Influence of Transverse Process Landmark Localization on Palpation Accuracy of Lumbar Spine Models

Eric J. Snider, DO; Kenneth Pamperin, MS; Vanessa Pazdernik, MS; Brian F. Degenhardt, DO

From the Department of Osteopathic Manipulative Medicine at the A.T. Still University Kirksville College of Osteopathic Medicine in Missouri (Dr Snider) and the A.T. Still Research Institute at A.T. Still University in Kirksville, Missouri (Mr Pamperin, Ms Pazdernik, and Dr Degenhardt).

Financial Disclosures: None reported.

Support: This study was supported by the Osteopathic Heritage Foundation Endowment for Research in Osteopathic Diagnostic and Therapeutic Palpation (grant no. 508-305), the KOAA/KCOM Education Fund, and the A.T. Still University Strategic Research Fund.

Address correspondence to Eric J. Snider, DO, A.T. Still University Kirksville College of Osteopathic Medicine, 800 W Jefferson St, Kirksville, MO 63501-1443. Email: esnider@atsu.edu

Submitted March 31, 2017; final revision received January 12, 2018; accepted January 24, 2018.

Context: Accurate determination of transverse process displacement in the horizontal plane requires accurate transverse process landmark localization followed by accurate discrimination of asymmetry by the examiner’s palpating digits.

Objective: To determine whether the accurate localization of transverse process landmarks influences overall accuracy of asymmetry determination in third-year osteopathic medical students evaluating covered lumbar spine models.

Methods: A class of third-year osteopathic medical students was split into 2 groups and asked to determine whether the right transverse processes of covered lumbar spine models were anterior or posterior relative to the left transverse process. The marked model group (group A) was provided covered models with black dots on the fabric covers over the transverse process landmarks, while the covered models given to the students in the unmarked model group (group B) had no markings. Both groups were asked to assess asymmetry differences from L1 to L5 on 2 models. Landmarks were randomized for asymmetry (ranging from 2 mm to 6 mm) and direction (anterior or posterior on the right side). The number of correct responses was modeled as a binomial random variable in a generalized linear model to compare the effects of marked vs unmarked models on accuracy of palpation. The predicted probability of correctly determining the direction of the asymmetry and 95% CIs were calculated.

Results: The probability of correctly identifying the direction of asymmetry was 0.89 (95% CI, 0.87-0.91) for group A and 0.74 (95% CI, 0.71-0.78) for group B, a 15 percentage point difference (OR, 1.2; 95% CI, 1.1-1.3; P<.001). Assuming accurate perception of digit asymmetry and accurate localization of landmarks are independent and correct answers are given only if both events occur, then students were more likely to accurately perceive digit asymmetry (0.89) than accurately localize landmarks (0.83 vs 0.74 vs 0.89). Overall, more students accurately identified the direction of asymmetry when the right transverse process was anterior (0.87; 95% CI, 0.84-0.90) than when it was posterior (0.81; 95% CI, 0.77-0.84) (OR, 1.6; 95% CI, 1.2-2.1; P=.001).

Conclusions: Student palpation accuracy was better when transverse process landmark localization was provided on the lumbar spine models than when it was not. Students were more likely to accurately perceive digit asymmetry than accurately localize the landmarks. Improving palpation accuracy requires developing educational methods to improve both accurate landmark localization and accurate digit asymmetry perception.


Keywords: lumbar spine, palpation, transverse process
Diagnostic palpation of the lumbar spine is taught at all colleges of osteopathic medicine. This process involves accurately locating anatomic structures before determining somatic dysfunction characteristics, such as tenderness, asymmetry, motion, or tissue texture abnormalities. For example, accurate diagnosis of vertebral positional asymmetry in the horizontal plane requires 2 steps. The first step is to accurately localize the palpating digits over the right and left transverse processes. The second step is to accurately discriminate asymmetry of the transverse processes by the palpating digits. The eventual outcome of this diagnostic process determines in which directions forces should be applied when performing osteopathic manipulative treatment (OMT) on patients.

Evidence is inconsistent regarding the reliability of different methods of localization of spinal landmarks. Although studies have shown the validity of various methods of palpation, other studies have concluded that the reliability of manual palpation was less accurate than ultrasonography for inexperienced and experienced examiners; however, Hayes et al showed that palpation had comparable accuracy to ultrasonography in experienced examiners. Within the osteopathic medical school curriculum, it is impractical to rely on imaging of humans for feedback during the acquisition of diagnostic palpatory skills. Furthermore, a review of anatomical landmark asymmetry in the lumbar spine and pelvis indicated that “there are unexplored factors that, after standardization, may improve reliability and further the understanding of musculoskeletal palpatory examination.” Because imaging has inherent variability, models that can be precisely calibrated to known asymmetries offer a valuable tool to test and refine palpatory skills. Snider et al reported that calibrated lumbar spine models can be used to define accuracy thresholds at varying levels of rotational asymmetry; however, it was not possible to determine a cause for inaccuracy when it occurred. The inaccuracy could have been due to poor landmark localization or inaccurate perception of the transverse process positions when correctly localized. Additionally, imaging modalities would not be effective in determining why localization was inaccurate or how to improve palpatory skills.

The purpose of the current study was to determine the effect that accurate localization of the lumbar transverse processes had on overall accuracy of asymmetry determination in third-year osteopathic medical students evaluating covered lumbar spine models with or without marked landmarks. We hypothesized that students would be more likely to correctly identify the direction of asymmetry when transverse process landmarks were marked compared with when they were not.

Methods
The local institutional review board considered the current study to be exempt.

Participants and Procedures
As part of their standard curriculum, a single class of third-year osteopathic medical students participated in this cross-sectional cohort study. The students were divided into 2 groups. Students in the marked model group (group A) tested their palpatory skills on covered lumbar spine models in which the location of the transverse processes were marked, and students in the unmarked model group (group B) tested their palpatory skills using unmarked covered lumbar spine models. There were 14 testing sessions: 6 in the morning and 8 in the afternoon. Group A students were divided into 2 morning sessions and 6 afternoon sessions, and group B students were divided into 4 morning sessions and 2 afternoon sessions. Group assignment was prescheduled based on the circumstances of academic scheduling and, therefore, was not randomized.

Foam-covered bronze lumbar spine models were used to assess the palpatory skills of students evaluating positional asymmetry of the transverse processes of the lumbar spine (Figure 1). The construction and calibration of these models have been described previously.
The lumbar spine models were centered and mounted to a manipulation table. Students evaluated the models in a proctored clinical skills examination room and recorded their answers on a scantron form. To determine positional asymmetry of the model, the students indicated whether the model’s right transverse process was anterior or posterior to the model’s left transverse process. Students assessed asymmetry differences for L1 to L5 for 2 models (10 questions total). Landmarks were randomized for asymmetry (ranging from 2 mm to 6 mm) and direction (anterior or posterior on the right side) (Table 1). For group A, the covered models had black dots (approximately 4 mm in diameter) placed on the fabric covers over the transverse process landmarks, so students were able to localize to the correct landmark location. For group B, there were no markings on the fabric covers, so students had to localize to the correct landmark location without assistance. The lumbar spine model station was 1 station in a multiple-station day-long evaluation of general clinical examination skills.

Statistical Analysis
The number of correct responses was modeled as a binomial random variable in a generalized linear model to compare groups A and B (marked vs unmarked) and session times (morning vs afternoon). We estimated the marginal probability that the students achieved a single event (ie, accurate digit asymmetry perception and accurate transverse process landmark localization) and the joint probability that they achieved the simultaneous events of accurate transverse process landmark localization and digit asymmetry perception on this examination. To this end, we assumed the events were independent and a correct answer was given only if both events occurred.

A logistic regression model with random student effects was used to estimate effects of direction (right transverse process was anterior vs posterior) and asymmetry on performance while controlling for group. Because group assignment was not randomized, we examined whether the groups in the same class of students performed differently on the previous year’s similar lumbar spine examination to ensure there was no strong evidence for a baseline group difference. The 15-question lumbar examination was given to all students at the end of their second year using unmarked, covered models in the same range of asymmetries as the current study. Two versions of the second-year examination existed: both included 3 questions per asymmetry (2-6 mm), but they differed on the number that were anterior or posterior on the right. Therefore, a logistic regression model was used to test for group differences in performance from the previous year’s lumbar examination while controlling for direction and asymmetry. Estimates of the ORs and predicted probability of correctly determining the direction of the asymmetry were calculated with

<table>
<thead>
<tr>
<th>Vertebra Location</th>
<th>Asymmetry, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2</td>
</tr>
<tr>
<td>L1</td>
<td></td>
</tr>
<tr>
<td>L2</td>
<td></td>
</tr>
<tr>
<td>L3</td>
<td></td>
</tr>
<tr>
<td>L4</td>
<td></td>
</tr>
<tr>
<td>L5</td>
<td></td>
</tr>
</tbody>
</table>

* A blank cell indicates there was no assessment for that vertebra level or amount of asymmetry.
associated 95% CIs. Statistical significance was defined as \( P < .05 \). Analyses were conducted using SAS 9.4 software (SAS Institute, Inc).

**Results**

Of the 160 students included in the study, 90 were placed in the marked model group (24 in the morning sessions and 66 in the afternoon sessions) and 70 in the unmarked model group (46 in the morning sessions and 24 in the afternoon sessions). Group A students performed significantly better than group B students in correctly identifying the direction of asymmetry of landmarks (OR, 1.2; 95% CI, 1.1-1.3; \( P < .001 \)) (Table 2). The probability of correctly identifying the direction of asymmetry was 0.89 (95% CI, 0.87-0.91) for group A and 0.74 (95% CI, 0.71-0.78) for group B, a 15 percentage point difference. The probabilities for these events, assuming accurate transverse process landmark localization and digit asymmetry perception are independent events and occur only if the student correctly identifies the direction of landmark asymmetry, are presented in Table 3 and Figure 2. For group B, the probability of both events was 0.74. The marginal probability of accurate transverse process landmark localization was 0.83; therefore, the probability of accurate transverse process landmark localization but inaccurate digit asymmetry perception was 0.09. The marginal probability of accurate transverse process landmark localization was 0.89; therefore, the probability of inaccurate transverse process landmark localization but accurate digit asymmetry perception was 0.15. The probability that neither event would occur was 0.02.

Students testing in the morning sessions had poorer performance compared with those testing in the afternoon (Table 2). Overall, the probability of correctly identifying the direction of asymmetry was 0.80 (95% CI, 0.76-0.83) in morning sessions compared with
A difference did not depend on group assignment (\( P = .31 \)). The direction of the vertebral segment’s asymmetry affected the performance of students in both groups. Although there was a significant interaction between the direction and asymmetry (\( P = .03 \); Figure 3), overall, the performance was better when the right transverse process was anterior (0.87; 95% CI, 0.84-0.90) than when it was posterior (0.81; 95% CI, 0.77-0.84) (OR, 1.6; 95% CI, 1.2-2.1; \( P = .001 \)) (Table 2). The interaction between direction and asymmetry manifested at 2 mm compared with the remaining 3 to 6 mm of asymmetry, where the odds of accuracy were slightly better, although not significant, when the right transverse process was posterior. Across asymmetry, the effect of the direction of asymmetry did not depend on group assignment (\( P = .23 \)).

Because group assignment was not randomized but based on academic scheduling, data from 145 of 160 students were analyzed from the previous year’s examination to ensure there was no baseline group difference (data from 15 students were unavailable because they did not take the previous year’s lumbar examination). We found no significant difference in the performance of group A students (n=80) and group B students (n=65) based on the previous year’s lumbar examination (\( P = .60 \)).

**Table 2.** Probability of Third-Year Osteopathic Medical Students Correctly Identifying the Direction of Asymmetry in Group A (Marked Models) and Group B (Unmarked Models)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Marked Model Group</th>
<th>Unmarked Model Group</th>
<th>Total</th>
<th>P Value</th>
<th>OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Performance</td>
<td>0.89 (0.87-0.91)</td>
<td>0.74 (0.71-0.78)</td>
<td>.001</td>
<td>1.2 (1.1-1.3)</td>
<td></td>
</tr>
<tr>
<td>Session</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Morning</td>
<td>0.85 (0.80-0.89)</td>
<td>0.73 (0.69-0.77)</td>
<td>0.80 (0.76-0.83)</td>
<td>.008</td>
<td>1.0</td>
</tr>
<tr>
<td>Afternoon</td>
<td>0.91 (0.88-0.93)</td>
<td>0.78 (0.72-0.82)</td>
<td>0.85 (0.83-0.88)</td>
<td>.001</td>
<td>1.6 (1.2-2.1)</td>
</tr>
<tr>
<td>Right Transverse Process</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anterior</td>
<td>0.93 (0.90-0.95)</td>
<td>0.78 (0.73-0.83)</td>
<td>0.87 (0.84-0.90)</td>
<td>.001</td>
<td>1.6</td>
</tr>
<tr>
<td>Posterior</td>
<td>0.87 (0.83-0.90)</td>
<td>0.73 (0.67-0.78)</td>
<td>0.81 (0.77-0.84)</td>
<td>.001</td>
<td>1.0</td>
</tr>
</tbody>
</table>

* Inverse-logit transformation of predicted population margins balanced across group.

**Table 3.** Truth Table and Respective Probability of Third-Year Osteopathic Medical Students: Landmark Localization and Digit Asymmetry Perception

<table>
<thead>
<tr>
<th>Transverse Process Localization</th>
<th>Digit Asymmetry Perception</th>
<th>Identify Direction of Transverse Process Asymmetry</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accurate</td>
<td>Accurate</td>
<td>Yes</td>
<td>0.74</td>
</tr>
<tr>
<td>Accurate</td>
<td>Inaccurate</td>
<td>No</td>
<td>0.09</td>
</tr>
<tr>
<td>Inaccurate</td>
<td>Accurate</td>
<td>No</td>
<td>0.15</td>
</tr>
<tr>
<td>Inaccurate</td>
<td>Inaccurate</td>
<td>No</td>
<td>0.02</td>
</tr>
</tbody>
</table>

* Group A (marked model): \( Pr(P | L) = 0.89 \). Group B (unmarked model): \( Pr(P \cap L) = 0.74 \).
Discussion

To our knowledge, the current study is the first to investigate the effect of transverse process landmark localization on overall palpatory accuracy for asymmetry in the horizontal plane using objective lumbar spine models. Testing with marked models was intended to isolate the evaluation of the perception of only digit asymmetry, whereas testing with unmarked models challenged the examiner to both localize landmarks and perceive digit asymmetry. A previous study reported threshold accuracy for evaluating transverse process asymmetry but did not investigate potential causes.

In the current study, students who used marked models that indicated the exact location to palpate were 15 percentage points more accurate than students who palpated unmarked models. If we assume that students were correct only if accurate transverse process landmark localization and accurate digit asymmetry perception occurred and that these events are independent, this finding indicates the rate of both inaccurate localization and accurate perception of palpating digit asymmetry. Still, the students who used marked models were inaccurate 11% of the time, which represents the marginal probability of inaccurate digit asymmetry perception. This finding demonstrates that students are more likely to accurately perceive digit asymmetry than to accurately localize the transverse process landmarks, which suggests that education in manual skills development should place increased

![Venn diagram of the probability of accurate transverse process landmark localization and digit asymmetry perception in third-year osteopathic medical students evaluating a lumbar spine model.](image)

![Graph showing the probability of third-year osteopathic medical students correctly identifying the direction of asymmetry in group A (marked model) and group B (unmarked model) by direction of the right transverse process and asymmetry.](graph)
attention on teaching and assessing transverse process and other landmark localization skills. Future studies are needed to determine the rate at which students guess which transverse process is posterior and whether transverse process landmark localization and digit asymmetry perception are truly independent.

Several reasons may explain the lower accuracy in determining transverse process asymmetry when unmarked models were used. Students may have compared the facet on one side of the unmarked covered lumbar spine model to the transverse process on the other side. Alternatively, students may have selected the incorrect lumbar spinal level (eg, palpated L3 instead of L2) on one or both sides. A future study could examine the actual location of digit placement during palpation using sensor pads placed on the landmarks. Sensor pads could provide localization feedback during skill acquisition and could also be used for skill assessment. Additionally, a lumbar examination protocol that sequentially identifies multiple landmarks, such as the spinous process, the facet joints, and then the transverse processes, may improve localization of the transverse processes at a single spinal level. Yet, when comparing testing on lumbar models with examining humans, the localization of landmarks on humans is more challenging. When examining humans, the protocol for localization of lumbar landmarks should be confirmed with the localization of other regional landmarks, such as the iliac crests, sacral base, T12, and 12th ribs. We can be reasonably assured that the difference in student performance was not caused by the nonrandomization of the group assignments, because evaluation of the student groups based on testing results from the end of their second year suggested the groups had similar palpatory skills.

Students were more accurate in palpating when the right transverse process was anterior rather than posterior. This finding suggested that students are naturally calibrated to perceive the transverse processes as being symmetric at a location that is actually posterior on the right. In the current study, we did not collect data on which side of the examination table students stood to perform the examination. Generally, students are instructed to stand at the side of the examination table that places their dominant eye in the middle of the table. As such, a student with a dominant right eye would stand on the left side of the table. Future studies should evaluate a variety of factors related to sidedness, such as the relationship of the dominant eye or hand to the model, changes in proprioception and posture from standing at a specific side of the examination table, or the effect of having to reach farther with one arm than the other to palpate.

In the current study, the time of the testing session seemed to affect student performance: students who tested in the afternoon were more accurate in palpating than students who tested in the morning. Factors such as stress, circadian rhythms, amount of sleep, or level of fatigue could have caused the better performance in the afternoon. Although we did not collect data on these factors, it is possible that taking the examination in the afternoon was less stressful. The lumbar palpation examination was part of a full-day examination. The examination was divided into 2 sections, a half day for standardized patient testing and the other for assessing physician skills. The lumbar examination was part of the assessment of physician skills. Because students were required to pass the standardized patient testing or would have to repeat it at a later date, student stress could have been lower in the afternoon for those students who had completed the high-stakes examination in the morning.

Conclusion

When using the covered lumbar spine models, palpation accuracy was higher in students who were given the exact localization of transverse process landmarks than students who were not. Therefore, inaccurate diagnosis may still occur in examiners with good asymmetry determination skills because they are not palpating the intended anatomic structures. Clinically, inaccurate localization could result in inaccurate
diagnoses, leading an osteopathic physician to apply forces in the wrong direction when performing OMT, hampering its therapeutic potential and possibly causing harm to the patient. This clinical scenario emphasizes the importance of teaching osteopathic medical students to accurately localize to the landmarks they are evaluating. Protocols using multiple landmarks to confirm localization of a specific landmark increase examiner accuracy, which should improve the selection of the correct technique when performing OMT. Consequently, a protocol to assess localization needs to be included with assessments of asymmetry as part of the educational process for all levels of OMT training.

Acknowledgments

We appreciate the editorial support provided by Deborah Goggin, MA, ELS, from Research Support at A.T. Still University, and we thank Kelly Rogers from Academic Technologies at A.T. Still University for providing photographs of the models.

References


© 2018 American Osteopathic Association