. Subjects were recruited from the residents and faculty of the center's family medicine program. For the purposes of the present study, "thoracic excursion" was defined as follows:

> *Thoracic excursion equals thoracic circumference at the end of forced inspiration minus thoracic circumference at the end of forced expiration.*

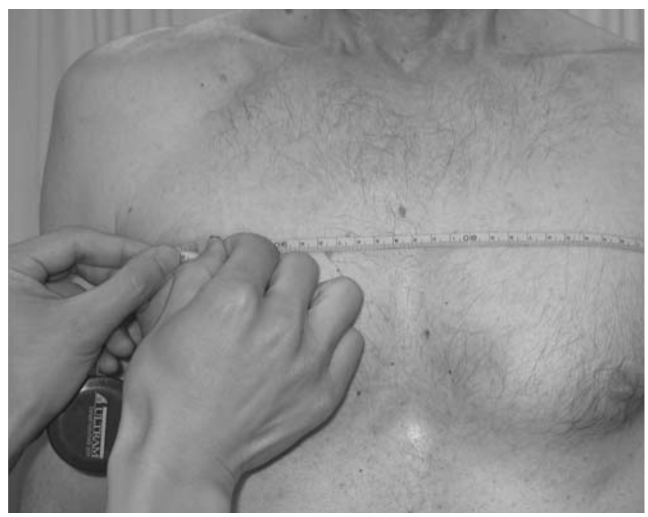

Figure 2. *Placement position of the cloth tape measure as used in the present study to measure upper thoracic excursion.*

Three examiners (including S.E.B. and H.C.) measured thoracic circumference at peak inhalation and peak exhalation three times for each of 6 subjects. Examiners included attending osteopathic physicians and residents. The measurements taken by each examiner were concealed by a research assistant who used an opaque sheet of paper to minimize the influence of an examiner's previous measurements on his or her own measurements as well as those of the other two examiners. Measurements were written down, rather than dictated orally, to preserve blinding protocols. As a further method to ensure interexaminer blinding, two examiners faced away from the subject while the third examiner was

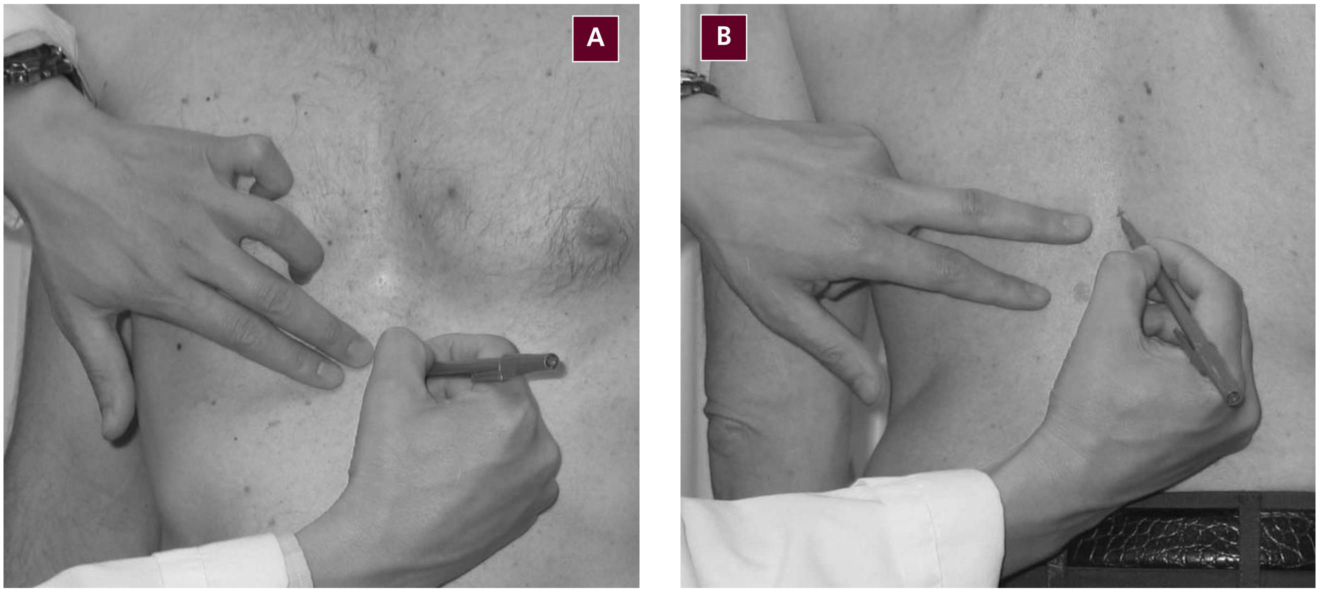

Figure 3. *Anatomic markers for measures of lower thoracic excursion using a cloth tape measure: (A) tip of the xiphoid process, and (B) 10th thoracic spinous process..*

placing the tape measure and noting final measurements. An independent observer ensured that this blinding procedure was performed consistently.

Measurements of thoracic excursion were taken in two sessions. In session 1 (n=5), interexaminer reliability was enhanced by asking the subjects to hold their breath during the inhalation or exhalation while each examiner took measurements successively. This study protocol ensured that the same thoracic circumference was available for each examiner to measure. Each examiner repositioned the tape on the subjects before each measurement.

In the second session (n=4), 3 subjects had participated in the first session. Session 2 more closely imitated clinical practice in that each subject took a new breath for each examiner, allowing each examiner to measure a full respiratory cycle. Each examiner repositioned the tape on the subject in each phase of the respiratory cycle.

In both sessions, examiners measured thoracic circumference with a cloth tape measure (Prestige Medical, Los Angeles, Calif), which was held around the circumference of the chest at one of two levels. For the upper thoracic excursion, the tape measure was placed at the level of the fifth thoracic spinous process and the third intercostal space at the midclavicular line. The anatomic markers for the upper thoracic excursion are shown in *Figure 1*, and the placement position of the tape for the upper measurement is shown in *Figure 2*. For the lower thoracic excursion, the tape measure was placed at the level of the 10th thoracic spinous process and the tip of the xiphoid process. The anatomic markers for the lower thoracic excursion are shown in *Figure 3*, and the placement position of the tape for the lower measurement is shown in *Figure 4*.

Regarding the hand position for holding the tape, it was noted that one of the examiners tended to begin measuring by pulling the end of the tape away from the subjects' bodies, while the other two examiners crossed the tape by crossing their hands, keeping the cloth measuring tape flat against the subjects' skin. We chose to standardize the measuring method to the "hands-crossed" technique to improve interexaminer consistency (*Figure 5*). Using this technique, the 0 point of the tape was not covered by the examiners' fingers, making the measurements easy to determine.

The anatomic markers were used to mark reference points for tape placement. Ink marks were made on each subject using a ballpoint pen. The upper point on the back was transferred to the scapulae with a ruler to ensure proper horizontal alignment. A research assistant ensured that the tape did not sag at the armpits or slip on the scapulae. The tape was held snuggly but not tightly, so the contour of soft tissue remained unchanged. During measurements, subjects were standing with their arms relaxed by their sides.

The intraclass correlation coefficient (ICC) was used for statistical analyses of the thoracic excursion measurements because it is the preferred technique of assessing agreement among examiners.[11] The ICC ranges from 0 to 1, with 0 representing no agreement and 1, perfect agreement. In most cases, ICCs greater than or equal to 0.75 indicate fair or substantial reliability; those greater than or equal to 0.90 indicate clinically valuable reliability.[11] Intraclass correlation coefficients were calculated separately for each session because the methods used to obtain measurements in each session were different. Standard deviations of thoracic excursion for each session and each measurement level were also calculated.

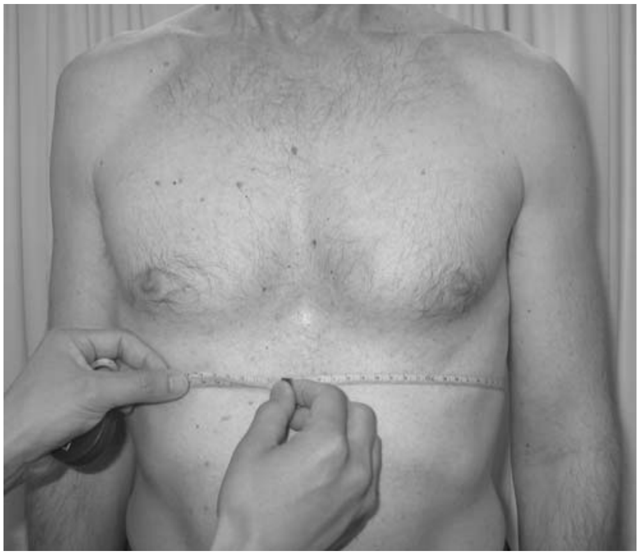

Figure 4. *Placement position of the cloth tape measure as used in the present study to measure lower thoracic excursion.*

Figure 5. *Hand position used by the present study's three examiners (including S.E.B. and H.C.) when using the cloth tape measure (Prestige Medical, Los Angeles, Calif) to determine thoracic excursion.*

Results

A total of 6 subjects were recruited for the present study. All subjects were healthy volunteers without serious respiratory or structural abnormalities of the thorax, such as kyphosis, pectus excavatum, or scoliosis. Men were recruited for the present study out of consideration for subject privacy and modesty because study protocols required that subjects be unclothed from the waist up for an extended period of time. Subjects ranged in age from 24 to 54 years with a mean (SD) of 36 (11.7) years. Their heights ranged from 175 cm to 183 cm with a mean (SD) of 178 cm (2.49 cm). Subjects' body weights ranged from 68 kg to 95.2 kg with a mean (SD) of 78.2 kg (10.8 kg).

For both sessions, mean (SD) of thoracic excursions, excursion ranges, and ICCs were recorded (*Table*):

- **Session 1 (n=5)**: Subjects' upper thoracic excursions ranged from 1 cm to 7 cm with a mean (SD) of 4.2 (0.8) cm, and an ICC of 0.91 (95% confidence interval [CI], 0.69-0.99). Lower thoracic excursions ranged from 1.5 cm to 7.8 cm with a mean (SD) of 5.9 (0.5) cm, and an ICC of 0.84 (95% CI, 0.69-0.99).
- **Session 2 (n=4)**: Subjects' upper thoracic excursions ranged from 1.7 cm to 6.6 cm with a mean (SD) of 3.6 (0.6) cm, and an ICC of 0.86 (95% CI, 0.69-0.99). Lower thoracic excursions ranged from 1.7 cm to 7.3 cm with a mean (SD) of 4.9 (0.6) cm, and an ICC of 0.81 (95% CI, 0.69-0.99).

The mean of all thoracic excursion SDs within the measurements of each subject in both sessions was 0.6 cm. When measurements for inhalation and exhalation thoracic circumference were considered separately, the ICCs were all greater than or equal to 0.99 (95% CI, 0.97-1.00).

Comment

The present study indicates that using a cloth tape measure with standardized procedures to assess thoracic excursion was highly reliable in male volunteers. The mean measurement of upper and lower thoracic excursions for all subjects ranged from 3.6 cm to 5.9 cm—considerably larger than the 0.6-cm mean SD of the three trials performed to measure the thoracic excursion of each subject. Because the variation among individual measurements was so much smaller than the value of the measurement being taken, we believe that the method of assessing thoracic excursion studied here could be used reli-

Table
Upper and Lower Thoracic Excursion Measurements and Intraclass Correlation Coefficients, cm* (N=6)

Thoracic Excursion	Session 1 (n=5)	Session 2 (n=4)
■ **Mean (SD)**		
□ Upper	4.2 (0.8)	3.6 (0.6)
□ Lower	5.9 (0.5)	4.9 (0.6)
■ **Range**		
□ Upper	1.0-7.0	1.7-6.6
□ Lower	1.5-7.8	1.7-7.3
■ **ICC†**		
□ Upper	0.91	0.86
□ Lower	0.84	0.81

* Thoracic excursion equals thoracic circumference at the end of forced inspiration minus thoracic circumference at the end of forced expiration. In session 1, each examiner made measurements during the same inhalation or exhalation while subjects held their breath. In session 2, each examiner measured a full respiratory cycle. Three of the 4 subjects in session 2 were also included in session 1.

† Intraclass correlation coefficients (ICC) (95% confidence interval, 0.69-0.99) were calculated separately for each session.

ably with most patients. Moreover, the ICCs for thoracic excursion were unusually substantial (0.81-0.91), suggesting that the technique yields reproducible results when performed by multiple trained examiners.

Both sessions yielded similar ICCs for thoracic excursion, indicating that the sessions had similar reliability. The procedures used in the first session maximized reliability, while the procedures used in the second session more closely reflected clinical reality. Thus, the similarities in ICC between these sessions strongly imply that the method of measurement used in the present study can be used in clinical settings to quantify thoracic excursion for such goals as patient diagnosis, disease classification, and interval assessment. Among the conditions requiring accurate assessment of thoracic excursion are ankylosing spondylitis, asthma, COPD, and thoracic scoliosis.

To best implement this method of assessing thoracic excursion, examiners should take the mean of three measurements of thoracic excursion at both the upper and lower levels of the chest. The mean overall SD among the subjects in the present study indicates that this method should be considered valid for changes in thoracic excursion that are expected to exceed 0.6 cm. The use of this technique in the prior study of OM procedures and asthma,[10] in which mean changes in thoracic excursion of 0.8 cm at the lower thoracic level and 0.9 cm at the upper thoracic level were found after a single treatment session with an OM procedure, should therefore have been valid.

Chest expansion has been studied since the 1960s as an important clinical criterion of ankylosing spondylitis.[12-14] Moll and Wright[12] evaluated chest expansion in subjects with ankylosing spondylitis (n=37), obesity (n=33), and COPD (n=31), comparing them with "normal" subjects (n=262). Moll and Wright[12] measured chest expansion with two techniques (using a caliper as well as a cloth tape measure) at the fourth intercostal space with subjects' arms elevated. They concluded that "circumferential measurement alone should be adequate."[12]

Burgos-Vargas et al[13] measured chest expansion circumferentially with a tape measure at the fourth intercostal space (arms elevated) in 157 healthy children and 35 children with juvenile spondyloarthropathies. The inter- and intraobserver ICCs resulting from these measurements were moderate, at 0.58 and 0.67, respectively.[13] By contrast, the ICCs in the present study were substantially greater, ranging from 0.81 to 0.91.

Fisher et al[14] reported on 33 subjects with ankylosing spondylitis, correlating measurements of chest expansion, spinal flexibility, vital capacity, and exercise tolerance. They wrote that their study "confirmed previous reports of a significant association between chest expansion and vital capacity," thereby supporting the clinical value of measuring thoracic excursion.[14]

Mitchell[15] reported the use of radiographic techniques for measuring sacroiliac respiratory movements. Such techniques could be applied to thoracic excursion, but they would have the disadvantages of extra expense and time requirements, technical considerations of consistency, and radiation exposure for subjects. Mitchell and Pruzzo[16] used photographic comparisons and a millimeter ruler to validate sacroiliac respiratory movements, but the accuracy of photographs of the thoracic cage may not be sufficient to quantify thoracic excursion.

There were a number of limitations in the present study, however. The sample size of the subjects was small, and all subjects were of one sex with a relatively narrow range of heights and weights. Examiner training was conducted verbally. Use of a written procedure with photographs of hand positions and anatomic markers would have enhanced procedural standardization. The subjects in the present study were physician volunteers. When working with subjects who are not physicians, instructions regarding breathing must be made more uniform and explicit than required by the present study.

Furthermore, it should be noted that measuring change in thoracic circumference at two levels is not the only way of quantifying thoracic excursion. Sequence and relationships of movements of the various parts of the thoracic cage may also be important aspects of measuring thoracic excursion in some patients, though the operational definition of this process used in the present study did not attempt to quantify these more complex physiologic changes. Even so, the current study is the first to measure thoracic excursion at multiple levels. It is our hope that this additional information will prove clinically relevant in the work of future researchers though some questions remain unanswered:

- Could a criterion standard (ie, "gold standard") be developed to assess the validity of this technique of measuring thoracic excursion?
- Does measuring thoracic excursion at two levels, as opposed to one, truly add valuable information?
- Can this method of measuring thoracic excursion be used with subjects in supine and seated positions?
- How does this measuring technique correlate with pulmonary function testing?

Conclusion

The present study strongly suggests that the tape-measure method of measuring thoracic excursion at two levels could be reliable and useful in a clinical setting. In particular, this method would be best applied when changes in thoracic excursion are expected to be greater than approximately 0.6 cm. We recommend that future researchers take the mean of three measurements at each thoracic level for each phase of the respiratory cycle.

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(continued)

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