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Movement does occur following a flexion or extension PIVM: Quantitative measurements of the interspinous space of the lower lumbar segments

Karl Rusch[1], Elizabeth Oakley[2], Emil Euaparadorn[1], Ayse Edeer[1]

[1]Physical Therapy Department, Dominican University New York, Orangeburg, NY

[2]Physical Therapy Department, Andrews University, Berrien Springs, MI

ABSTRACT

Single-group, repeated measures study utilizing convenience sampling of healthy young subjects to determine if interspinous spacing changes with flexion or extension passive intervertebral movements utilizing real-time ultrasound (RTUS) and if so then by how much in the lower lumbar segments. Data was utilized from 50 total subjects (31 females and 19 males) with an average age of 25.90 ± 4.54 years between the ages of 18–45 were measured via RTUS and images were taken in side-lying 4 times. Digital measurements were taken from the peak of the spinous processes of L4-L5 and L5-S1. The distance of each segment was measured in millimeters in each position of neutral side-lying and follow a flexion/extension PIVM. Descriptive statistics were used to summarize data and presented as mean ± SD. An independent sample *t* test was used to compare the mean age, and baseline (neutral) interspinous distance measurements between female and male subjects. *p* value was set at 0.05 and all of the comparisons were two-tailed. Repeated measures ANCOVAs on interspinous space between L4-5 and L5-S1 before-after the flexion and extension PIVMs were made by including covariates gender, height, and age. The measured interspinous distances between L4-L5 (F = 128.58, df=1,48, $p < 0.001$, ηp^2 = 0.728. $p < 0.001$) and L5-S1 (F = 168.27, df=1,48, $p < 0.001$, ηp^2 = 0.778) were significantly higher following the flexion PIVM compared to neutral 1. The measured interspinous distances between L4-L5 (F = 72.821, df=1,48, $p < 0.001$, $p < 0.001$, ηp^2 = 0.603) and L5-S1 (F = 113.358, df=1,48, $p < 0.001$, ηp^2 = 0.703) were significantly lower following the extension PIVM than neutral 2. Gender (F = 0.878, df=4,44, p = 0.485) and height (p = 0.799) were not significantly associated with those above-mentioned changes. However, age was found to be significantly related to L4-L5 flexion (F = 7.38, df=1,47, p = 0.009, ηp^2 = 0.136). The direction of relation between age and L4-L5 flexion (β = 0.351, t = 2.60, p = 0.013, p = 0.013) was positive and linear. After controlling for age, there were significant changes in L5-S1 flexion (F = 6.168, df=1,47, p = 0.017, ηp^2 = 0.116) and extension (F = 8.321, df=1,47, p = 0.006, ηp^2 = 0.150). During a flexion and extension PIVM there were statistically significant changes in interspinous movement regardless of the subjects' gender and height, and age. These findings validate the changes in interspinous distance during a lumbar PIVM technique through objective imaging with RTUS and provide baseline data for future research to identify if lower spinal dysfunctions will ultimately result in any changes to the resting position of interspinous spaces and during flexion or extension PIVMs.

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Introduction

Low back pain (LBP) is the most common musculoskeletal problem globally, as well as the leader in years lived with disability [1]. Personal and societal impacts of LBP are high, particularly regarding the quality of life and workability that ultimately doubles healthcare costs when seeking further care for these effects rather than primary care of LBP itself [2]. The burden of musculoskeletal diseases has found back pain often occurs due to degeneration but there are many underlying factors that can cause back pain, which makes treatment options uncertain [3].

Contact Karl Rusch ✉ karl.rusch@duny.edu Physical Therapy Department, Dominican University New York, Orangeburg, NY.

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The mechanical diagnosis and therapy classification model, the movement system impairment syndromes model, the mechanism-based classification system, and the treatment-based classification system are the four primary LBP classification systems widely used in physical therapy [4–7]. Three out of four of these classification systems incorporate the need for a hands-on mechanical assessment but fail to describe or include commonly used assessment techniques such as passive intervertebral motion (PIVM) [4–9]. Since one of the factors that can contribute to LBP is mechanical, it is important for physical therapists to have manual techniques that can accurately assess segmental spinal movement [8,9]. A PIVM is a technique utilized by physical therapists to identify whether a joint space is hypermobile, hypomobile, or normal to facilitate their decision-making for the specific treatment options [10–13]. Additionally, it is used to open or create increased distance between spinal segments in the direction of flexion and close or decrease the distance between spinal segments in the direction of extension [14,15]. A PIVM has been shown to have moderate to high face validity for identifying segmental motion in assessing mechanical deficits of the spine [8–9].

Changes in the interspinous space have been shown to occur in static lumbar flexion and extension positions in supine by bolstering the legs, dynamically during functional activities such as a forward bend, and in individuals with degeneration in their spine when in certain postures measured with various imaging techniques such as Magnetic Resonance Imaging (MRI), realtime ultrasound (RTUS), and intraoperative and quantitative fluoroscopy [16–20]. Changes in interspinous space during PIVMs have been examined with plain radiographs (X-ray), however, the researchers investigated the concurrent validity between the manual therapy assessment technique and an X-ray rather than the interspinous space changes itself.

It has been shown that RTUS is valid and reliable compared to an MRI which is considered the gold standard in measuring interspinous spaces as well as other structures within the spine with an Intraclass Correlation (ICC) of 0.94 compared to MRI (ICC of 0.98) [19,21–25]. By evaluating interspinous space and the changes in interspinous space with a valid and reliable assessment method such as RTUS during spinal movements in a healthy population, objective and quantitative evidence can be established to determine whether motion occurs and how much it occurs. The physical therapists can decide on certain therapeutic techniques based on their interpretation of opening and closing movements in the spinal segments during PIVMs, in addition, they can compare the changes in the interspinous space of the individuals with LBP and other spinal pathologies with the normative values to determine if too much or too little movement occurs.

There is no study measuring the interspinous space during a PIVM nor is there any literature demonstrating movement occurs with a passive movement utilizing RTUS. The purpose of this study was to investigate if there was movement in the interspinous spaces following a flexion and extension PIVM to validate that the movement the physical therapist perceives actually occurs and to determine the amount of the changes in the interspinous space as normative data. We hypothesized that interspinous space increases with a flexion PIVM and decreases with an extension PIVM.

Materials and Methods

Population, study design, instrumentation

This was a single-group, repeated measure study utilizing convenience sampling of healthy young subjects. Data were utilized from 50 total subjects (31 females and 19 males) with an average age of 25.90 ± 4.54 years. This study was approved by the Andrews University Institutional Review Board (IRB) committee (IRB #: 20-035), and Dominican College's IRB committee (IRB #: 2019-0627-02).

Participants were required to sign an informed consent form, fill out a demographic sheet, and were briefed on all experimental procedures before the data collection was performed. The inclusion criteria were healthy participants between the ages of 18 and 45. Exclusion criteria included no back pain within the past 6 months that required medical attention, no spinal surgeries or instrumentation, no diagnoses associated with stiffness (rheumatoid arthritis and ankylosing spondylitis), and a (+) passive lumbar extension test due to its high sensitivity to rule out lumbar instability [26]. During a passive lumbar extension test, the subjects were placed in a prone position and the examiner lifted bilateral lower extremities until there were extension forces in the spine with a negative test being pain-free in the lumbar spine.

Data collection was performed by two researchers. Researcher one administered the informed consent, gave a verbal explanation of the purpose of the study and the procedure, and utilized the RTUS

for measurements. Researcher two performed the passive lumbar extension test to ensure the participant was qualified to participate, the goniometric measurements to determine each baseline, and all flexion and extension PIVM techniques [27–32].

Materials included in this study were a Mindray DP-30 Digital Ultrasonic Imaging System (Arnold, Maryland) used for interspinous distance measurements and a universal goniometer used for hip flexion measurements. RTUS images were taken from the peak of the spinous process of the fourth and fifth lumbar vertebrae (L4-L5) and fifth lumbar vertebrae to the sacrum (L5-S1). A linear array transducer was used and the frequency was set as 7.5 MHz which allowed for appropriate viewing of the spinous processes. B-mode images were acquired from the RTUS machine and used for interspinous distance measurements.

Procedures

The independent variables were flexion and extension PIVMs from L4-S1. After being approved, the participant positioned themselves side-lying in a rested position. Researcher one moved the legs in order to flex the hips to 45° which was measured with a goniometer [21,33]. This position was selected to standardize the starting point for consistency without influencing movement at the lumbar spine. The starting point was measured prior to each PIVM technique.

The method used for identifying the interspinous spaces was described by Chin et al. [34] in which the sacrum (S1) is the first identifiable bone due to its unique shape and the ultrasound head was moved superiorly to identify the peak of the spinous process of L5 and then L4. This process was repeated for each measurement.

The baseline RTUS images were taken in the starting position as a neutral 1 measurement. The first PIVM was performed while palpating the interspinous spaces of L3-L4, L4-L5, and L5-S1 [35]. When the motion was felt at the level of L3-L4 interspinous space, the researcher rested the legs in place. Performing the PIVM in this way ensured the movement was taken up in the segments that were being measured (L4-L5, L5-S1). The RTUS images were taken in that position as the first PIVM measurement. The participant then went back into the side-lying starting position and the second baseline RTUS images were taken as neutral 2 measurements. The second PIVM was performed in the opposite direction and RTUS images were taken in that position. A total of four RTUS images were taken: neutral 1, first PIVM, neutral 2, and second PIVM. The flexion and extension PIVMs were performed in a random order to eliminate the order effect.

Outcome measures

The dependent variable was the distance from the peak of one spinous process to the peak of the adjacent spinous process measured in millimeters (mm) on the RTUS images. The images taken from the RTUS during neutral 1 and neutral 2, flexion and extension PVIMs were used to measure the distance between the peak of one spinous process to the peak of the adjacent spinous process using a digital caliper on the RTUS (Figs. 1 and 2). The (S1), which is the easiest landmark to obtain onscreen visually, was used as the starting point for all measurements.

Statistical analysis

A pilot study was conducted with 10 subjects to determine the appropriate sample size needed to detect changes of 2 mm in the interspinous spaces of L3-L4 by comparing our subject pool with those of Chleboun et al. [16] Based on the G*Power calculation, the sample size was determined to be 49 healthy subjects using an alpha of 0.05 and a power level of 80% from healthy young between the ages of 18 and 45.

Descriptive statistics were used to summarize data and presented as mean ± SD. An independent sample *t*-test was used to compare the mean age and baseline (neutral) interspinous distance measurements between female and male subjects. Data were checked for the assumptions of related statistical tests such as normality and homogeneity. Normality was tested by the Kolmogorov–Smirnov test and homogeneity of variances was tested via Levene's test. The distance from the peak of one spinous process to the peak of the adjacent spinous process between L4-5 and L5-S1 measured in mm was used for statistical analysis. Repeated measures ANCOVAs on interspinous space between L4-5 and L5-S1 before/after the flexion and extension PIVMs were made by including covariates gender, height, and age. Age was found as a covariate significantly associated with the dependent variable, a follow-up linear regression test was used to see the directionality and magnitude of the association. All of the comparisons were two-tailed and *p*-value was set at 0.05. Partial eta-squared (η_p^2) was reported as effect size when necessary. Statistical Package for the Social Sciences version 24 and G* Power were used for power and statistical analyses.

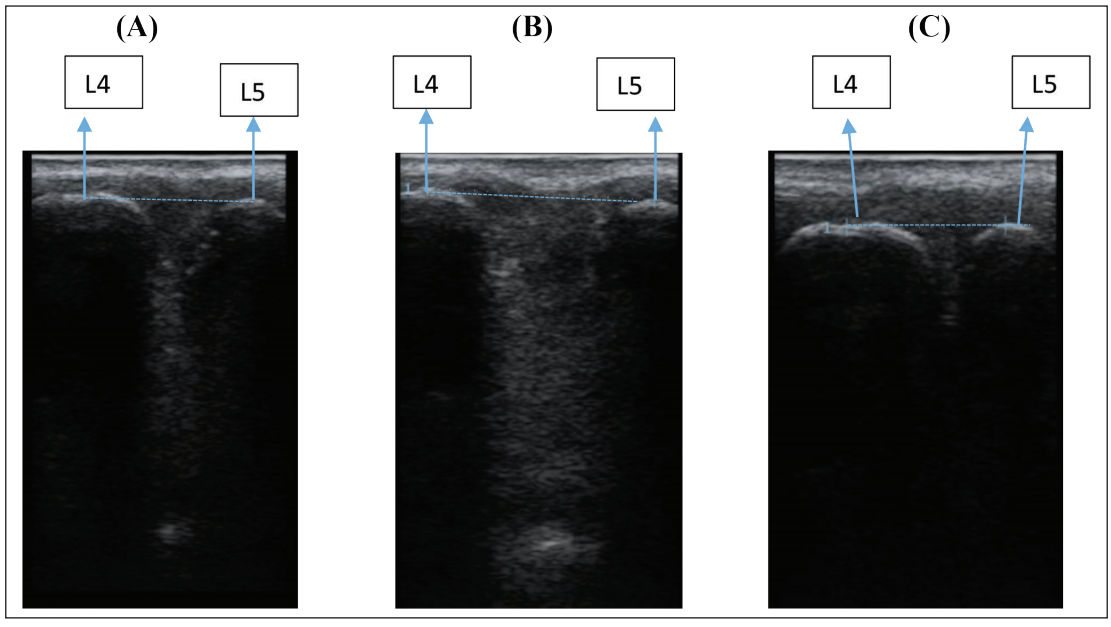


Figure 1. L4-L5 Interspinous distance measurements in (A) neutral, (B) flexion, and (C) extension PIVM.

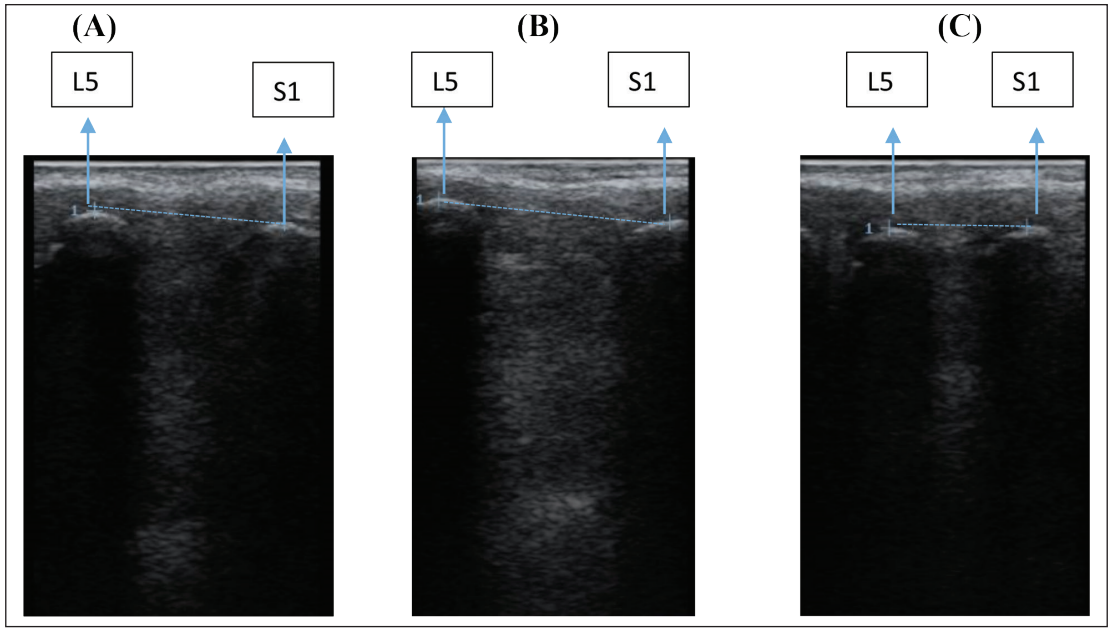


Figure 2. L5-S1 Interspinous distance measurements in (A) neutral, (B) flexion, and (C) extension PIVM.

Results

Subjects

There were originally 60 participants, however, 10 participants were excluded for reasons including time constraints in which they were not able to stay or reschedule, lumbar pain or symptoms during a passive lumbar extension test, inability to find bony landmarks with RTUS, and one individual that had a (−) passive extension test but later found to have a functional retrolisthesis which is when a bony segment translates posteriorly. The sample consisted of 31 females (62%) and 19 males (38%). The mean age of participants was 25.90 ± 4.54 years. Age was not significantly different between males and females ($p > 0.05$). The mean height of participants was 66.50 ± 3.74 inches, and the male subjects' heights were statistically significantly higher than the female subjects ($p < 0.05$). None of the neutral inter-spinal distances were statistically

Table 1. Gender comparisons of age, height, and baseline interspinous distance in neutral 1 and 2 positions ($\bar{x}$: Mean, SD: Standard deviation).

Gender		Age (Yrs.)	Height (inches)	L4-L5 (mm) (neutral1)	L5-S1 (mm) (neutral1)	L4-L5 (mm) (neutral2)	L5-S1 (mm) (neutral2)
Females	$\bar{x}$	25.1	64.5	26.2	24.9	26.5	25.2
	SD	4.1	3.0	2.1	03.0	2.2	3.3
Males	$\bar{x}$	27.1	69.6	28.2	26.3	27.9	26.8
	SD	5.0	2.4	4.6	03.7	3.6	3.4
	t	−1.48	−6.12	−1.70	−1.41	−1.38	−1.62
p	df	48	48	22.6	48	24.7	47
	p	0.143	<0.001	0.101	0.163	0.178	0.111

Table 2. Minimum, maximum, average interspinous distance, and mean changes in mm at baseline and following flexion and extension PIVMs ($\bar{x}$: Mean, SD: Standard Deviation).

Measurement	Minimum	Maximum	Interspinous distance $\bar{x}$ ± SD	Mean changes in interspinous distances $\bar{x}$ ± SD
Neutral 1 (L4-L5)	21.4	37.1	27.0 ± 3.4	4.7 ± 0.2
Flexion (L4-L5)	23.6	45.6	31.7 ± 3.8	
Neutral 1 (L5-S1)	17.6	33.5	25.5 ± 3.3	5.4 ± 0.2
Flexion (L5-S1)	23.0	38.3	30.9 ± 3.9	
Neutral 2 (L4-L5)	21.9	35.0	27.0 ± 2.8	3.3 ± 0.2
Extension (L4-5)	13.6	35.2	23.7 ± 3.6	
Neutral-2 (L5-1)	18.4	33.9	25.8 ± 3.4	4.2 ± 0.2
Extension (L5-S1)	14.6	30.0	21.6 ± 3.5	

significantly different between males and females, although males have longer interspinous distances than females ($p > 0.05$) (Table 1).

Measurements at baseline (neutral 1 or 2) and following flexion and extension PIVMs at L4-L5 and L5-S1 can be seen in Table 2. The interspinous distance increased with a flexion PIVM and decreased with an extension PIVM.

Effect of PIVM on space between lumbar spines

The measured interspinous distances between L4-L5 ($F = 128.58$, df = 1.48, $p < 0.001$, $\eta_p^2 = 0.728$, $p < 0.001$) and L5-S1 ($F = 168.27$, df=1.48, $p < 0.001$, $\eta_p^2 = 0.778$) were significantly higher following the flexion PIVM compared to neutral 1. The measured interspinous distances between L4-L5 ($F = 72.821$, df=1.48, $p < 0.001$, $p < 0.001$, $\eta_p^2 = 0.603$) and L5-S1 ($F = 113.358$, df=1.48, $p < 0.001$, $\eta_p^2 = 0.703$) were significantly lower following the extension PIVM than neutral 2. Gender ($F = 0.878$, df=4.44, $p = 0.485$) and height ($p = 0.799$) were not significantly associated with the above-mentioned changes. However, age was found to be significantly related to L4-L5 flexion ($F = 7.38$, df=1.47, $p = 0.009$, $\eta_p^2 = 0.136$). The direction of the relation between age and L4-L5 flexion ($\beta = 0.351$, t= 2.60, $p = 0.013$, $p = 0.013$) was positive and linear. After controlling for age, there were significant changes in L5-S1 flexion ($F = 6.168$, df=1.47, $p = 0.017$, $\eta_p^2 = 0.116$) and extension ($F = 8.321$, df=1.47, $p = 0.006$, $\eta_p^2 = 0.150$). Table 2 shows the mean changes in measured interspinous distances following flexion and extension compared to the neutral position.

Discussion

In this study, we aimed to determine if there is movement in the interspinous spaces following a flexion and extension PIVM and to validate that the movement a physical therapist perceives is actually occurring in the interspinous spaces. It was found that the interspinous distances between L4-L5 and L5-S1 were significantly greater following a flexion PIVM compared to neutral and significantly lower following an extension PIVM.

With 31 males and 19 females participating in our study and considering gender, age, and height as potential confounders for interspinous spacing,

the ANCOVA analyses were performed before and after spinal flexion and extension PIVMs by including gender, height, and age as covariates.

It was found that gender was not associated with changes during flexion and extension PIVMs at both the L4-L5 and L5-S1 levels, indicating that discrepancies in the number of subjects between males and females did not influence the changes during flexion and extension PIVMs. Although the male subjects were significantly taller than the female subjects in our study, height did not appear to be associated with the changes occurring during flexion and extension PIVMs at both the L4-L5 and L5-S1 levels.

It was found that age was not significantly associated with the changes in the interspinous space during flexion and extension PIVMs, except at the L4-L5 level during flexion PIVMs. The direction of the relation between age and L4-L5 flexion was positive and linear which meant as age increased the amount of interspinous movement increased at the L4-L5 level. This was an interesting finding, as a previous meta-analysis found flexion and extension range of motion to decrease from an asymptomatic individual in each decade from 20 to 60 [36]. Based on these contradictory findings, we can hypothesize the two main differences is that our population in this study had sagittal plane movements performed on them passively, not actively with no weight-bearing influence, and that the mean age of our subjects was in the mid-twenties.

In our study, there was an average of 4.7 and 5.4 mm of interspinous movement between L4-L5 and L5-S1 following a flexion PIVM respectively, and 3.3 and 4.2 mm of interspinous movement between L4-L5 and L5-S1, respectively following an extension PIVM. These values can be used as an average interspinous movement that occurs following a flexion and extension PIVM technique as a baseline in a normal, healthy population which can help with future studies where injuries may have an effect on these values. Abbott et al. [9] stated that there was skepticism regarding the reliability of a PIVM technique and when looking at <6 mm of movement that may be difficult to assess, however they showed the face validity of PIVMs for identifying if movement occurs. In our study, we were able to quantify the amount of interspinous movement that occurs with the PIVM technique in a healthy population.

Chleboun et al. [16] measured the distance between spinous processes at each lumbar segment (L1–2, L2–3, L3–4, L4–5) while subjects were in a supine position and the lumbar spine in three different positions (resting, lumbar flexion, and lumbar extension) using MRI and US imaging in six asymptomatic subjects. They reported that the interspinous distance was similar between US imaging and MRI, except at L3–4 flexion extension. In their study, the mean interspinous distance at L4-L5 in the neutral position was 22.7 ± 3.2 mm which was similar to our study with a mean of 27.02 ± 3.4. We also measured interspinous distance at L5-S1 in neutral which was 25.5 ± 3.3 mm. Due to the similarity of the mean interspinous distance at L4-L5 in the neutral position with Chleboun's et al. [16] study and using a dataset comprised of 50 participants, the average interspinous distance in our study can be considered a baseline value in the neutral spine position for healthy individuals.

The linear change for flexion and extension PIVMs from neutral increased and decreased as expected and our research hypothesis was therefore accepted. This study confirmed that when palpating interspinous spacing during a PIVM technique, the perceived movement of opening and closing has been quantified in a healthy population.

Limitations of this study consisted of an exclusion of a few subjects due to artifacts found on the RTUS images which made them unusable. Other limitations include the accurate palpation L4-S1 although great care was taken to identify specific landmarks and the variability of palpation of segments and subjectivity of movement during a PIVM [8,9,34,37]. Gender distribution in our study was not equal between men and women, but the ANCOVA results indicate that gender was not an important covariate that affected changes that occurred at interspinous distances at L4-L5 or L5-S1. RTUS has validated the use of a PIVM technique when assessing the movement of interspinous spaces. With baseline, normative data in a healthy population, future research can be expanded to assessing lower lumbar segments with a PIVM technique in individuals with lower lumbar dysfunction while being able to quantify changes that occur in interspinous spacing with RTUS.

Conclusion

During a flexion and extension PIVM, there were statistically significant changes in interspinous movement regardless of the subjects' gender and height and age. These findings validate the changes in the interspinous distance during a lumbar PIVM technique through objective imaging with RTUS and provide baseline data for future research to identify

if lower spinal dysfunctions will ultimately result in any changes to the resting position of interspinous spaces and during flexion or extension PIVMs.

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