Exploring the Influence of perineal biometrics and stiffness measured by elastography during pregnancy on perineal tears: A pilot study

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Abstract

Objectives: This study aimed to describe the biometrics and elasticity of the perineal body and the anal sphincter in the ninth month of pregnancy and explore their association with the risk of perineal tears during childbirth.

Methods: In this prospective observational study, pregnant women at 36-40 weeks of gestation were included. Using transperineal 2D-mode ultrasound and shear wave elastography (SWE), we measured the biometrics and stiffness of the perineal body (PB), external anal sphincter (EAS), internal anal sphincter (IAS), and anal mucosa (AM) at rest and during Valsalva maneuvers.

Results: Of the 16 women, 10 (62.5%) underwent a perineal tear. All were first degree perineal tears. Women with perineal tear had statistically a higher perineal body area at rest (0.9 ± 0.1 cm^2 versus 0.7 ± 0.1 cm^2, p=0.03), a thicker EAS at 9 o'clock at rest (0.6 ± 0.2 cm vs 0.4 ± 0.1 cm, p=0.03), a smaller anteroposterior diameter (1.7 ± 0.2 cm vs 2 ± 0.2 cm, p=0.047), a smaller lateral diameter (1.4 ± 0.2 cm vs 1.6 ± 0.1 cm, p=0.05) and a thinner IAS in average at rest (0.2 ± 0.0 cm vs 0.3 ± 0.0 cm, p=0.007) and at 12 o'clock at rest (0.2 ± 0.1 cm vs 0.3 ± 0.0 cm, p=0.002). The PB, EAS, IAS and AM elastic modulus in the ninth month of pregnancy tended to be higher in women with a perineal tear.

Conclusion: Assessing perineal and anal sphincter biometrics and stiffness via ultrasound and SWE is feasible and may indicate a risk of perineal tears.

Trial registration: The study was registered on (NCT05556304).

Key words: perineum, elasticity, anal sphincter, perineal body, obstetric anal sphincter injury, OASIS

Manuscript

Introduction

During childbirth, the morphological and dynamic adaptation of the perineum to the fetal presentation depends on its resistance to the stresses induced by the presentation [1]. Under the effect of the compression of the presentation, the perineum becomes thinner until sometimes it tears. Perineal tears can be more or less severe. Stages III and IV obstetrical anal sphincter injury prevalence varies between 0.25 and 6% in the general population, between 1.4 and 16% in primiparous patients and 0.4 and 2.7% in multiparous patients [2]. They are the source of significant morbidity such as anal incontinence, chronic perineal pain or sexual dysfunction [2–4].

Data concerning the mechanical properties of the perineum [5–14] and fetal stresses [15–20] during the delivery are very limited. They are essentially numerical models of the distension of the levator ani muscles, also called the pelvic floor, using the finite element method [14, 21–23].

A key component of the perineum is the perineal body. This fibromuscular pyramidal structure that is located between the vagina and the anus, is a confluence of multiple muscle attachments. It protects the anal sphincter during vaginal delivery. Birth models usually contain the vagina, rectum, bladder, ligaments and sometimes the levator ani muscles [13, 16, 21, 23–25]. But the perineal body and perineal muscle are never included. The two main limitations of the perineal body modeling are its difficulty to be identified and the absence of knowledge of its real biomechanical parameters. According to Buyuk et al., pregnancy and delivery significantly modify the perineal body dimensions [26]. In order to better understand perineal mechanical properties, in-vivo non-invasive measurement are needed. Shear Waves Elastography (SWE) aims to quantitatively image the stiffness of soft tissues [27, 28]. Its advantage is the possibility to perform in the same time perineal biometrics using B-mode ultrasound and stiffness measurements. Rostaminia et al. study showed that SWE could be used to quantify perineal body stiffness during labor [29]. But there is no study comparing the influence of the perineal body elasticity at the end of pregnancy and perineal tears.

We hypothesized that measurements of perineal biometrics and elasticity during the ninth month of pregnancy could be associated with a risk of perineal tears. The aim of the study was to describe the biometrics and the elastic properties of the perineal body and the anal sphincter at the ninth month prenatal visit and to explore the association between these measurements and the risk of perineal trauma during childbirth.

Methods

Settings

This prospective observational and monocentric study was conducted in the department of Obstetrics and Gynecology of Besancon University Hospital (France) between January 2023 and August 2023.

Population

Pregnant women over 18 years old, volunteers, with a normal singleton pregnancy, non in labor and who agreed to participate in the study were recruited during their ninth prenatal visit. The exclusion criteria were: women with a history of pelvic floor disorder (urinary incontinence, anal incontinence and/ or pelvic organ prolapse), women with a history of genital excision, women with a body mass index higher than 35 kg/m², women with a chronic muscular disease or connective tissue disease, women with a psychiatric pathology requiring a hospitalization and women unable to understand the French language.

Women were informed of the study during a prenatal visit by their obstetrician and/or midwife. Eligible women were contacted by the investigator to further inform them about the study and to include them if they were volunteers. Pregnancy follow-up was carried out as usual, without any modification of the latter. The delivery was conducted in the usual way with the midwife and the obstetrician if necessary. None of the measures impacted the delivery progress. During deliveries, the fetal head was usually supported by the accoucheur through the perineum during expulsion. After the head restitution, the Couder's maneuver (delivery of the anterior arm) was usually performed.

Data collection

Each recruited patient's demographic and obstetrical data were retrieved from electronic medical chart. During their ninth prenatal visit, the following demographic and obstetrical data were collected from the medical record: age, height, pre-pregnancy weight, current weight, gestational age, skin phototype according to Fitzpatrick's classification, smoking during pregnancy, the use of a medical device for perineal stretching such as Epino® during pregnancy, the performance of a perineal massage during pregnancy, and the uterine height.

During delivery, obstetrical data were collected such as follow: spontaneous or induced labor, no analgesia, epidural analgesia or end-of-labor spinal anesthesia, duration of the active phase of labor, duration of the second stage of labor (descent phase and expulsion phase), duration of the expulsion phase (duration between the beginning of pushing efforts and birth, in minutes), delivery mode (spontaneous vaginal delivery, instrumental vaginal delivery or caesarean section), performance of Couder's maneuver, performance of an episiotomy, diagnosis of a perineal tear or not according to the RCOG classification [3], and diagnosis of anterior perineal tear. The following neonatal characteristics were collected from the medical record: neonatal weight, height and head circumference.

Ultrasound B-mode assessment of the perineum

During the ninth month of pregnancy, an ultrasound B-mode assessment of the perineum was performed with the AIXPLORER device (Supersonic™ MACH30 Imagine, C6-1X probe, Supersonic, Aix-en-Provence, France) in a gynecological position. Ultrasound B-mode characteristics of the anal sphincter and the perineal body were studied at rest and during the Valsalva maneuver by a translabial perineal approach described by Dietz et al., Asfour et al. and Rostaminia [29–31] (Figure 1.). The perineal body (PB) length, height and area were measured in the sagittal plane. The external anal sphincter (EAS), interna anal sphincter (IAS) and anal mucosa (AM) anteroposterior and lateral diameters were measured in the transversal plane. EAS and IAS thicknesses were measured at 12, 3 and 9 o'clock from its outer to inner border in the transversal plan. Measurements were made 5 times at rest. A mean value was then calculated for each variable.

Shear Wave Elastography assessment of the perineum

During the same ninth prenatal visit, a Shear Wave Elastography (SWE) assessment of the perineum was performed. The ultrasound shear wave elastography is a non-invasive method to determine tissue stiffness in real time [27, 28]. In this technique, ultrasound induces the propagation of a shear wave along the main axis of the ultrasound probe. The speed of the wave's propagation is correlated to the shear modulus and the tissue stiffness. The stiffer the tissue is, faster the wave's propagation is. SWE technique produces a color-coded quantitative map of tissue elasticity in kPa.

Perineal SWE measurements were performed with the AIXPLORER device (Supersonic™ MACH30 Imagine, C6-1X probe, Supersonic, Aix-en-Provence, France) in a gynecological position. For imaging, the probe was placed on vulvar fourchette while avoiding any pressure on the tissue, as excessive pressure applied by the probe could interfere with measurements [32]. A B-mode ultrasound was always performed before SWE measurements to identify PB, EAS, IAS and AM. Then, measurements were performed according to Gachon et al. [8, 9] for the EAS and Rostaminia et al. and Chen et al. [29, 33] for the PB. The SWE measurements of the IAS and AM were performed using the same technique. For the PB, the region of interest (ROI) was manually drawn over its global area (Figure 2.). A homogeneous circular ROI manually drawn along the margin of the structure being evaluated from its outer to inner border for the following reference points: the EAS at 12 o'clock, at 3 and 9 o'clock, the

IAS at 12 o'clock, at 3 and 9 o'clock and the anal mucosa at 3 and 9 o'clock and at 12 o'clock. Measurements were made 5 times at rest and 5 times during 5-second Valsalva maneuvers. Mean values at rest and during the Valsalva maneuvers were then calculated for each variable.

The Aixplorer® device provided elastic modulus assessment (kPa) within the ROI. Larger elastic modulus indicates that the tissue is associated with greater stiffness.

Statistical analysis

Continuous variables were reported as means and standard deviations. Categorical variables were reported as numbers and percentages. Data from women who underwent a cesarean section delivery were excluded from results. Demographic and obstetrical characteristics were compared between women with perineal tears at delivery (regardless of severity) and those with an intact perineum using a Student t-test or a Fisher test when data were quantitative or qualitative, respectively. The association between perineal B-mode ultrasound biometrics or SWE measurements with perineal tears at delivery were assessed using Student t-test.

Statistical analyses were performed using R software (version 4.3.0). For all analyses, significance will be considered for $p<0.05$.

Ethics consideration

The investigator orally informed and provided a written information to each woman prior to inclusion in the trial. To participate in the trial, the woman gave an informed consent. This study was approved by an ethical committee (Comité de Protection des Personnes SUD EST III) and is referenced with the ID RCB 2022-A01117-36. Patients or the public were not involved in the design, or conduct, or reporting, or dissemination plans of our research.

Results

During the study period, 32 women were approached and 18 (56.3%) women were included in the study. Then 2 women were excluded because of cesarean section deliveries (Figure 3.). Demographic and obstetrical characteristics of women who sustained a vaginal delivery are compared in Table 1. Five women (31.2%) were nulliparous. None were smokers or used a device for perineal stretching such as Epino® during pregnancy. Among the 16 women who underwent a vaginal delivery, 10 (62.5%) perineal tears occurred. All were first degree perineal tears. Considering the 16 women, mean length, height and area of the PB were 1.3 ± 0.3 cm, 0.7 ± 0.2 cm, and 0.8 ± 0.2 cm^2 respectively. Mean EAS thickness at 12 o'clock was 0.5 ± 0.3 cm. Mean IAS thickness at 12 o'clock was 0.3 ± 0.1 cm.

Compared with those without perineal tears, women with perineal tear had statistically a higher perineal body area at rest (0.9 ± 0.1 cm^2 versus 0.7 ± 0.1 cm^2, p=0.03), a thicker EAS at 9 o'clock at rest (0.6 ± 0.2 cm vs 0.4 ± 0.1 cm, p=0.03), a smaller anteroposterior diameter (1.7 ± 0.2 cm vs 2 ± 0.2 cm, p=0.047), a smaller lateral diameter (1.4 ± 0.2 cm vs 1.6 ± 0.1 cm, p=0.05) and a thinner IAS in average at rest (0.2 ± 0.0 cm vs 0.3 ± 0.0 cm, p=0.007) and at 12 o'clock at rest (0.2 ± 0.1 cm vs 0.3 ± 0.0 cm, p=0.002) (Table 2.). No B-mode ultrasound measurements of the perineum during Valsalva maneuver were statistically different between women who had a perineal tear and those who did not. The PB, EAS, IAS and AM elastic modulus in the ninth month of pregnancy tended to be higher in women with a perineal tear at delivery, but it was not statistically significant (Table 3).

Discussion

We provided the first report of in vivo assessment of perineal body and anal sphincter biometrics using B-mode ultrasound from 36 to 40 weeks of gestation. In this study, a 0.2 cm^2 higher PB area was associated with perineal tears during vaginal deliveries. A few millimeters smaller IAS (3 mm for the antero-posterior diameter and 2 mm for the lateral diameter) and a 1 mm thinner IAS at 12 o'clock using ultrasound were associated with perineal tears during vaginal deliveries. As far as we know, no study in the literature has studied if B-mode ultrasound biometrics of PB or the anal sphincter were risk factors of perineal tears. Anal sphincter biometrics from this cohort are similar to Mendoza et al. study who measured anal sphincter in 111 nulliparous women [30]. Zhou et al. studied the perineal body height using B-mode ultrasound with the probe placed on the PB [34]. Among 45 nulliparous women attending urological and gynecologic clinic, PB height was similar to our results (0.7 cm in nulliparous women) at rest and during the Valsalva maneuver.

In this study, elasticity measurements during the ninth month of pregnancy at rest or during the Valsalva maneuver of PB and the anal sphincter using SWE were not associated with perineal tears. However, a trend toward an increase in elastic modulus of EAS, IAS and AM was observed in women with a perineal tear. In the literature, there are no studies that have assessed the influence of the perineal body stiffness outside of labor on perineal tears. Nevertheless, Rostaminia et al. study showed that shear wave elastography could be used to quantify perineal body stiffness during labor [29]. They reported that perineal laceration was more prevalent in women with stiffer perineal body. The PB stiffness values using SWE from Rostaminia et al. study were in the same order of magnitude as our study (15.3 kPa). Chen et al. had previously demonstrated the feasibility of estimating perineal body tissue properties by using quantitative US elastography among 20 nulliparous non-pregnant women [33]. The estimated elastic moduli were normally distributed with a mean of 28.0 kPa and a standard deviation of 4.7 kPa but their elastic modulus were obtained with quasistatic elastography among non-pregnant nulliparous women. Zhou et al. studied the elasticity of the perineal body using SWE among 45 nulliparous non-pregnant women attending the urological and gynecologic clinic [34]. Similar to our study, PB stiffness increased during the Valsalva maneuver (23.8 kPa vs 25.0 kPa).

In this study, EAS, IAS and AM stiffness were not statistically different between women who had a perineal tear and those who did not. However, a trend toward higher EAS, IAS and AM stiffness was observed in women with a perineal tear. The hypothesis of Gachon et al. was that stiffer EAS at Valsalva in late pregnancy would be less likely to suffer from perineal tears at delivery [35]. This trend was also found in our cohort .

The main strength of this study is its originality. It is the first study to report in vivo assessment of both PB and anal sphincter biometrics and stiffness during pregnancy in women. In the literature, there are no data on biomechanical properties of each structure of the perineum for each woman. These characteristics have been described in the sow using invasive tensile tests [36]. Second, SWE is a safe, non-invasive, real-time method for investigating the mechanical properties of tissue. It has the ability to evaluate specific anatomy such as the perineal body for example. SWE is a reliable tool for measuring elastic properties of PB and EAS at rest and during the Valsalva maneuver [9, 29, 34, 37].

In order to understand perineal tears during childbirth, a perineal mapping is needed. It involves data analysis based on the sizes and the trajectory of the fetal head in the birth canal, the size of the genital hiatus and the perineal body, the size and mechanical properties of the perineal tissues and pushing efforts. The size and the trajectory of the fetal head in the birth canal can be obtained with fetal and obstetrical 2D-ultrasound measurements. Biometrics of the perineal body, the internal and external anal sphincters and the anal mucosa can be obtained with 2D perineal ultrasound. Perineal elasticity can be assessed by SWE. All of these data can be transferred to a Finite Element model of the perineum during deliveries [6, 38, 39].

The main limitation of this study is the small number of women included. This is due to the originality of the study, which is a pilot study on this research topic with PB, EAS, IAS and AM mucosa data during the ninth month of pregnancy. This limitation does not allow us to investigate the association between second degree perineal tears and obstetrical sphincter anal injury at delivery and the elastic properties of the PB and the anal sphincter. Therefore, a larger prospective and multicenter study is needed to validate the usefulness of SWE in predicting perineal tears. SWE could also help to evaluate hypotheses such as perineal massage or warm compress on the perineal body before or during labor could be beneficial in reducing the risk of laceration.

Conclusion

In vivo assessment of both the perineal body and anal sphincter biometrics and stiffness during pregnancy in women is feasible using ultrasound and shear wave elastography. The perineal body and anal sphincter biometrics could influence perineal tears during delivery. Their stiffness needs to be studied in a larger cohort.

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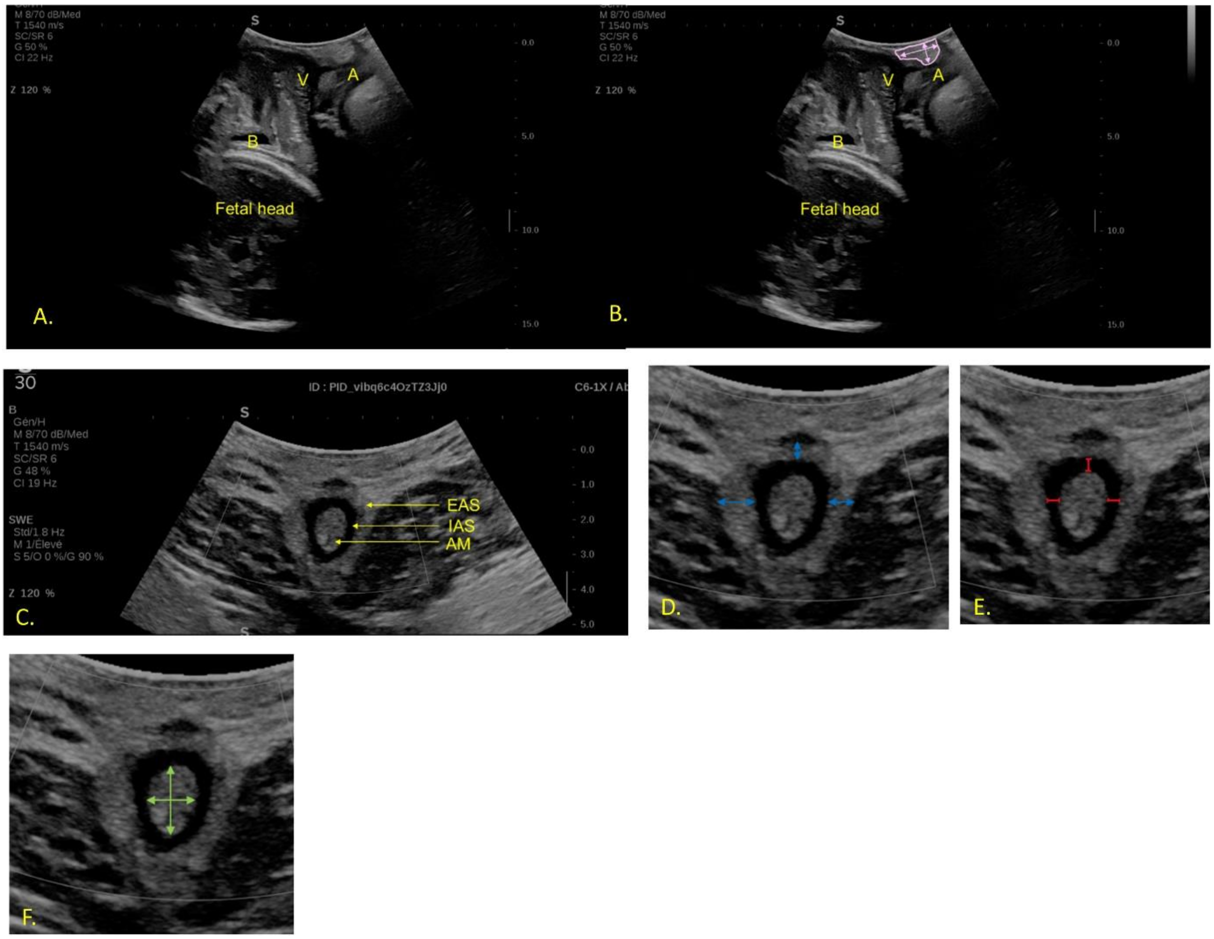

Figure 1. Perineal body, anal sphincter and anal mucosa biometrics using B-mode Ultrasound (Supersonic™ MACH30 Imagine, Aix-en-Provence, France). A. Pelvic and perineal anatomy in sagittal plane. B: Bladder, V: Vagina, A: Anal canal. C. Perineal body (pink marks) assessment in sagittal plane (its length, height and area). D. Anal sphincter anatomy in transversal plane. EAS: External anal sphincter, IAS: Internal anal sphincter, AM: Anal mucosa. E. External anal sphincter thickness measured at 12, 3 and 9 o'clock. F. Internal anal sphincter thickness measured at 12, 3 and 9 o'clock. G. Anteroposterior and lateral diameters of the anal mucosa.

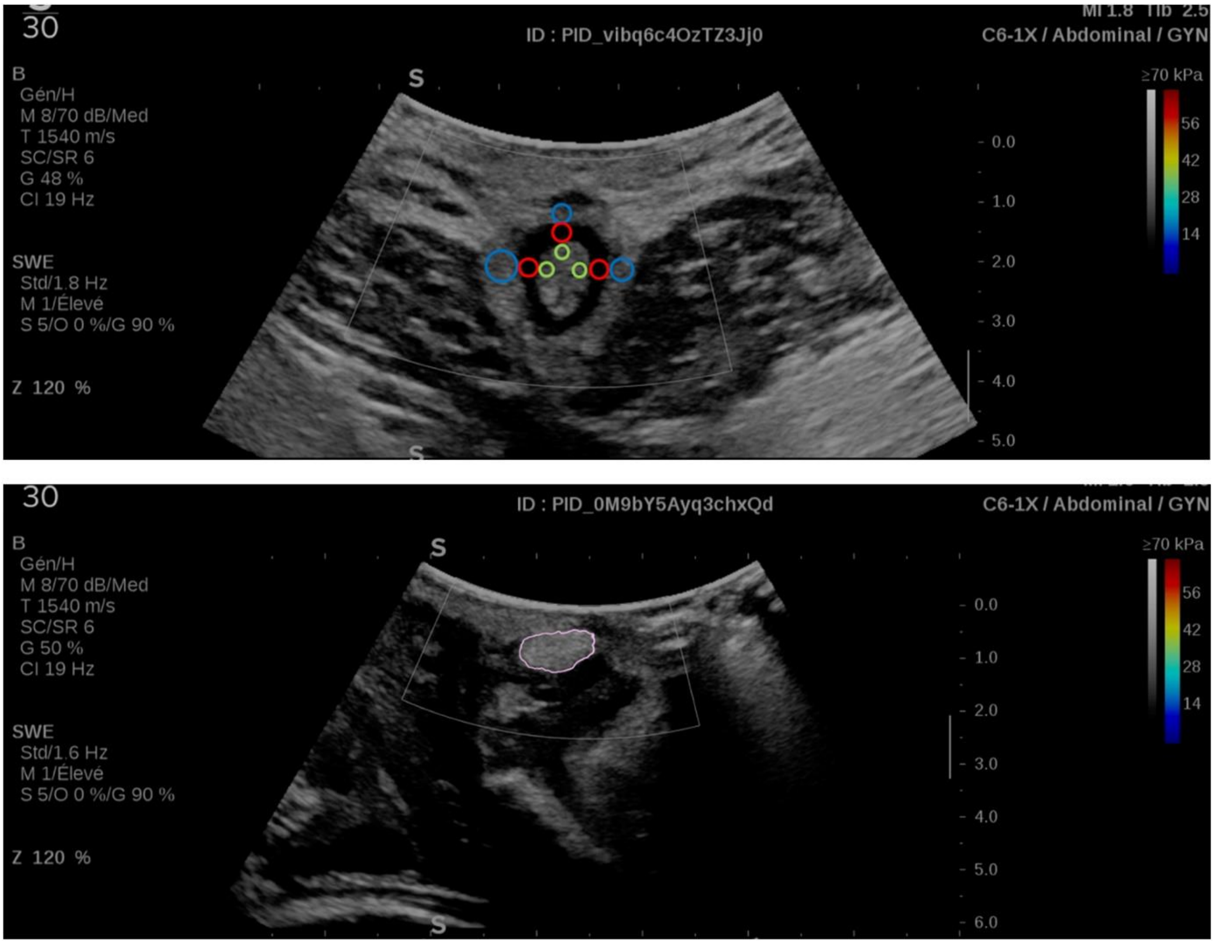

Figure 2. Perineum assessment using Shear Wave Elastography (Supersonic™ MACH30 Imagine, Aix-en-Provence, France). Area surrounded by pink line: perineal body assessment. Blue circles: external anal sphincter assessment at 12 o'clock, at 3 and 9 o'clock. Red circles: internal anal sphincter assessment at 12 o'clock, at 3 and 9 o'clock. Green circles: anal mucosa assessment at 12, 3 and 9 o'clock.

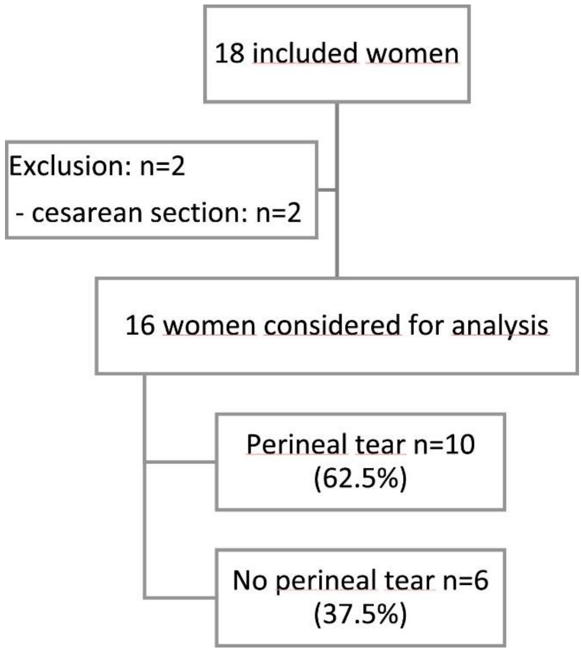

Figure 3. Flow chart

Table 1. Comparison of demographics and obstetrical characteristics between women who had a perineal tear or not during their vaginal delivery.

	Perineal tears		p-value
	No (n=6)	Yes (n=10)	
Age (y)	33.3 ± 5.4	29.1 ± 4.3	0.1
Parity	1 ± 0.6	0.7 ± 0.7	0.4
Nulliparous woman	1 (16.7)	4 (40.0)	0.6
BMI (kg/m²)	22.0 ± 2.6	24.9 ± 3.3	0.07
Cutaneous phototype	3.2 ± 1.3	3.0 ± 0.9	0.8
Perineal massage	1 (16.7)	0	0.4
Gestational age at measurements (weeks)	38.6 ± 0.3	38 ± 1.2	0.1
Birth Gestational age (weeks)	39.8 ± 0.9	40.3 ± 1.2	0.4
Uterine length (cm)	32.0 ± 1.5	31.1 ± 1.4	0.2
Inducted labor	0	1 (10.0)	/
Peridural analgesia	6 (100)	10 (100)	/
Active labor (5-10 cm) duration (min)	76.0 ± 85.8	193.0 ± 192.3	0.1
Labor second stage (10 cm-delivery) duration (min)	74.7 ± 72.1	144.6 ± 130.0	0.2
Pushing duration (min)	5.2 ± 3.7	10.8 ± 11.3	0.2
Mode of delivery			1
Normal VD	6 (100)	9 (90.0)	
Assisted VD	0	1 (10.0)	
Episiotomy	0	0	/
Couder's maneuver	5 (83.3)	9 (90.0)	1
Perineal tear degree			
First degree	/	10 (100)	
Second degree	/	0	
OASIS	/	0	
Labia minora tear	0	3 (30.0)	0.2
Birth weight (g)	3351.7 ± 433.2	3517 ± 326.3	0.4
Head circumference (cm)	34.6 ± 1.6	34.6 ± 1.3	1

Data are expressed as mean ± SD or number of cases (percentage).

BMI: body mass index; VD: vaginal delivery; OASIS: obstetrical anal sphincter injury.

Table 2. Comparison of perineal biometrics during the ninth month of pregnancy according to the occurrence or not of a perineal tear during vaginal delivery.

	Perineal tear		p-value
	No (n=6)	Yes (n=10)	
Perineal body			
Length (cm)			
Rest	1.2 ± 0.2	1.4 ± 0.3	0.4
Valsalva	1.3 ± 0.6	1.3 ± 0.3	0.9
Height (cm)			
Rest	0.7 ± 0.2	0.8 ± 0.1	0.4
Valsalva	0.7 ± 0.2	0.6 ± 0.2	0.4
Area (cm²)			
Rest	0.7 ± 0.1	0.9 ± 0.1	**0.03**
Valsalva	0.6 ± 0.3	0.9 ± 0.3	0.4
EAS			
Anteroposterior diameter (cm)			
Rest	2.8 ± 0.2	2.8 ± 0.6	0.8
Valsalva	2.6 ± 0.5	2.7 ± 0.6	0.8
Lateral diameter (cm)			
Rest	2.5 ± 0.2	2.6 ± 0.3	0.9
Valsalva	2.7 ± 0.4	2.7 ± 0.4	0.8
EAS thickness			
Mean (cm)			
Rest	0.4 ± 0.1	0.5 ± 0.2	0.2
Valsalva	0.5 ± 0.08	0.5 ± 0.2	0.6
At 12 o'clock (cm)			
Rest	0.3 ± 0.1	0.5 ± 0.2	0.2
Valsalva	0.4 ± 0.1	0.4 ± 0.3	0.8
At 3 o'clock (cm)			
Rest	0.4 ± 0.1	0.5 ± 0.1	0.4
Valsalva	0.5 ± 0.2	0.6 ± 0.3	0.6
At 9 o'clock (cm)			
Rest	0.4 ± 0.1	0.6 ± 0.2	**0.03**
Valsalva	0.5 ± 0.1	0.6 ± 0.2	0.5
IAS			
Anteroposterior diameter (cm)			
Rest	2 ± 0.2	1.7 ± 0.2	**0.047**
Valsalva	1.8 ± 0.3	1.7 ± 0.2	0.3
Lateral diameter (cm)			
Rest	1.6 ± 0.1	1.4 ± 0.2	**0.05**
Valsalva	1.7 ± 0.2	1.5 ± 0.2	0.2
IAS thickness			
Mean (cm)			
Rest	0.3 ± 0.0	0.2 ± 0.0	**0.007**
Valsalva	0.3 ± 0.1	0.2 ± 0.1	0.04
At 12 o'clock (cm)			
Rest	0.3 ± 0.0	0.2 ± 0.1	**0.002**
Valsalva	0.3 ± 0.1	0.3 ± 0.1	1
At 3 o'clock (cm)			
Rest	0.3 ± 0.1	0.2 ± 0.1	0.1
Valsalva	0.3 ± 0.1	0.2 ± 0.1	0.7
At 9 o'clock (cm)			
Rest	0.3 ± 0.1	0.2 ± 0.0	0.2
Valsalva	0.3 ± 0.1	0.2 ± 0.1	0.2
Anal mucosa			
Anteroposterior diameter (cm)			
Rest	1.3 ± 0.1	1.1 ± 0.2	0.1
Valsalva	1.1 ± 0.06	1.1 ± 0.2	0.5
Lateral diameter (cm)			
Rest	1.0 ± 0.1	0.9 ± 0.2	0.2
Valsalva	1.1 ± 0.2	1.0 ± 0.1	0.2

Data are expressed as mean ± SD. EAS: external anal sphincter; IAS: internal anal sphincter.

Table 3. Comparison of perineal elastic modulus using Shear Wave Elastography during the ninth month of pregnancy according to the occurrence or not of a perineal tear during vaginal delivery

	Perineal tears		p-value
	No (n=6)	Yes (n=10)	
Perineal body			
Rest	17.8 ± 13.6	14.3 ± 7.3	0.6
Valsalva	23.0 ± 16.2	26.0 ± 19.3	0.8
EAS			
Mean			
Rest (kPa)	11.9 ± 5.6	14.6 ± 8.9	0.5
Valsalva (kPa)	19.5 ± 7.4	15.7 ± 8.0	0.3
At 12 o'clock			
Rest (kPa)	16.4 ± 12.5	20.4 ± 13.7	0.6
Valsalva (kPa)	25.6 ± 19.0	23.2 ± 12.6	0.8
At 3 o'clock			
Rest (kPa)	10.0 ± 3.9	12.6 ± 8.1	0.4
Valsalva (kPa)	12.9 ± 8.2	12.1 ± 8.3	0.9
At 9 o'clock			
Rest (kPa)	9.4 ± 5.8	10.7 ± 5.9	0.7
Valsalva (kPa)	19.9 ± 15.9	11.6 ± 5.8	0.3
IAS			
Mean			
Rest (kPa)	10.9 ± 4.8	13.4 ± 9.5	0.5
Valsalva (kPa)	14.9 ± 8.3	14.3 ± 8.2	0.9
At 12 o'clock			
Rest (kPa)	15.2 ± 10.9	19.6 ± 14.7	0.5
Valsalva (kPa)	19.3 ± 13.0	20.2 ± 13.1	0.9
At 3 o'clock			
Rest (kPa)	9.2 ± 6.1	10.6 ± 9.4	0.7
Valsalva (kPa)	14.0 ± 12.8	10.7 ± 7.5	0.6
At 9 o'clock			
Rest (kPa)	8.4 ± 5.6	10.2 ± 8.2	0.6
Valsalva (kPa)	11.6 ± 5.8	12.1 ± 8.3	0.9
Anal mucosa			
Mean			
Rest (kPa)	8.4 ± 3.7	11.5 ± 10.3	0.4
Valsalva (kPa)	13.0 ± 9.7	11.6 ± 7.4	0.8
At 12 o'clock			
Rest (kPa)	9.7 ± 5.9	13.2 ± 13.2	0.5
Valsalva (kPa)	15.7 ± 11.6	13.2 ± 11.6	0.7
At 3 o'clock			
Rest (kPa)	7.9 ± 5.0	11.1 ± 11.2	0.4
Valsalva (kPa)	14.2 ± 12.8	9.9 ± 7.4	0.5
At 9 o'clock			
Rest (kPa)	7.9 ± 4.6	10.2 ± 8.1	0.5
Valsalva (kPa)	9.1 ± 6.1	11.7 ± 8.3	0.5

Data are expressed as mean ± SD. EAS: external anal sphincter; IAS: internal anal sphincter.