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Effect of positional asymmetry palpatory models on improvement and retention of accuracy during pelvic asymmetry assessments

<https://doi.org/10.1515/jom-2024-0194>

Received September 15, 2024; accepted May 12, 2025;

published online July 16, 2025

Abstract

Context: Asymmetry of bony landmarks, such as the anterior superior iliac spine (ASIS) or posterior superior iliac spine (PSIS), is often utilized to identify somatic dysfunction in the pelvis. However, establishing good accuracy for these assessments can be challenging, so objective training models have been developed to enhance learning and accuracy.

Objectives: The objective of this study was to determine the effect of training with positional asymmetry models with objective feedback on the improvement and retention of pelvic asymmetry assessment accuracy.

Methods: First-year osteopathic medical students and undergraduate interns were recruited for model training. After a basic technique demonstration, they completed a 72-question baseline assessment on the ASIS and PSIS models. Subsequent training was conducted for 5 h per week (1 h/day) for two consecutive weeks. Model accuracy was assessed four times at baseline, midpoint, final, and

retention. Assessments were scored as a percent of the correctly identified asymmetries, and change scores were calculated by comparison with the previous assessment score (i.e., baseline to midpoint, midpoint to final, final to retention) and overall (baseline to retention).

Results: Twelve students (age range, 20.3–29.2 years) participated. At baseline, overall scores were 57.6 % for ASIS and 72.9 % for PSIS models. For ASIS models, the change scores improved from baseline to midpoint (+18.9 %, $p<0.001$) and from midpoint to final (+6.6 %, $p=0.01$) but decreased from final to retention (–7.2 %, $p=0.01$). The overall retention scores were higher than baseline (+18.3 %, $p<0.001$). For PSIS models, the change scores improved from baseline to midpoint (+13.0 %, $p<0.001$), and the overall retention scores were higher than baseline (+15.0 %, $p<0.001$).

Conclusions: Training with positional asymmetry models with objective feedback resulted in significant sustained improvements in ASIS and PSIS positional asymmetry assessment accuracy. Integration of these models into the standard medical curriculum should be considered.

Keywords: anatomy; bony landmarks; bony landmark asymmetry; musculoskeletal system; pelvis; somatic dysfunction

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A common diagnostic criterion for identifying pelvic somatic dysfunction is the asymmetry of bony landmarks [1], such as the anterior superior iliac spine (ASIS) and posterior superior iliac spine (PSIS). To perform this assessment, the patient lies supine for the ASIS evaluation and prone for the PSIS evaluation. The examiner stands to the side, facing the patient's head. The examiner then places their thumbs under the ASIS or PSIS on each side to determine if one side is superior, equal, or inferior to the other. Combining these asymmetry assessment results with other pelvic landmarks, such as the iliac crest, pubic tubercle, and ischial tuberosity, and with lateralization tests, the examiner determines one criterion for somatic dysfunction that guides subsequent treatment. This technique is commonly taught to medical students during one or two laboratory sessions, in which they partner as examiners and patients.

Previous studies investigating bony landmark asymmetry assessments have primarily evaluated interobserver and intraobserver reliability [1–12]. Systematic reviews have reported low levels of reliability with pelvic asymmetry assessments [2–4], which may be influenced by variations in examiner profession and teaching methodology between osteopathic medicine [5–9], physical therapy [10–12], and chiropractic [13]. Assessment of validity has been rarely considered, and when attempted, it has shown limited validity for these tests [14]. Because assessments were performed on human patients, quantifying asymmetry accurately is challenging. Consequently, research has been limited to reliability studies with low κ values, calling into question the clinical relevance of these palpatory tests [15, 16]. Previous researchers have utilized objective models to evaluate accuracy at the known asymmetries. Fossum et al. [17] found that participants improved in identifying asymmetries after 2 weeks of training. Stovall et al. [18] reported that physicians and fellows were more accurate from the right side before training, and fellows increased accuracy for both sides of the model after training. Lee et al. [19] utilized models to investigate the percent correctness, sensitivity, and specificity of ASIS assessments at 10-mm, 5-mm, and equal asymmetries. They reported no difference in overall accuracy based on eye dominance, concluding that ASIS assessment was a sensitive but not specific test for asymmetries of 5 mm or greater [19].

Because positional asymmetry models have known asymmetry values, they can be effective for teaching palpatory skills. Such models provide objective feedback, allowing students to calibrate their eyes and hands, and show progression of skills development. Models may be utilized to identify trends or challenges related to palpatory assessment. Recently Colonna and Mazzanti [20] highlighted the need for objective feedback modalities to enhance training with palpatory tests. Given these potential benefits, more studies, including those with higher precision models, are necessary to refine the pelvic asymmetry assessment learning model. Therefore, the purpose of the current study was to determine the effect of training with positional asymmetry models on the improvement and retention of pelvic asymmetry assessment accuracy. We hypothesized that this training would improve the students' retention of accurate skills.

Methods

The current study utilized a prospective design to determine the effect of training with positional asymmetry models on pelvic asymmetry assessment accuracy over a 3-week duration. All study procedures (examinations and practice times)

were completed during June and July of 2022 and 2023. The study was deemed exempt by the A.T. Still University-Kirksville Institutional Review Board, and no funding was required. Five first-year osteopathic medical students (OMS1) and seven undergraduate students (novice) were recruited from those interested in being part of the medical student research elective in Osteopathic Manipulative Medicine or the undergraduate Clinician Researcher Development Program. By enrolling in the research internship or elective, students provided consent to participate in research activities. Participant age and dominant eye were recorded. Examiners were instructed to stand on the opposite side of the table of their eye dominance and to center their eye over the middle of the treatment table when performing the testing.

Two types of positional asymmetry models spatially imitated ASIS or PSIS landmarks (Figure 1). Each model consisted of six pairs of 12.7×3.175 mm rectangular metal ridges separated by 24.0 cm on ASIS models and by 11.5 cm on PSIS models. Each ridge was independently adjustable in 1-mm increments (toward the head or foot of the treatment table) to create asymmetries up to 12 mm. A 3-mm thick thermoplastic elastomer sheet was placed over the palpation surface of the models to hide visual cues and simulate soft tissue. Models were secured in place to prevent shifting and to maintain a central position relative to the table. Examiners adjusted the table height as needed.

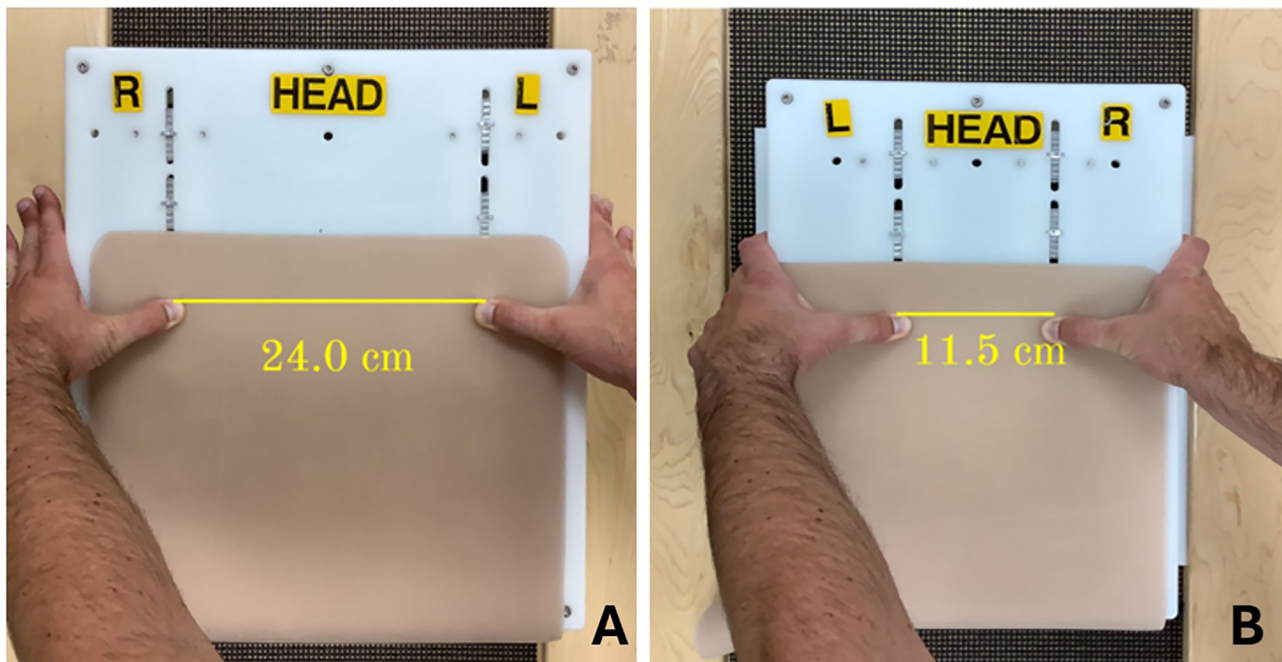
A 72-question assessment test, consisting of 36 ASIS and 36 PSIS questions, was created and accessed through Research Electronic Data Capture (REDCap) software (Nashville, TN). The examiners had to determine whether the right-side landmark was superior, inferior, or equal to the left. Asymmetry values were set at -8 , -6 , -4 , -2 , 0 (equal), 2 , 4 , 6 , or 8 mm. Positive and negative values were assigned to asymmetries to indicate the direction: positive values indicated that the right landmark was superior to the left, and the negative values indicated that the right landmark was inferior to the left. Each asymmetry value appeared four times at random in the assessment. The answers were scored in REDCap.

Initially, examiners observed a 30-min demonstration of the assessment, including time to identify their dominant eye, ask questions, and practice the process. They then completed the baseline assessment. Examiners trained on the models for 5 h per week (1 h/day) over 2 weeks with self-directed practice and objective feedback. Incorrect assessments required participants to remove the gel pad and re-evaluate to identify errors. After 2 weeks of training, there was a 1-week washout period. Accuracy was evaluated at baseline, midpoint (1 week of training), final (2 weeks of training), and retention (1-week post training). To minimize any potential priming effects, half of the examiners began

Table 1: Estimated mean scores of student accuracy for correct identification of asymmetry when palpating positional asymmetry models.

Asymmetry, mm	Baseline	Midpoint	Change (p-Value)	Final	Change (p-Value)	Retention	Change (p-Value)	Overall change (p-Value)
Anterior superior iliac spine (ASIS) models								
Overall	57.6 %	76.5 %	18.9 % (<0.001)	83.1 %	6.6 % (0.01)	75.9 %	−7.2 % (0.01)	18.3 % (<0.001)
−8	64.6 %	91.7 %	27.1 % (<0.001)	97.9 %	6.3 % (0.38)	95.8 %	−2.1 % (0.77)	31.2 % (<0.001)
−6	60.4 %	91.7 %	31.3 % (<0.001)	89.6 %	−2.1 % (0.76)	93.8 %	4.2 % (0.56)	33.3 % (<0.001)
−4	52.1 %	66.7 %	14.6 % (0.04)	87.5 %	20.8 % (0.003)	87.5 %	0 % (>0.99)	35.4 % (<0.001)
−2	52.1 %	45.8 %	−6.3 % (0.38)	70.8 %	25.0 % (<0.001)	56.3 %	−14.6 % (0.04)	4.2 % (0.56)
0 (equal)	29.2 %	41.7 %	12.5 % (0.08)	54.2 %	12.5 % (0.08)	33.3 %	−20.8 % (0.003)	4.2 % (0.56)
2	47.9 %	79.2 %	31.2 % (<0.001)	66.7 %	−12.5 % (0.08)	60.4 %	−6.3 % (0.38)	12.5 % (0.08)
4	70.8 %	77.1 %	6.3 % (0.38)	87.5 %	10.4 % (0.14)	77.1 %	−10.4 % (0.14)	6.2 % (0.38)
6	66.7 %	97.2 %	30.6 % (<0.001)	97.9 %	0.7 % (0.93)	91.7 %	−6.3 % (0.38)	25.0 % (<0.001)
8	75.0 %	97.9 %	22.9 % (<0.001)	95.8 %	−2.1 % (0.77)	87.5 %	−8.3 % (0.24)	12.5 % (0.08)
Posterior superior iliac spine (PSIS) models								
Overall	72.9 %	85.9 %	13.0 % (<0.001)	85.2 %	−0.7 % (0.74)	87.9 %	2.7 % (0.21)	15.0 % (<0.001)
−8	93.8 %	97.2 %	3.5 % (0.65)	100 %	2.8 % (0.72)	100 %	0 % (>0.99)	6.3 % (0.38)
−6	89.6 %	97.9 %	8.3 % (0.24)	89.6 %	−8.3 % (0.24)	100 %	10.4 % (0.14)	10.4 % (0.14)
−4	77.1 %	89.6 %	12.5 % (0.08)	97.9 %	8.3 % (0.24)	95.8 %	−2.1 % (0.77)	18.7 % (0.01)
−2	43.8 %	79.2 %	35.4 % (<0.001)	72.9 %	−6.2 % (0.38)	77.2 %	4.3 % (0.54)	33.5 % (<0.001)
0 (equal)	47.9 %	60.4 %	12.5 % (0.08)	54.2 %	−6.2 % (0.38)	52.1 %	−2.1 % (0.77)	4.2 % (0.56)
2	64.6 %	66.7 %	2.1 % (0.77)	62.5 %	−4.2 % (0.56)	76.7 %	14.2 % (0.047)	12.1 % (0.09)
4	70.8 %	89.6 %	18.8 % (0.01)	97.9 %	8.3 % (0.24)	91.7 %	−6.3 % (0.38)	20.8 % (0.003)
6	81.3 %	95.8 %	14.6 % (0.04)	91.7 %	−4.2 % (0.56)	97.9 %	6.2 % (0.38)	16.7 % (0.02)
8	87.5 %	96.7 %	9.2 % (0.17)	100 %	3.3 % (0.62)	100 %	0 % (>0.99)	12.5 % (0.08)

Accuracy was assessed weekly after training at baseline, midpoint, final, and retention. Changes in scores were calculated from week to week (i.e., baseline to midpoint, midpoint to final, final to retention) and overall (baseline to retention).

**Figure 1:** Positional asymmetry models for (A) anterior superior iliac spine (ASIS) landmarks and (B) posterior superior iliac spine (PSIS) landmarks. L, left-side landmark; R, right-side landmark.

each assessment on the ASIS models, whereas the other half started on the PSIS models.

For all assessments, accuracy was scored as the correct determination of asymmetry. Because of the potential correlation of the assessments made by the same examiner, a mixed-effect model was utilized to investigate the effect of training. By including the examiners as random effects, our mixed-effect model extended a three-way analysis of variance (ANOVA) to accommodate the correlated assessment outcomes. In addition to the random effects of examiners, the following were included in the model as fixed effects: the asymmetry values of the ASIS and PSIS models, weeks (baseline, midpoint, final, and retention), the examiners' preferred side of the table, and all of the two-way and three-way interactions. The model was fitted based on 1728 ASIS and 1728 PSIS responses. Estimated marginal means and standard errors (SE) were utilized to quantify and test for changes in scores from week to week and overall (baseline to retention). Retention was assessed utilizing estimated marginal means and SE to determine if the side of the table affected overall accuracy. The influence of the examiners' side of the table on accuracy for specific asymmetry values (2, 4, 6, and 8 mm) in both the superior and inferior outcomes was also evaluated. Analyses were performed utilizing SPSS version 29.0 (IBM Corp., Armonk, NY), and $p < 0.05$ was considered statistically significant.

Results

Twelve students (mean [SD] age, 23.8 [2.9] years; range, 20.3–29.2 years) participated as examiners. Of these, seven students had no prior palpation training, and five had completed a year of osteopathic medical school. Based on their dominant eyes, six students stood on the left side of the treatment table, and six stood on the right.

The estimated mean scores for the ASIS models are presented in Table 1. Scores by examiners' preferred side of the table are presented in Appendix 1. The estimated marginal mean score at baseline was 57.6 %. Overall, the accuracy scores improved from baseline to midpoint (+18.9 %, $p < 0.001$) and from midpoint to final (+6.6 %, $p = 0.01$). The scores decreased from final to retention (–7.2 %, $p = 0.01$), but the overall scores from baseline to retention improved (+18.3 %, $p < 0.001$). The OMS1 students performed better than the novice students at baseline on the ASIS landmarks (OMS1, 70.6 %; novice, 48.4 %; $p = 0.003$), but no differences were observed at the midpoint (OMS1, 75.2 %; novice, 77.5 %; $p = 0.73$), final (OMS1, 87.2 %; novice, 80.2 %; $p = 0.29$), or retention (OMS1, 80.0 %; novice, 73.0 %; $p = 0.29$) assessments.

The estimated mean scores for the PSIS are presented in Table 1. The scores by examiners' preferred side of the table are presented in Appendix 1. The estimated marginal mean score at baseline was 72.9 %. Overall, the accuracy scores improved from baseline to midpoint (+13.0 %, $p < 0.001$). Although the scores changed from midpoint to final (–0.7 %) and from final to retention (+2.7 %), they were not significant (both $p > 0.21$). The overall scores from baseline to retention improved (+15.0 %, $p < 0.001$). The OMS1 students performed better than the novice students at baseline on PSIS landmarks (OMS1, 87.4 %; novice, 62.7 %; $p < 0.001$), but no differences were observed at the midpoint (OMS1, 86.2 %; novice, 85.7 %; $p = 0.91$), final (OMS1, 87.8 %; novice, 83.3 %; $p = 0.37$), or retention (OMS1, 90.0 %; novice, 86.5 %; $p = 0.48$) assessments.

Performance differences based on the examiners' side of the table were compared to baseline results. Overall, ASIS scores did not significantly differ between the left (59.7 %) or right (55.6 %) sides ($p = 0.55$). However, PSIS scores were higher for those on the left side (79.2 %) compared to the right (66.7 %, $p = 0.02$) (Table 2). Examiners on the right side

Table 2: Differences in student accuracy for correct identification of asymmetry at baseline when palpating positional asymmetry models based on the examiners' preferred side of the table.

Asymmetry, mm	ASIS preferred side of the table		p-Value	PSIS preferred side of the table		p-Value
	Left	Right		Left	Right	
Overall	59.7 %	55.6 %	0.55	79.2 %	66.7 %	0.02
–8	83.3 %	45.8 %	<0.001	100 %	87.5 %	0.26
–6	83.3 %	37.5 %	<0.001	95.8 %	83.3 %	0.26
–4	79.2 %	25.0 %	<0.001	66.7 %	87.5 %	0.06
–2	70.8 %	33.3 %	<0.001	25.0 %	62.5 %	<0.001
0 (equal)	12.5 %	45.8 %	0.003	37.5 %	58.3 %	0.06
2	20.8 %	75.0 %	<0.001	87.5 %	41.7 %	<0.001
4	66.7 %	75.0 %	0.46	100 %	41.7 %	<0.001
6	58.3 %	75.0 %	0.14	100 %	62.5 %	<0.001
8	62.5 %	87.5 %	0.03	100 %	75.0 %	0.03

ASIS, anterior superior iliac spine; PSIS, posterior superior iliac spine.

Table 3: Differences in student accuracy for correct identification of individual inferior and superior asymmetry values when palpating positional asymmetry models based on the examiners' preferred side of the table.

Asymmetry, mm	Left side of table		Difference	p-Value	Right side of table		Difference	p-Value
	Inferior	Superior			Inferior	Superior		
Anterior superior iliac spine (ASIS) models								
Baseline								
2	70.8 %	20.8 %	−50.0 %	<0.001	33.3 %	75.0 %	41.7 %	<0.001
4	79.2 %	66.7 %	−12.5 %	0.21	25.0 %	75.0 %	50.0 %	<0.001
6	83.3 %	58.3 %	−25.0 %	0.01	37.5 %	75.0 %	37.5 %	<0.001
8	83.3 %	62.5 %	−20.8 %	0.04	45.8 %	87.5 %	41.7 %	<0.001
Midpoint								
2	62.5 %	70.8 %	8.3 %	0.41	29.2 %	87.5 %	58.3 %	<0.001
4	79.2 %	58.3 %	−20.9 %	0.04	54.2 %	95.8 %	41.6 %	<0.001
6	96.7 %	94.4 %	−2.3 %	0.83	86.7 %	100 %	13.3 %	0.20
8	100 %	95.8 %	−4.2 %	0.68	83.3 %	100 %	16.7 %	0.10
Final								
2	83.3 %	50.0 %	−33.3 %	<0.001	58.3 %	83.3 %	25.0 %	0.01
4	95.8 %	83.3 %	−12.5 %	0.21	79.2 %	91.7 %	12.5 %	0.21
6	95.8 %	95.8 %	0 %	>0.99	83.3 %	100 %	16.7 %	0.10
8	95.8 %	95.8 %	0 %	>0.99	100 %	95.8 %	−4.2 %	0.68
Retention								
2	70.8 %	50.0 %	−20.8 %	0.04	41.7 %	70.8 %	29.1 %	0.004
4	87.5 %	66.7 %	−20.8 %	0.04	87.5 %	87.5 %	0 %	>0.99
6	100 %	83.3 %	−16.7 %	0.10	87.5 %	100 %	12.5 %	0.21
8	100 %	87.5 %	−12.5 %	0.21	91.7 %	87.5 %	−4.2 %	0.68
Posterior superior iliac spine (PSIS) models								
Baseline								
2	25.0 %	87.5 %	62.5 %	<0.001	62.5 %	41.7 %	−20.8 %	0.04
4	66.7 %	100 %	33.3 %	<0.001	87.5 %	41.7 %	−45.8 %	<0.001
6	95.8 %	100 %	4.2 %	0.68	83.3 %	62.5 %	−20.8 %	0.04
8	100 %	100 %	0 %	>0.99	87.5 %	75.0 %	−12.5 %	0.21
Midpoint								
2	62.5 %	75.0 %	12.5 %	0.21	95.8 %	58.3 %	−37.5 %	<0.001
4	87.5 %	95.8 %	8.3 %	0.41	91.7 %	83.3 %	−8.4 %	0.41
6	95.8 %	100 %	4.2 %	0.68	100 %	91.7 %	−8.3 %	0.41
8	94.4 %	96.7 %	2.3 %	0.83	100 %	96.7 %	−3.3 %	0.75
Final								
2	66.7 %	91.7 %	25.0 %	0.01	79.2 %	33.3 %	−45.9 %	<0.001
4	95.8 %	100 %	4.2 %	0.68	100 %	95.8 %	−4.2 %	0.68
6	87.5 %	100 %	12.5 %	0.21	91.7 %	83.3 %	−8.4 %	0.41
8	100 %	100 %	0 %	>0.99	100 %	100 %	0 %	>0.99
Retention								
2	75.0 %	87.5 %	12.5 %	0.21	79.4 %	65.8 %	−13.6 %	0.18
4	91.7 %	100 %	8.3 %	0.41	100 %	83.3 %	−16.7 %	0.10
6	100 %	100 %	0 %	>0.99	100 %	95.8 %	−4.2 %	0.68
8	100 %	100 %	0 %	>0.99	100 %	100 %	0 %	>0.99

Accuracy was assessed weekly after training at baseline, midpoint, final, and retention.

had better ASIS scores for equal (+33.3 %, $p=0.003$), 2 mm (+54.2 %, $p<0.03$), and 8 mm (+25.0 %, $p<0.03$), but worse for all PSIS superior asymmetry values (all $p<0.03$). They also had worse ASIS scores for all inferior ASIS asymmetry values (all $p<0.001$), but better scores on the inferior PSIS asymmetry value of −2 mm (+37.5 %, $p<0.001$).

Comparisons between the examiners' side of the table and performance for asymmetry outcomes are presented in Table 3 and Appendix 2. For those examining from the left side, ASIS scores for superior asymmetries were lower than inferior asymmetries at baseline (−2 mm, −50.0 %; −6 mm, −25.0 %; −8 mm, −20.8 %; all $p<0.04$), at midpoint (−4 mm, −20.9 %;

$p=0.04$), at final (-2 mm, -33.3% ; $p<0.001$), and at retention (-2 mm, -20.8% ; -4 mm, -20.8% ; both $p=0.04$). Those on the right side of the table had higher ASIS scores for superior asymmetries at baseline (all $p<0.001$), midpoint (2 mm, $+58.3\%$; 4 mm, $+41.6\%$; both $p<0.001$), final (2 mm, $+25.0\%$, $p=0.01$), and retention (2 mm, $+29.1\%$, $p=0.004$).

For those examining from the left side, PSIS scores for superior asymmetries were higher than inferior asymmetries at baseline (2 mm, $+62.5\%$; 4 mm, $+33.3\%$; both $p<0.001$) and final (2 mm, $+25.0\%$; $p=0.01$). Those on the right side had lower PSIS scores for superior asymmetries at baseline (-2 mm, -20.8% ; -4 mm, -45.8% ; -6 mm, -20.8% ; all $p<0.04$), midpoint (2 mm, -37.5% , $p<0.001$); and final (2 mm, -45.9% ; $p<0.001$).

Discussion

In the current study, we investigated the effect of training with positional asymmetry models on the improvement and retention of accuracy with pelvic landmark assessments for asymmetry. At baseline, accuracy was better for asymmetries on PSIS than ASIS landmarks (Table 1). Subsequent assessments indicated improvement in the overall scores for both landmarks at midpoint and for the ASIS landmarks at final (Table 2). Retention assessment showed sustained improvements for PSIS models but a decline for ASIS models even though both remained improved from baseline. Our findings suggested that objective feedback with quantified asymmetries significantly enhanced the accuracy of identifying positional asymmetries on simulated models.

Results also indicated that larger asymmetry values and spatially closer landmarks were more accurately identified (Table 1). The ASIS assessments, where the landmarks are over 2 times farther apart than the PSIS assessments, appeared to be more prone to errors. It seems that the greater the eye movement, the more difficult it is to accurately assess the landmarks.

With training, improvements began to plateau for both landmarks at the midpoint assessment (especially for asymmetries ≥ 4 mm), probably caused by a ceiling effect. The accuracy of the ASIS assessments were usually at least 10 % lower than the accuracy for the PSIS assessments. Additionally, although students with 1 year of palpatory experience had greater accuracy than those with no experience at baseline, there were no statistical differences in accuracy between the groups on the midpoint, final, or retention assessments for both models. This result suggested that, within 5 h of practice, the skills of students with no

experience were comparable to those with 1 year of standard curricular training. However, our results also showed consistently higher, but not statistically significant, performance trends for the OMS1 students at the midpoint, final, or retention assessments. It is possible that the current statistical findings may not be telling the whole story because of the small sample size. Additional studies with larger sample sizes are necessary to evaluate actual performance differences between the two groups. This line of research is necessary in establishing evidence-based curricular designs.

The results of the current study had similarities to previous research. Like the study by Stovall et al. [18] we evaluated asymmetry at 2-mm increments in both directions of asymmetry, which allowed for a higher level of precision compared to the study by Lee et al. [19], who utilized 5-mm increments. Unlike previous studies, we tested each asymmetry four times, twice for each direction of asymmetry, which minimized the statistical influence of chance correctness. We also specifically evaluated performance patterns for those standing at different sides of the table, focusing on accuracy characteristics vs. reliability as previously reported [18]. We found that those standing on the left side of the table (right eye dominant) more consistently saw the right ASIS inferior and the right PSIS superior. For those examining from the right side of the table (left eye dominant), it was the opposite. They more consistently saw the right ASIS superior and the right PSIS inferior.

It was unexpected to see that the examination location would show better accuracy with opposite findings. Because of the design of the models, the introduction given during study orientation demonstrating how to localize the landmarks, and the consistent trends seen in the data, it seemed unlikely that poor landmark localization was the cause for the data pattern. Although we cannot rule out the visual system as a potential source for error, it seemed that visual perception would be constant during the study period. Looking more closely at the data, it seems that accuracy was consistently better when the landmark on the opposite side of the table was superior to the landmark on the same side of the table as the examiner (Table 2 and 3, and Appendix 1 and 2). Looking at the students' examination process, it appeared that student examiners were setting up an internal frame of reference based on their head position and posture (Figure 2). Comparing eye and body position with the data supported a predictable skewing of zero and consistently poor accuracy in one direction of asymmetry. If the dominant eye is not in the midline between the landmarks and the eyes are not in the same horizontal plane as the landmarks being assessed, the examiner's internal frame of reference is skewed, and a region associated with smaller asymmetries (Figure 2 – pink

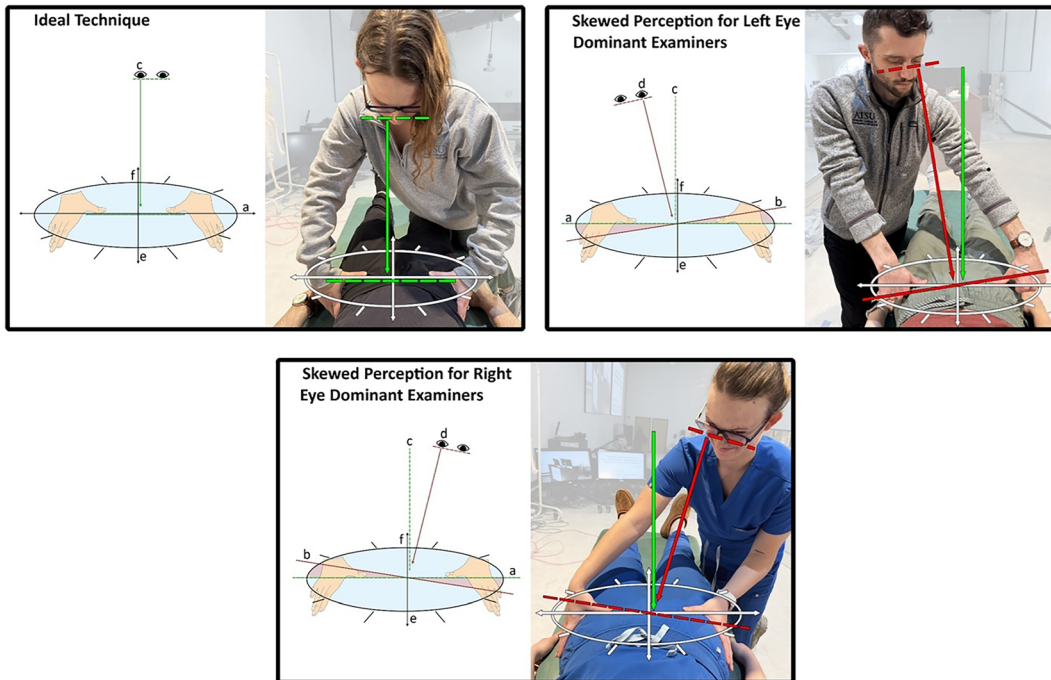


Figure 2: Impact of examiner body position on landmark localization. (a) Actual horizontal plane; (b) perceived horizontal plane; (c) ideally positioned examiner dominant eye/line of view; (d) misaligned dominant eye; (e) towards the head; (f) towards the feet; (g) shaded area-error zone.

shaded zone) will appear correct to the examiner but will actually be incorrect. With practice, adjusting posture so the dominant eye was in the midline of the model and the shoulders and head were in the horizontal plane of the table and model, the curves seen in Appendix 2 shifted to have the lowest point at zero, the shape of the curves looked more symmetrical for both positive and negative asymmetries, and the overall score demonstrated improved accuracy.

From an examiner's perspective, the poor body position during palpatory assessment seemed to be an underrotation or relaxation of the trunk, shoulders, and head. Through training with the palpatory models, the student examiners identified ways to mitigate these errors by lowering the height of the table in order to establish a more comfortable examination posture aligned with the cardinal planes of the model. This learned behavior also seemed to reduce the skewed side-specific misidentification of asymmetry (Appendix 2).

The independent, time-based training utilized in this study (1h/day, 5 days/week for 2 weeks) allowed us to quantify the amount of time necessary for our student examiners to improve and sustain their skills. Further, the flexibility of this training approach allowed the examiners to incorporate self-assessment into their personal schedules and to make evidence-informed individualized postural adjustments to their skills. Consequently, this training

approach does not require additional formal laboratory time to achieve improved performance.

The primary limitation of the current study was that only 12 OMS1 and novice examiners participated, so the results may not be generalizable to larger groups or to learners with more palpatory experience. Additionally, our positional asymmetry training models have identical features, so they do not account for human landmark anatomical variability. The models lack the variability in soft-tissue and landmark characteristics typically observed in humans. Although the models were covered with a thermoplastic elastomer sheet to simulate soft tissue, it cannot fully replicate human tissue. Additionally, centering humans on a treatment table is more challenging than positioning models, and this difference can complicate an examiner's determination of an ideal frame of reference.

Currently, palpatory training with humans lacks objective feedback. As such, these models were specifically designed to be simplified and idealized human approximations to help student examiners utilize objective feedback to develop awareness of basic examination principles and reinforce ideal performance habits. Ideally, this objective feedback during training may increase test accuracy on humans. At this time, we believe that the use of models provides a method for developing essential motor skills that can be applied when examining humans, which may potentially improve the reliability of such

findings. However, it is still unknown how the palpation skills developed through training with the models will translate to examining human patients.

Future investigations should include a larger sample size, such as an entire medical school class. Studies should also evaluate the performance accuracy of practicing osteopathic physicians to determine the effects of time-based training for those with expert-level experience. Other studies, similar to the work of Lavazza et al. [21] should consider investigating how the frequency and duration of training sessions affect palpation accuracy. Similarly, future studies should explore the impact of extended training gaps on accuracy and evaluate the optimal frequency and duration of recalibration. Ultimately, this line of research aims to objectively characterize palpation skills for assessing pelvic landmark asymmetry and establish the clinical relevance of this test.

Conclusions

The current study found that the ability of student examiners to accurately identify asymmetries decreased if the landmark on their side of the treatment table was superior. However, training with positional asymmetry models and objective feedback significantly improved palpation accuracy for both ASIS and PSIS landmarks after 5 h over 1 week. Continued training further enhanced accuracy for the ASIS landmarks and maintained it for PSIS landmarks. These results underscored the value of objective feedback for developing palpation skills by helping examiners accurately assess challenging asymmetries. Incorporating positional asymmetry models into medical training appears to be a promising educational tool for standardizing and improving pelvic asymmetry assessments.

Acknowledgments: The authors would like to thank Deborah Goggin, MA, ELS (Department of Research Support at A.T. Still University) and the A.T. Still University Writing Center for their assistance.

Research ethics: The current study was deemed exempt by the A.T. Still University-Kirksville Institutional Review Board (IRB #BD20221107-001).

Informed consent: By enrolling in the research internship or elective, participants provided consent to participate in research activities.

Author contributions: All authors have accepted responsibility for the entire content of this manuscript and approved its submission.

Use of Large Language Models, AI and Machine Learning Tools: None declared.

Conflict of interest: None declared.

Research funding: None declared.

Data availability: Not applicable.

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- Supplementary Material:** This article contains supplementary material (<https://doi.org/10.1515/jom-2024-0194>).