International Journal of Women's Health

Dovepress
Taylor & Francis Group

Open Access Full Text Article

ORIGINAL RESEARCH

Dynamic Changes in Pubic Symphysis and Superior Pubic Ligament During Pregnancy: A Study Using Ultrasound Shear-Wave Elastography

Peifen Chen[1], Wenqiang Lin[2]

[1]Department of Radiology, The First Affiliated Hospital of Shantou University Medical College, Shantou, Guangdong Province, People's Republic of China; [2]Department of Ultrasound, The First Affiliated Hospital of Shantou University Medical College, Shantou, Guangdong Province, People's Republic of China

Correspondence: Wenqiang Lin, The First Affiliated Hospital of Shantou University Medical College, 57 Changping Road, Shantou, Guangdong Province, 515041, People's Republic of China, Tel +8615815086980, Email stronggerlin@163.com

Purpose: This study aimed to analyze the morphology and elasticity of the pubic symphysis and superior pubic ligament during pregnancy using high-frequency ultrasound and shear-wave elastography, providing anatomical insights into pregnancy-related pelvic adaptations.

Patients and Methods: A retrospective analysis included 202 participants, categorized into non-pregnant, first, second, and third trimester, and postpartum groups. Ultrasound and shear-wave elastography were employed to measure pubic symphysis width, superior pubic ligament length, thickness, and elasticity. Statistical comparisons were performed using one-way ANOVA and Tukey's post-hoc tests.

Results: Pubic symphysis width increased significantly from the second trimester (5.54 ± 1.24 mm) to peak in the third trimester (6.40 ± 2.06 mm, $P < 0.001$), remaining elevated postpartum (5.77 ± 1.62 mm). The SPL thickened (non-pregnant: 4.63 ± 1.12 mm vs third trimester: 8.22 ± 1.45 mm) and lengthened (23.74 ± 4.78 mm vs 40.54 ± 5.90 mm, $P < 0.001$) progressively. SWE revealed increased SPL elasticity in the third trimester (3.20 ± 0.50 cm/s, $P < 0.001$), declining postpartum (2.47 ± 0.28 cm/s). Elasticity correlated with SPL length in the first (*r* = 0.425) and third trimesters (*r* = 0.363) but not with age, PS width, or thickness ($P > 0.05$).

Conclusion: This study is the first to evaluate dynamic morphological and elastic changes in the pubic symphysis and superior pubic ligament using high-frequency ultrasound and shear-wave elastography. The findings provide critical insights into pelvic adaptations during pregnancy and postpartum, offering valuable anatomical references for the clinical management of pregnancy-associated pelvic discomfort and dysfunction.

Keywords: high-frequency ultrasound, shear wave elastography, pubic symphysis, superior pubic ligament, pregnancy-associated pelvic adaptations

Introduction

The pelvis is a robust anatomical structure composed of the hip bones, sacrum, and coccyx, encircled by various ligaments. As the foundation structure of the spine, the pelvis provides essential support and balance for the upper body, facilitating the free extension of the arms and hands to perform precise movements. Furthermore, it functions as a fulcrum that facilitates bipedalism, enabling stable locomotion.[1] The pelvis serves crucial biomechanical functions, principally encompassing the protection of pelvic viscera from external traumatic forces and the provision of ligamentous support for musculoskeletal attachments and visceral organ spatial orientation. Additionally, it facilitates obstetric adaptation through gestational modulation of fibrocartilaginous joint laxity, thereby increasing pelvic capacity to

Received: 4 March 2025
Accepted: 5 July 2025
Published: 18 July 2025

accommodate parturition processes.[2,3] The pubic symphysis (PS) joint, which forms the anterior arch, and the sacroiliac joint, which constitutes the posterior arch, are particularly significant.[4]

The PS is a non-synovial joint formed by the pubic bones, with interarticular fibrocartilage providing a cushioning function. Several strong ligaments encircle the joint, contributing to the stability of the anterior pelvic arch, including the superior, inferior, anterior, and posterior ligaments of the PS.[5,6] The stability of the PS suggests that it is a relatively rigid structure, permitting minimal motion. As a result, the PS is less likely to exhibit pathological signs or symptoms in clinical practice and, therefore, is less frequently emphasized compared to other weight-bearing, active joints.[7]

Several imaging modalities, including X-rays, CT scans, MRIs, and ultrasounds, can be used to visualize the structure of the PS. However, X-rays and CT scans are contraindicated during pregnancy due to their radiation properties. In contrast, ultrasound offers several advantages over MRI, including simplicity, efficiency, and cost-effectiveness, rendering it a suitable option for low-risk screening during pregnancy.[8–10] High-frequency ultrasound further enhances the clarity in visualizing the PS joint and its ligaments.

The primary objective of this study was to characterize changes in the PS during pregnancy by analyzing the morphology and elasticity values of both the PS and the superior pubic ligament (SPL) using high-frequency ultrasound and shear-wave elastography (SWE). Ultimately, this study aims to provide an anatomical reference for the clinical investigation of discomfort and dysfunction in this region.

Materials and Methods

Patients

This study performed a retrospective analysis of female participants who underwent ultrasonography of the PS between March 2023 and February 2024 at The First Affiliated Hospital of Shantou University Medical College. The inclusion criteria were as follows: 1) women over 18 years of age; 2) women with no prior pregnancies; 3) women who were pregnant for the first time; and 4) women who underwent ultrasound within one week after transvaginal delivery. The exclusion criteria were as follows: 1) women under 18 years of age; 2) women with multiple pregnancies; 3) women with non-vaginal deliveries; 4) women with pregnancy loss; and 5) women with systemic diseases or a history of pelvic trauma, including hyperparathyroidism, diabetes mellitus, rheumatic diseases, tumors, and other disorders. These exclusion criteria were based on the premise that such conditions could affect the morphology of the PS and the reliability of the study results. This retrospective study was approved by the Ethics Committee of the First Affiliated Hospital of Shantou University Medical College (Approval No.: B-2023-136, B-2025-072). Patient consent was waived as the study utilized anonymized ultrasound data collected during routine clinical care. All procedures adhered to the ethical standards of the Declaration of Helsinki, ensuring patient confidentiality and data security.

Ultrasonic Examination

The examinations were conducted by a physician with over five years of experience using a Resona R9T ultrasound system (Mindray Bio-Medical Electronics Co., Ltd., Shenzhen, China), equipped with an L15-3WU high-frequency line array probe (3–15 MHz). The system integrates SWE technology. The participant was positioned in the supine position on the examination table after emptying the bladder. The probe was positioned horizontally on the plane of the PS, perpendicular to the skin. The probe was tilted systematically toward the lower abdomen to acquire an oblique coronal view of the PS joint. Due to the anatomical structure and the physical properties of ultrasound waves, obtaining a standard coronal view of the PS was challenging. Image quality and visibility were optimized by adjusting the image depth and grayscale gain. The image should be frozen and stored once it appears clear and stable The elastography function was activated by selecting the “Elasto” button, which initiates the procedure. A high-quality SWE should be selected, and the region of interest should be set to encompass the PS joint and SPL. The participant should be instructed to relax their abdomen and hold their breath while the elastographic image stabilized. Finally, the image should be frozen and stored for further analysis.

Image Quality Control

To ensure the reliability and consistency of the study, a quality control procedure was applied to the ultrasound images. The image depth was adjusted to optimize visibility, positioning the hypoechoic symphysis cartilage centrally in the field of view and aligning the hyperechoic pubic bone parallel to the horizontal axis. Additionally, grayscale gain was adjusted to enhance the visibility of both the PS and SPL during image acquisition. Elasticity image quality control was ensured by a stability index of at least 4 stars (maximum of 5 stars) and an elasticity confidence interval of 90% or higher within the region of interest.

Data Collection

The participant's age and gestational age were recorded. A physician with over five years of experience measured the width of the PS, as well as the length and thickness of the SPL using the built-in measuring tool of the ultrasound system. Elasticity values for the central region of the SPL were measured using SWE mode. A sampling frame with a diameter of 3 mm was selected, and the measurements were recorded in centimeters per second. After completing the measurements, the values were averaged over five readings and recorded for further analysis. The measurer had no access to clinical information about the participant prior to performing the measurements.

Statistical Analysis

Statistical analysis was performed using SPSS software (version 22.0, Chicago, IL, USA). The normality of the data was assessed using the Shapiro–Wilk test and quantile-quantile (Q-Q) plots. Data that followed a normal distribution were reported as the mean and standard deviation (SD). A one-way analysis of variance (ANOVA) was used to compare data across multiple groups. Post-hoc analyses were performed using Tukey's test to adjust for multiple comparisons. Effect sizes (η^2) were calculated to quantify the magnitude of observed differences. For non-normal distributed data, Welch's ANOVA and Games-Howell post-hoc tests were applied. Data plotting was performed using OriginPro (version 2021, OriginLab Corporation, Northampton, MA, USA). All P-values were two-sided, with $P < 0.05$ considered statistically significant.

Results

A total of 252 participants underwent ultrasonography of the PS between March 2023 and February 2024. After excluding cases that did not meet the inclusion criteria, 202 participants (mean age: 29.32 ± 3.12 years; range: 18–41 years) were included in the study. According to the guidelines of the International Society of Ultrasound in Obstetrics and Gynecology (ISUOG), the participants were categorized into the following groups: non-pregnant, first trimester (≤14 weeks), second trimester (15–28 weeks), third trimester (≥29 weeks), and postpartum.[11–13] The sample sizes for each group were as follows: 43 participants in the non-pregnant group; 35 participants in the first trimester (mean gestational age: 9.34 ± 2.92 weeks; range: 5–14 weeks); 40 participants in the second trimester (mean gestational age: 23.15 ± 3.59 weeks; range: 15–28 weeks); 46 participants in the third trimester (mean gestational age: 35.61 ± 3.36 weeks; range: 29–40 weeks); and 38 participants in the postpartum group (mean postpartum days: 3.03 ± 1.44; range: 1–7) (Figure 1).

The PS width exhibited progressive dilation during pregnancy. In non-pregnant women, the mean PS width was 4.14 ± 0.95 mm, increasing significantly from the second trimester (5.54 ± 1.24 mm, $P < 0.001$) and peaking in the third trimester (6.40 ± 2.06 mm, $P < 0.001$). Postpartum measurements (5.77 ± 1.62 mm) remained elevated compared to baseline ($P < 0.001$) but showed no significant difference from third-trimester values ($P > 0.05$, $\eta^2 = 0.257$) (Figure 2 and Table 1). Two cases in the third trimester (10.5 mm, 10.1 mm) and one postpartum case (10.1 mm) exceeded the 10 mm threshold for PS widening, yet none reported pain.

In the non-pregnant cohort, the SPL appeared as a short, flattened, hypoechoic, band-like structure on ultrasonographic imaging. The SPL thickened progressively from non-pregnant values (4.63 ± 1.12 mm) to 8.22 ± 1.45 mm in the third trimester ($P < 0.001$, $\eta^2 = 0.480$), similarly, SPL length increased from 23.74 ± 4.78 mm (non-pregnant) to 40.54 ± 5.90 mm (third trimester) ($P < 0.001$, $\eta^2 = 0.465$). Postpartum values for thickness (7.43 ± 1.59 mm) and length (38.61 ± 8.99 mm) remained comparable to third-trimester measurements ($P > 0.05$) (Table 1 and Figure 3).

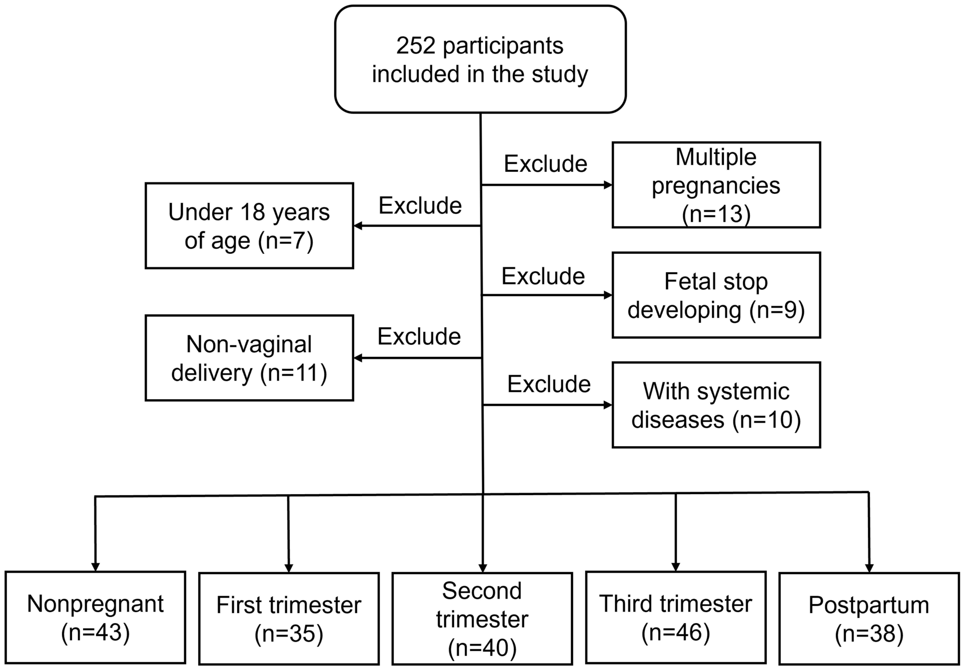

Figure 1 Flowchart of the study.

SPL elasticity, measured via shear-wave speed (cm/s), remained stable in early and mid-pregnancy (2.62 ± 0.38 to 2.65 ± 0.51 cm/s, $P > 0.05$) but increased significantly in the third trimester (3.20 ± 0.50 cm/s, $P < 0.001$, $\eta^2 = 0.324$). Postpartum elasticity declined to 2.47 ± 0.28 cm/s ($P < 0.001$ vs third trimester) (Figure 4 and Table 1).

Pearson correlation analysis was performed to evaluate the associations between SPL elasticity and covariates across gestational groups (Table 2). In the first trimester, SPL elasticity exhibited a moderate positive correlation with SPL length (*r* = 0.425, $P = 0.011$). Similarly, a significant correlation between SPL elasticity and length persisted in the third trimester (*r* = 0.363, $P = 0.013$). Notably, no significant correlations were observed between SPL elasticity and age, PS width, or SPL thickness in any gestational group ($P > 0.05$ for all comparisons). In postpartum women, SPL elasticity demonstrated a marginal but non-significant association with SPL length (*r* = 0.208, $P = 0.083$). These findings suggest that ligament elongation during pregnancy may contribute to increased SPL elasticity, particularly in the first and third trimesters, independent of maternal age, PS widening, or ligament thickening.

Data normality was confirmed via Shapiro–Wilk tests ($P > 0.05$). One-way ANOVA with Tukey's post-hoc adjustments was applied for group comparisons. Effect sizes (η^2) indicated large effects for PS width ($\eta^2 = 0.257$), SPL thickness ($\eta^2 = 0.480$), SPL lengthened ($\eta^2 = 0.465$) and elasticity ($\eta^2 = 0.324$) with sufficient post-hoc power (>80%).

Discussion

Throughout human evolution, the pelvis has evolved into a wider and more vertical structure, a transformation resulting from the ongoing compromise between the demands of efficient bipedal locomotion and childbirth.[1] This evolutionary trade-off has resulted in a distinct pelvic configuration that accommodates both functions, particularly through modifications to the ilium, the upper part of the pelvis. A comparison of the human and chimpanzee ilium reveals that the human ilium is shorter and wider—an adaptation that supports balance during bipedal locomotion.[4] The lower pelvis, or true pelvis, consists of the pubic bone, ischial bones, lower ilia and sacrum, forming its anterior and posterior walls. This structure serves as the passage through which the fetus moves during labor, necessitating a precise and coordinated interaction of forces. The anatomical configuration of the pelvic inlet, characterized by a shorter anteroposterior diameter (distance from the pubic symphysis to the sacral promontory) and a wider transverse diameter (maximum distance between the lateral boundaries of the pelvic inlet), necessitates fetal rotation during labor to align the fetal head with these dimensions. This spatial mismatch between the fetal head (typically oriented in the anteroposterior plane) and the

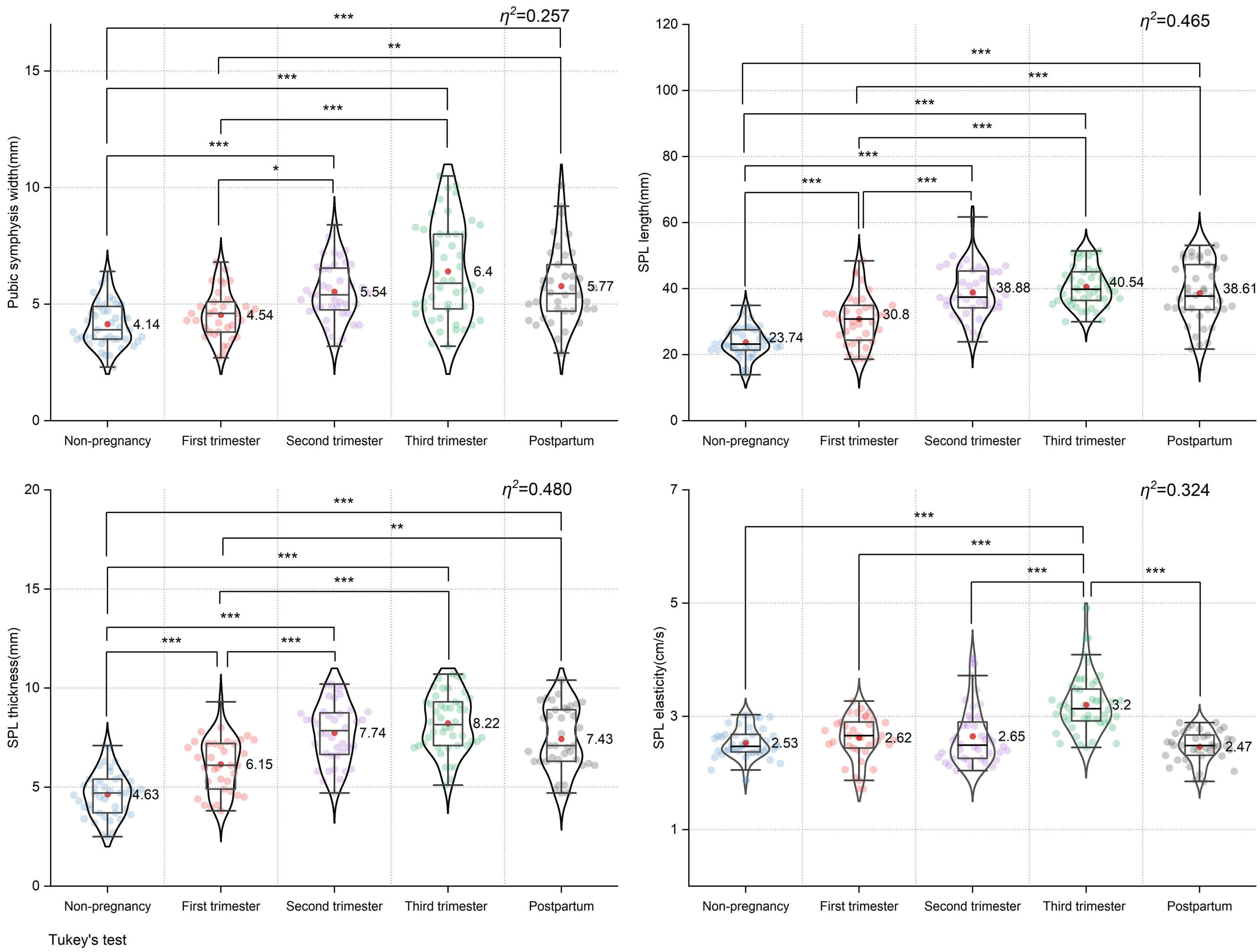

Figure 2 Violin plots of ultrasound measurements across different pregnancy stages. Different numbers of asterisks represent different p-value levels via Tukey's post hoc test: *means $P < 0.05$, **means $P < 0.01$, ***means $P < 0.001$.

pelvic inlet's transverse dominance requires the fetus to rotate approximately 90 degrees to navigate the birth canal efficiently. This anatomical adaptation exerts bidirectional mechanical forces on the pelvic walls, thereby inducing progressive expansion of maternal pelvic capacity throughout mid-to-late gestation. This physiological remodeling plays a pivotal role in biomechanical mechanisms underlying parturition dynamics.[14]

Table 1 Baseline Characteristics and One-Way ANOVA Analysis and Tukey's Tests of Ultrasound Parameters Across Subgroups

	Non-pregnancy (n=43)	Pregnancy			Postpartum (n=38)	*P*	η^2
		First Trimester (n=35)	Second Trimester (n=40)	Third Trimester (n=46)			
Age (years)	25.86±4.54	30.60±4.37[a]	30.53±3.19[a]	30.28±4.05[a]	29.63±4.10[a]	<0.001	0.171
PS width (mm)	4.14±0.95	4.54±1.01	5.54±1.24[ab]	6.40±2.06[ab]	5.77±1.62[ab]	<0.001	0.257
SPL length (mm)	23.74±4.78	30.80±7.68[a]	38.88±7.68[ab]	40.54±5.90[ab]	38.61±8.99[ab]	<0.001	0.465
SPL thickness (mm)	4.63±1.12	6.15±1.35[a]	7.74±1.49[ab]	8.22±1.45[ab]	7.43±1.59[ab]	<0.001	0.480
SPL elasticity (cm/s)	2.53±0.26[c]	2.62±0.38[c]	2.65±0.51[c]	3.20±0.50	2.47±0.28[c]	<0.001	0.324

Note: Different superscript letters (a, b, c) denote pairwise comparisons via Tukey's post hoc test (P <0.05): a = non-pregnancy group, b = first trimester group, c = third trimester group.
Abbreviations: PS, Pubic symphysis; SPL, Superior pubic ligament.

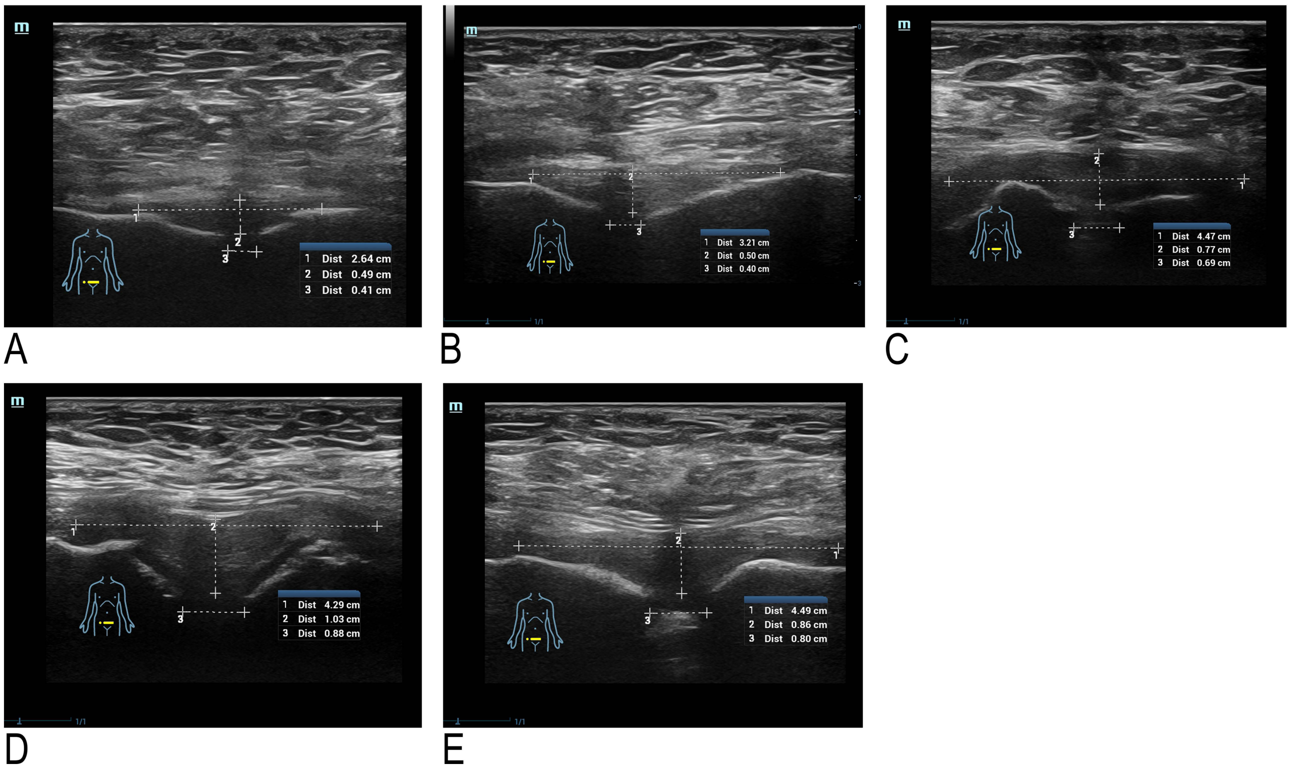

Figure 3 Ultrasonographic features and measurements of the PS and SPL across different pregnancy stages. (**A**) is a 25-year-old non-pregnant woman. (**B**) is a 22-year-old woman at 10 weeks' gestation. (**C**) is a 29-year-old woman at 27 weeks' gestation. (**D**) is a 28-year-old woman at 38 weeks' gestation. (**E**) is a woman with 40 weeks' gestation who was examined six days postpartum after a normal delivery. The SPL is located at the upper portion of the pubic bone and is bilaterally attached to the PS. In non-pregnant women, the SPL is a short, thin, triangular structure. It begins to thicken and lengthen during early pregnancy, reaches maximum length and thickness during late pregnancy, and remains long and thick after delivery. The distance between the PS starts to increase in mid-pregnancy, reaches its peak in late pregnancy, and undergoes slight contraction postpartum. Dist 1 is indicative of SPL length, Dist 2 of SPL thickness, and Dist 3 of PS width.

The human pelvis is a robust, ring-like structure reinforced by strong ligaments that resist tensile, compressive, and shear forces, ensuring stability and preventing loosening.[7,15] During pregnancy, the pelvis undergoes adaptive changes to accommodate fetal growth and delivery, including widening of the PS joint and sacroiliac joint, which increases the space between the pubic bones for childbirth.[16] According to existing literature, the PS joint width in the general population is typically 4–5 mm, widening to 6–8 mm during pregnancy.[17] This change, characterized by minimal movement, is essential for facilitating fetal growth and delivery.

In this study, the mean PS width in healthy, non-pregnant women aged over 18 years was 4.14 ± 0.95 mm (range 2.3–6.4 mm), consistent with the findings of Becker et al.[6] These measurements establish a baseline for understanding normal anatomical variation prior to the physiological changes of pregnancy. Additionally, in non-pregnant adult females, the SPL presented as a short, flattened, strip-like structure with a mean length of 23.74 ± 4.78 mm and a thickness of 4.63 ± 1.12 mm. This morphology is characteristic of the PS joint and SPL in the absence of tensile forces or internal compression. However, the increased tensile forces on the SPL during pregnancy may lead to different structural adaptations to handle the widening of the PS joint. The measurements and observations from this study provide valuable insights into the normal configuration of the PS and its supporting structures in non-pregnant females. Understanding these baseline characteristics is crucial for assessing pregnancy-related changes, such as PS widening and augmented tensile forces on the SPL.

Relaxin, a member of the insulin-like superfamily of hormones, is secreted by the corpus luteum and placenta. It plays a pivotal role in influencing pelvic volume changes during pregnancy, with the primary secretion occurring during the first trimester and the perinatal period.[18–20] Relaxin induces collagen modifications by activating collagenase enzymes, which compromise the structural integrity of cartilage and tendons, reducing their tensile strength. This results in increased joint laxity, greater inter-joint distance, and an overall increase in pelvic volume to accommodate the growing

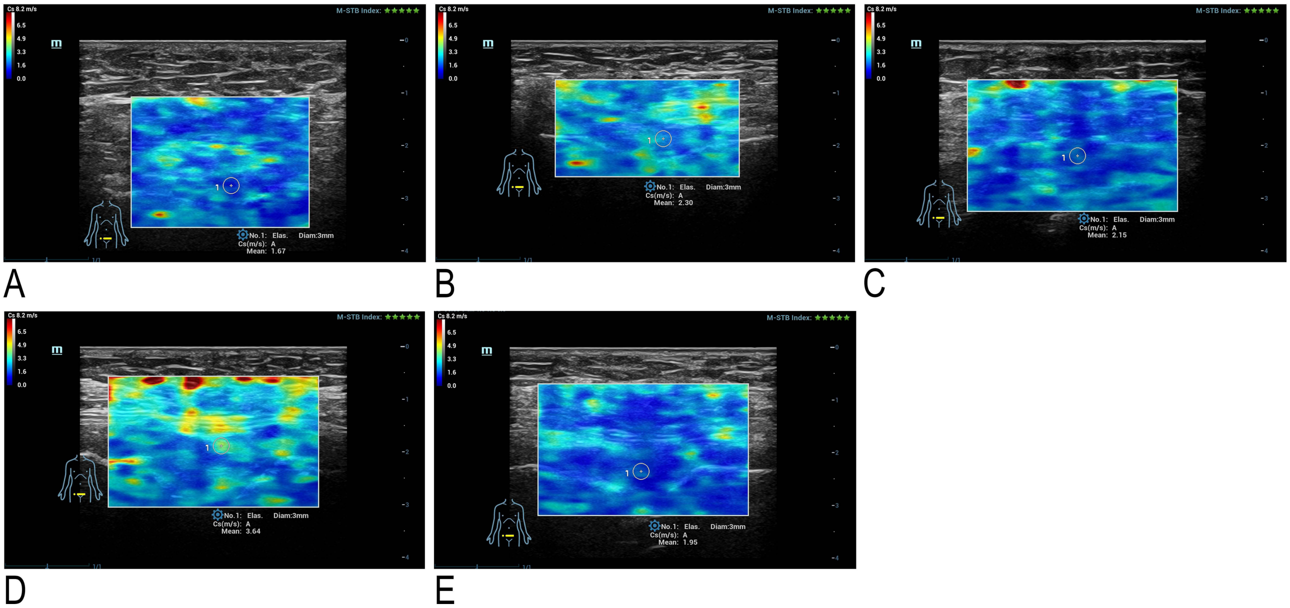

Figure 4 Real-time shear wave elastography and measurements of the SPL at various stages of pregnancy. (**A**) is a 25-year-old non-pregnant woman. (**B**) is a 22-year-old woman at 10 weeks' gestation. (**C**) is a 29-year-old woman at 27 weeks' gestation. (**D**) is a 28-year-old woman at 38 weeks' gestation. (**E**) is a woman with 40 weeks' gestation who was examined six days postpartum after a normal delivery. The SPL exhibits maximum elasticity during the third trimester of pregnancy, followed by a decrease postpartum. The colours displayed on the elasticity scale represent varying degrees of elasticity, with red indicates high elasticity and blue indicates low elasticity.

fetus.[20] Joint laxity is thought to begin around the 10–12 weeks of gestational age,[21] initiating early pelvic adjustments that facilitate later pregnancy adaptations.

Our study observed that the SPL lengthened and thickened during the first trimester, contrasting with the structural properties observed in non-pregnant women. Despite these early changes in ligament morphology, we did not detect significant alterations in the width of the PS or the elasticity of the SPL during this phase. This suggests that although hormonal changes are initiating connective tissue remodeling, pelvic structures have not yet undergone substantial modifications typically associated with later pregnancy stages. The lack of significant changes in PS width and ligament elasticity during the first trimester may be attributed to the gradual nature of the hormonal effects on ligamentous tissue remodeling. While relaxin initiates change in connective tissues, the thickening and coarsening of the ligaments observed in our study indicate that these adaptations are still in the early stages. As pelvic volume does not significantly expand during the first trimester, the pelvic walls are not exposed to the excessive pressures that would drive further changes in the PS and ligament elasticity. These findings suggest that significant pelvic changes, including increased PS width and ligament elasticity, may not occur until later stages of pregnancy. The first trimester, while characterized by hormonal influences on ligamentous remodeling, does not yet subject the pelvic structures to the pressures necessary for these

Table 2 Pearson Correlations Between SPL Elasticity and Covariates Across Gestational Groups

Gestational Group	Age	PS Width	SPL Length	SPL Thickness
Non-pregnant	0.204 (0.189)	0.021 (0.895)	0.069 (0.658)	0.063 (0.690)
First trimester	0.209 (0.228)	0.147 (0.399)	0.425 (0.011) *	0.040 (0.818)
Second trimester	0.007 (0.967)	0.083 (0.609)	0.123 (0.450)	0.144 (0.375)
Third trimester	0.064 (0.670)	0.167 (0.268)	0.363 (0.013) *	0.174 (0.247)
Postpartum	0.063 (0.709)	0.209 (0.207)	0.208 (0.083)	0.142 (0.395)

Notes: Data are presented as Pearson correlation coefficients (r) with P-values in parentheses. Asterisk indicate statistically significant correlations ($P < 0.05$).

Abbreviations: PS, pubic symphysis; SPL, superior pubic ligament.

changes. This highlights the gradual nature of pelvic adaptation, with more substantial changes likely occurring in the second and third trimesters as fetal growth and hormonal activity increase.

During the second and third trimesters of pregnancy, significant changes occur in the SPL and PS as the body adapts to accommodate the growing fetus. The SPL elongates and thickens, while the PS widens in preparation for delivery. These structural adaptations facilitate the changes in pelvic volume and provide the necessary flexibility for fetal passage during labor. We hypothesize that the widening of the PS in the third trimester is influenced by several factors: increased fetal volume, amniotic fluid, and placental appendages; the descent of the fetal head or trunk during the final stages of pregnancy; and the increased mechanical pressure on the pelvic ring, which elevates the load on the PS joint, facilitating its sustained widening in preparation for delivery.[22,23]

Existing literature indicates that relaxin induces the breakdown and reorganization of elastic fibers in the PS ligaments, increasing water content, which contributes to tenderness and edema.[15] These changes are essential for enhancing the flexibility of the pelvic structures as they adapt to the demands of labor. In our study, SPL elasticity values were higher in the third trimester, likely due to the continued widening of the PS joint. During this phase, the SPL experiences increased horizontal tension, stretching laterally like a spring, reflecting the increased mechanical load placed on the pelvic ring during fetal descent and positioning. Among the four PS ligaments, the SPL is unique in lacking additional tendon components, making it less influenced by biomechanical forces from adjacent anatomical structures.[24] However, the SPL exhibits the lowest resistance to stress, rendering it particularly vulnerable to biomechanical changes. As the pelvis undergoes greater strain during pregnancy, particularly in the third trimester, the SPL becomes increasingly susceptible to such stresses, making it the most vulnerable ligament during stress tests.[15,25] These findings underscore the critical role of the SPL in the adaptive changes occurring in the pelvic structures during pregnancy. As the ligament becomes more elastic and subject to increasing tension, it is essential for clinicians to recognize its vulnerability, particularly as pregnancy progresses into the third trimester. Understanding these biomechanical changes is crucial for better managing the physical demands placed on the pelvic region during labor and delivery.

Pregnancy-associated pubic symphysis pain (PAPP) is characterized by discomfort in the PS region during pregnancy or the postpartum period. It is a rare complication that often remains undiagnosed during the perinatal period. Yoo et al reported a prevalence of 0.26%, highlighting its rarity.[26] The pathogenesis of PAPP remains incompletely understood; however, existing literature suggests that when the PS width exceeds 10 millimeters, the resulting instability may lead to aseptic inflammation. In cases where this inflammation becomes severe, it can cause significant separation of the symphysis and injury to the surrounding ligaments, contributing to the onset of pain.[17]

In this study, participants with a PS width greater than 10 mm were identified in both the late pregnancy and postpartum groups. However, none of these cases exhibited symptoms of pubic pain, suggesting that the relationship between PS widening and PAPP is more complex than previously thought. While increased width is commonly associated with instability, it does not always result in pain, indicating that additional factors must contribute to the development of PAPP. Physiological widening of the PS occurs during pregnancy and remains stable through the perinatal period following delivery. Additionally, the morphology of the SPL does not immediately return to its pre-pregnancy state postpartum, and its elasticity decreases. We hypothesize that recovery from morphological changes in the PS joint and SPL requires an extended period. Fukano et al support this hypothesis, proposing a minimum recovery period of three months.[27]

Ligament lengthening and laxity are potential causes of anterior pelvic instability, these changes may predispose individuals to PAPP, especially if the ligaments fail to return to their original state postpartum.[28,29] Several studies suggest that multiple pregnancies constitute a risk factor for PS separation and pain. The repeated stretching and remodeling of the ligaments during each pregnancy can weaken their elasticity over time, making them more prone to injury and separation during subsequent pregnancies.[17,23,26] Icke et al[30] propose that the PS gap widens during upright stance, placing horizontal tensile forces on the symphysis. These forces are absorbed by the syndesmotic ligaments, which may become overstretched. Thus, during recovery, weight-bearing activities or physical exertion can exacerbate ligament injury and potentially lead to joint separation, resulting in discomfort in the affected region. This suggests that, during the postpartum period, resuming normal physical activities too soon may exacerbate the symptoms of PAPP.

 https://doi.org/10.2147/IJWH.S520999

However, most studies have focused primarily on PS separation,[23,31,32] neglecting the integrity of the joint and ligaments during pregnancy and postpartum.

To the best of our knowledge, this study is the first to utilize high-frequency ultrasound combined with SWE to assess dynamic changes in the morphology and elasticity of the PS and SPL during pregnancy. Our findings provide a novel perspective on the role of these anatomical structures in accommodating fetal growth and preparing for childbirth. Furthermore, these insights may lead to improved clinical practices for diagnosing and managing conditions such as PAPP during pregnancy and the postpartum period.

However, it is important to acknowledge the study's limitations. Due to the retrospective design, it was not possible to track changes in the PS across different stages of pregnancy within the same participants. This limitation is further compounded by individual differences among participants, which could introduce variability into the data. Secondly, a longitudinal follow-up to monitor the recovery of the SPL in postpartum female was not performed. Thirdly, additional data and multicenter studies are required to validate and refine our findings. Finally, the effects of multiple pregnancies and cesarean sections on the morphology of the PS remain unclear, highlighting an important avenue for future research.

Conclusions

This study demonstrated dynamic morphological and elastic changes in the PS and SPL across pregnancy stages using high-frequency ultrasound combined with shear-wave elastography. Key findings include progressive widening of the PS from the second trimester, peak values in the third trimester, and persistent morphological alterations postpartum. The SPL exhibited significant thickening and lengthening during pregnancy, with elasticity increasing in the third trimester followed by a postpartum decline. These observations highlight the adaptive capacity of pelvic structures to accommodate fetal growth and parturition.

While postpartum PS and SPL morphology remained similar to late-pregnancy measurements, the reduced elasticity of the SPL postpartum may reflect incomplete recovery of ligamentous biomechanical properties. These structural and functional changes provide critical anatomical insights into pregnancy-related pelvic adaptations. Further longitudinal studies are needed to explore the clinical implications of these findings, including potential associations between postpartum ligamentous elasticity and pelvic stability.

Acknowledgment

The present study received no financial support from any particular grants from funding agencies in the public, commercial, or nonprofit sectors.

Disclosure

The authors report no conflicts of interest in this work.

References

1. Le Huec JC, Saddiki R, Franke J, Rigal J, Aunoble S. Equilibrium of the human body and the gravity line: the basics. *Eur Spine J*. 2011;20(Suppl 5):558–563. doi:10.1007/s00586-011-1939-7
2. Martelli F, Youssef A, Capogna MV, et al. Longitudinal changes of subpubic arch angle throughout pregnancy. *Gynecol Obstet Invest*. 2020;85 (1):100–106. doi:10.1159/000504096
3. Zhang S, Dumas G, Hemmerich A. Measurement of pubic symphysis width in different birthing positions using ultrasound. *J Biomech*. 2020;113:110114. doi:10.1016/j.jbiomech.2020.110114
4. Gruss LT, Schmitt D. The evolution of the human pelvis: changing adaptations to bipedalism, obstetrics and thermoregulation. *Philos Trans R Soc Lond B Biol Sci*. 2015;370(1663):20140063. doi:10.1098/rstb.2014.0063
5. Mazura M, Kachlik D, Blankova A, et al. A morphologic analysis of the pubic symphysis using CT and MRI. *J Am Acad Orthop Surg*. 2022;30(13): e939–48. doi:10.5435/JAAOS-D-21-00933
6. Becker I, Stringer MD, Jeffery R, Woodley SJ. Sonographic anatomy of the pubic symphysis in healthy nulliparous women. *Clin Anat*. 2014;27 (7):1058–1067. doi:10.1002/ca.22423
7. Alicioglu B, Kartal O, Gurbuz H, Sut N. Symphysis pubis distance in adults: a retrospective computed tomography study. *Surg Radiol Anat*. 2008;30 (2):153–157. doi:10.1007/s00276-007-0295-0
8. Khorashadi L, Petscavage JM, Richardson ML. Postpartum symphysis pubis diastasis. *Radiol Case Rep*. 2011;6(3):542. doi:10.2484/rcr.v6i3.542
9. Heim JA, Vang S, Lips E, Asche SE, Ly T, Das K. Pubic symphysis separation and regression in vaginal versus cesarean delivery. *J Obstet Gynaecol Can*. 2022;44(1):42–47. doi:10.1016/j.jogc.2021.07.015

10. Nitsche JF, Howell T. Peripartum pubic symphysis separation: a case report and review of the literature. *Obstet Gynecol Surv*. 2011;66(3):153–158. doi:10.1097/OGX.0b013e31821f84d9
11. Bilardo CM, Chaoui R, Hyett JA; International Society of Ultrasound in Obstetrics and Gynecology, et al. ISUOG practice guidelines (updated): performance of 11-14-week ultrasound scan. *Ultrasound Obstet Gynecol*. 2023;61(1):127–143. doi:10.1002/uog.26106
12. Salomon LJ, Alfirevic Z, Berghella V, et al. ISUOG practice guidelines (updated): performance of the routine mid-trimester fetal ultrasound scan. *Ultrasound Obstet Gynecol*. 2022;59(6):840–856. doi:10.1002/uog.24888
13. Khalil A, Sotiriadis A, D'Antonio F, et al. ISUOG practice guidelines: performance of third-trimester obstetric ultrasound scan. *Ultrasound Obstet Gynecol*. 2024;63(1):131–147. doi:10.1002/uog.27538
14. Kjeldsen LL, Blankholm AD, Jurik AG, Salvig JD, Maimburg RD. Pelvic capacity in pregnant women, identified using magnetic resonance imaging. *Acta Obstet Gynecol Scand*. 2021;100(8):1454–1462. doi:10.1111/aogs.14168
15. Becker I, Woodley SJ, Stringer MD. The adult human pubic symphysis: a systematic review. *J Anat*. 2010;217(5):475–487. doi:10.1111/j.1469-7580.2010.01300.x
16. Shnaekel KL, Magann EF, Ahmadi S. Pubic symphysis rupture and separation during pregnancy. *Obstet Gynecol Surv*. 2015;70(11):713–718. doi:10.1097/OGX.0000000000000247
17. Sung J-H, Kang M, Lim S-J, Choi S-J, Oh S-Y, Roh C-R. A case-control study of clinical characteristics and risk factors of symptomatic postpartum pubic symphysis diastasis. *Sci Rep-UK*. 2021;11(1):3289. doi:10.1038/s41598-021-82835-8
18. Sherwood OD. Relaxin's physiological roles and other diverse actions. *Endocr Rev*. 2004;25(2):205–234. doi:10.1210/er.2003-0013
19. Chawla JJ, Arora D, Sandhu N, Jain M, Kumari A. Pubic symphysis diastasis: a case series and literature review. *Oman Med J*. 2017;32(6):510–514. doi:10.5001/omj.2017.97
20. Dehghan F, Haerian BS, Muniandy S, Yusof A, Dragoo JL, Salleh N. The effect of relaxin on the musculoskeletal system. *Scand J Med Sci Spor*. 2014;24(4):e220–229. doi:10.1111/sms.12149
21. Heckman JD, Sassard R. Musculoskeletal considerations in pregnancy. *J Bone Joint Surg Am*. 1994;76(11):1720–1730. doi:10.2106/00004623-199411000-00018
22. Anastasio MK, Anastasio AT, Kuller JA. Peripartum Pubic Symphysis Diastasis. *Obstet Gynecol Surv*. 2023;78(6):369–375. doi:10.1097/OGX.0000000000001156
23. Rustamova S, Predanic M, Sumersille M, Cohen WR. Changes in symphysis pubis width during labor. *J Perinat Med*. 2009;37(4):370–373. doi:10.1515/JPM.2009.051
24. Pieroh P, Li Z-L, Kawata S, et al. The topography and morphometrics of the pubic ligaments. *Ann Anat*. 2021;236:151698. doi:10.1016/j.aanat.2021.151698
25. Mathieu T, Van Glabbeek F, Van Nassauw L, Van Den Plas K, Denteneer L, Stassijns G. New insights into the musculotendinous and ligamentous attachments at the pubic symphysis: a systematic review. *Ann Anat*. 2022;244:151959. doi:10.1016/j.aanat.2022.151959
26. Yoo JJ, Ha Y-C, Lee Y-K, Hong JS, Kang B-J, Koo K-H. Incidence and risk factors of symptomatic peripartum diastasis of pubic symphysis. *J Korean Med Sci*. 2014;29(2):281–286. doi:10.3346/jkms.2014.29.2.281
27. Fukano M, Aisaka K, Nose-Ogura S, Fujii T, Torii S. Progressive changes in lumbopelvic alignment during the three month-postpartum recovery period. *Int J Env Res Pub He*. 2022;19(10):5807. doi:10.3390/ijerph19105807
28. Bhardwaj A, Nagandla K. Musculoskeletal symptoms and orthopaedic complications in pregnancy: pathophysiology, diagnostic approaches and modern management. *Postgrad Med J*. 2014;90(1066):450–460. doi:10.1136/postgradmedj-2013-132377
29. So CC, Niakan LS, Garza-Gongora RD. Imaging of the pubic symphysis: anatomy and pathologic conditions. *Radiographics*. 2023;43(2):e220058. doi:10.1148/rg.220058
30. Icke C, Koebke J. Normal stress pattern of the pubic symphysis. *Anat Cell Biol*. 2014;47(1):40–43. doi:10.5115/acb.2014.47.1.40
31. Aydın S, Bakar RZ, Aydın ÇA, Özcan P. Assessment of postpartum symphysis pubis distention with 3D ultrasonography: a novel method. *Clin Imag*. 2016;40(2):185–190. doi:10.1016/j.clinimag.2015.10.015
32. Ely Cheikh T, Fatiha E, Khadija I, et al. Pubic disjunction following vaginal delivery in a multiparous woman: a case report. *Ann Med Surg*. 2021;68:102629. doi:10.1016/j.amsu.2021.102629