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ARE MATERNAL PELVIC FLOOR AND BONY PELVIC DIMENSIONS MEASURED BY 3D/4D TRANSPERINEAL ULTRASOUND ASSOCIATED WITH FETAL BREECH PRESENTATION?

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ABSTRACT

OBJECTIVES

In a cohort of nulliparous women at term, the study aimed to: (1) assess the correlation between subpubic arch angle (SPA) and fetal breech presentation, (2) investigate the relationship between pelvic floor dimensions (at rest, during pelvic floor muscle contraction, and maternal pushing) and breech presentation, and (3) examine the prevalence between levator ani muscle co-activation and breech presentation.

MATERIALS AND METHODS

In this prospective observational study, 124 nulliparous women at term with a single fetus in either cephalic (n=93) or breech (n=31) presentation were recruited. A transabdominal scan was performed to confirm fetal presentation, followed by 3D/4D transperineal ultrasound (TPUS) to measure SPA, anteroposterior diameter (APD) and transverse diameter (TD) of the levator hiatus, and levator ani muscle hiatal area. TPUS measurements were taken at rest, during maximum pelvic floor muscle contraction, and during maximal maternal pushing. We compared maternal and neonatal characteristics and all TPUS measurements between the two groups. Additionally, we compared the prevalence of LAM co-activation between the two groups.

RESULTS

Women with a breech fetus had a lower BMI compared to those with a cephalic presentation (25.9±3.9 vs 27.8±5.0 kg/m², P=0.03). They also had a narrower SPA (100±9° vs 109±15°, P<0.001), smaller APD during pushing (52±11 mm vs 57±9 mm, P=0.03), and a smaller increase in APD during pushing, both in absolute terms (2.2±4.8 mm vs 5.4±5.9 mm, P<0.01) and proportionally (3.7±9.3% vs 8.7±9.8%, P=0.02). The prevalence of LAM co-activation was more than two-fold higher in women with a breech presentation (32.2% vs 13.9%, P=0.02).

CONCLUSION

Maternal pelvic characteristics, especially the subpubic arch angle and the ability to relax the pelvic floor during pushing, may significantly influence the incidence of breech presentation in nulliparous women at term.

INTRODUCTION

The fetal position relative to the birth canal is crucial for a successful delivery and should therefore be assessed early in labor. Key factors to consider include fetal lie, presentation, attitude, and position[1].

Fetal lie

Fetal lie refers to the relationship between the fetal long axis and the maternal long axis, and it can be classified as *longitudinal*, *transverse*, or *oblique*. The fetal lie is *longitudinal* when both axes are longitudinal and parallel to each other. It is the most frequent type, accounting for 99% of pregnancies after 28 weeks' gestation. The fetal lie is *transverse* when the fetal axis is perpendicular to maternal axis. The *oblique lie* is a transient lie, which occurs occasionally, and it is characterized by an angle of 45 degrees between maternal and fetal long axis (figure 1)[1].

Figure 1

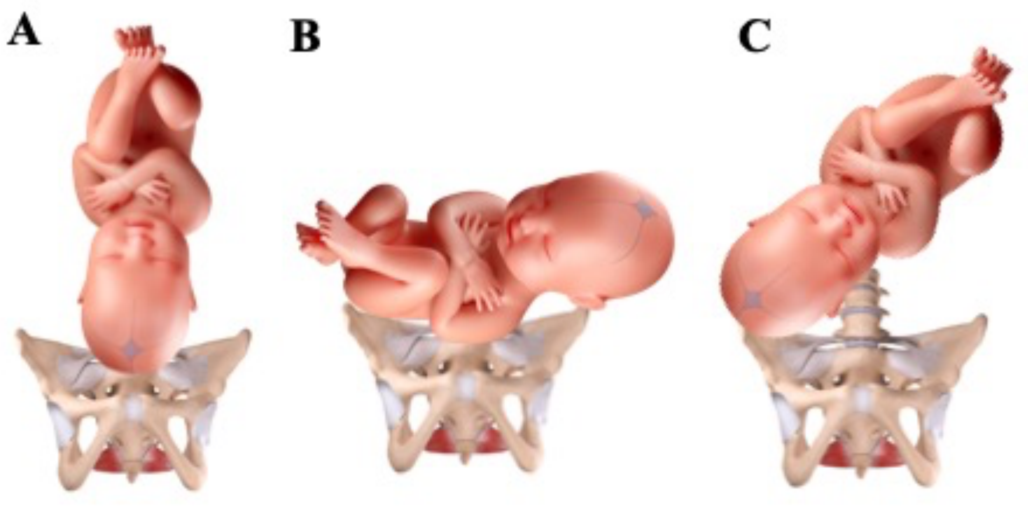

Figure 1 - Different types of fetal lie: **(A) longitudinal lie**, when the fetal and the maternal long axis are longitudinal and parallel to each other, **(B) transverse lie** when the fetal axis is perpendicular to maternal long axis, and **(C) oblique lie***,* when there is an angle of 45 degrees between maternal and fetal axis[1].

Fetal presentation

The fetal presentation describes the fetal part that is closest to the pelvic inlet or, in case of labor, is the lowest part in the birth canal. Fetal presentations are generally classified as follows (figure 2):

- *Cephalic,* when the fetal head is the lowest part of the fetus closest to the maternal pelvic inlet.
- *Breech*, when the fetal buttocks are the lowest part of the fetus closest to the maternal pelvic inlet.
- *Shoulder,* when the fetal shoulder is the lowest part of the fetus closest to the maternal pelvic inlet.
- *Compound*, when more than one fetal structure is positioned closest to the pelvic inlet[1].

Figure 2

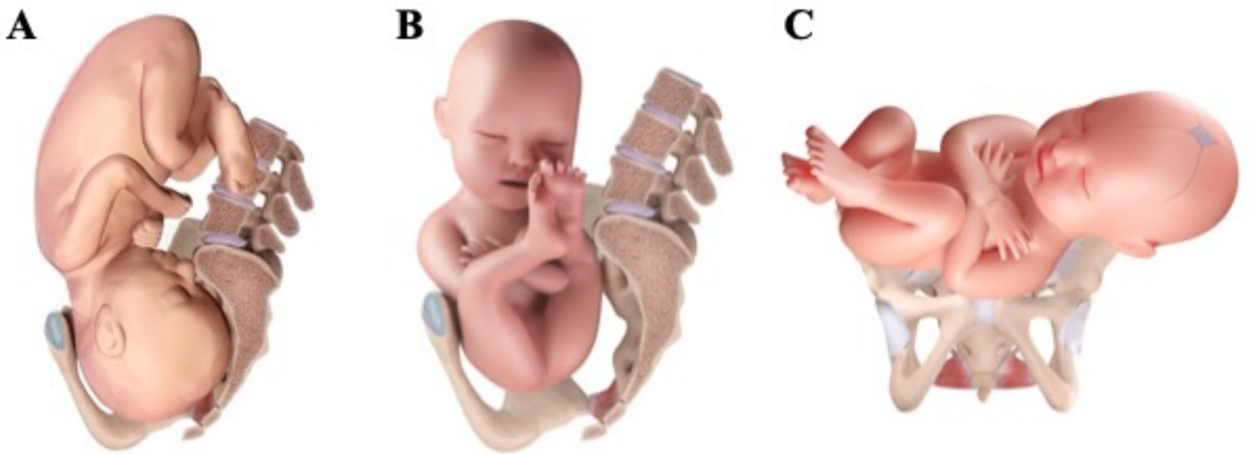

Figure 2 - Different types of fetal presentation: **(A) cephalic presentation***,* where the fetal head is the lowest part of the fetus closest to the maternal pelvic inlet **(B) breech presentation**, where the fetal buttocks are the lowest part of the fetus closest to the maternal pelvic inlet, and **(C) shoulder presentation***,* where the fetal shoulder is the lowest part of the fetus closest to the maternal pelvic inlet[1].

Fetal attitude

During last months of pregnancy, the fetus assumes a characteristic posture, known as fetal attitude. The fetus folds upon itself, forming an ovoid shape that roughly corresponds to the shape of the uterine cavity. In the case of a cephalic presentation, the back becomes significantly convex, and the head is sharply flexed, with the chin almost in contact with the chest. The thighs are flexed over the abdomen, and the legs are bent at the knees[2] (Figure 3). Abnormal deviations from this attitude occur when the fetal head becomes increasingly extended, leading to presentations such as the face presentation.

Figure 3

Figure 3 - In the physiological attitude, the fetus is folded upon itself and assumes the form of an ovoid that corresponds roughly to the shape of the uterine cavity: the back becomes markedly convex; the head is sharply flexed with the chin almost in contact with the chest. The thighs are flexed over the abdomen and the legs are bent at the knees.

Fetal position

Fetal position refers to the relationship of a part of the fetal presenting portion to the right or left side of the birth canal. In vertex and breech presentations, the fetal occiput and sacrum, respectively, serve as the reference points. To provide a more precise description of the fetal position, the orientation of the presenting part is considered in relation to the anterior, transverse, and posterior portions of the maternal pelvis. Since the presenting part may be positioned anteriorly, transversely, or posteriorly on either the right or left side, there are six possible variations for each of the three presentations[2].

Breech presentation

Near term, the fetus typically turns spontaneously to a cephalic presentation as the increasing bulk of the buttocks seek the more spacious fundus[3]. However, if the fetal buttocks or legs enter the pelvis before the head, the presentation becomes breech.

Breech presentation occurs in approximately 3-4% of singleton pregnancies at term, though it is more common in preterm pregnancies and in multiparous women[4]. In some cases, breech presentation results from factors that prevent the normal rotation of the fetus, such as a septum that protrudes into the uterine cavity[5] or placenta previa[3]. The principal factors associated with breech presentation, as reported in the literature, are the presence of uterine malformation or myomas, oligohydramnios, preterm delivery, some congenital malformations and a small-for-gestational-age fetus[6].

There are three types of breech presentation, based on the position of fetus's lower limbs (figure 4):

- *Frank variety*: the fetal buttocks are the lowest fetal part of the fetus, with the hips flexed and the knees extended. This is the most common type, accounting for about two-thirds of cases.

- *Complete variety*: both the buttocks and feet are positioned low in the birth canal, with the legs folded (hips flexed, knees flexed), but the feet are not below the buttocks. This type accounts for about one-third of cases.
- *Footling variety*: a rare condition in which the legs are positioned down in the birth canal, with one or both feet being the lowest part of the fetus closest to the pelvic inlet.

Figure 4

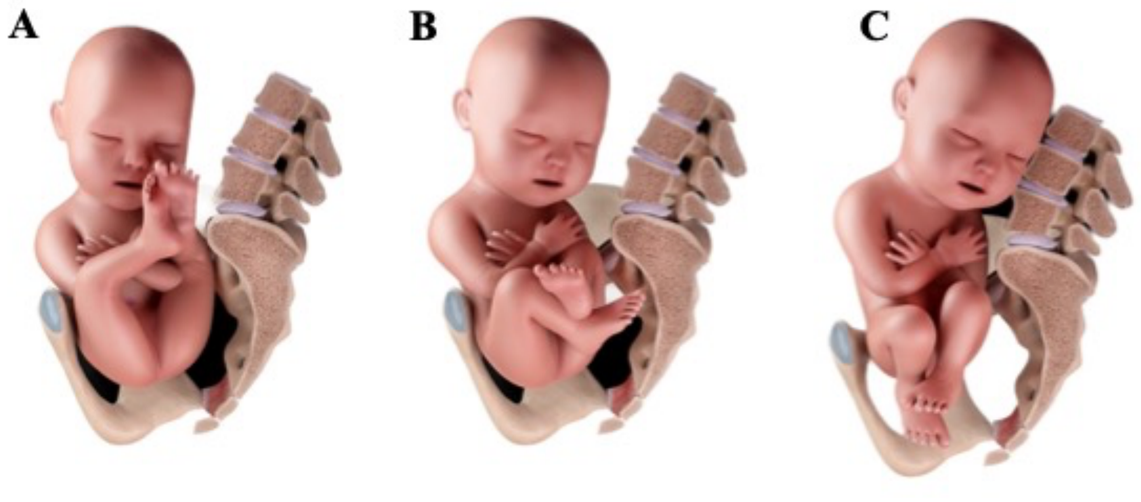

Figure 4 - Different types of breech presentation: **(A) frank breech presentation**, when the fetal buttocks are the closest fetal part to the pelvic inlet, with hips flexed and knees extended **(B) complete breech presentation**, when buttocks and feet are down in the fetal birth canal and legs are folded (hips flexed, knees flexed, but feet not below the fetal buttocks), and **(C) footling breech presentation**, when the legs are down in the birth canal and one foot or both feet are the closest part to pelvic inlet[1].

Breech presentation and mode of delivery

Perinatal morbidity and mortality after 37 weeks' gestation for fetuses in breech presentation appear higher than in those in cephalic presentation, for all modes of delivery combined. The risk of traumatic injuries during any type of breech delivery is estimated to be less than 1%. The most frequent are clavicle fracture, hematomas or contusions, brachial plexus injuries, and perineal hematomas. Breech presentation is also associated with a higher risk of hip dysplasia. Compared with cephalic presentation, breech presentation does not appear to be associated with a higher risk of cerebral palsy[6].

The *Term Breech Trial*, a randomized controlled trial published in 2000, demonstrated that planned cesarean section is superior to planned vaginal delivery for fetuses in breech presentation at term. The study involved a total of 2083 women from 121 centers across 26 countries. Of these, 1041 were randomized to planned cesarean section group and 1042 to the planned vaginal birth group. The data showed that the risk of perinatal/neonatal mortality or serious neonatal morbidity was significantly lower in the planned cesarean section group compared to the planned vaginal birth group (17 of 1039 [1.6%] *vs* 52 of 1039 [5.0%], RR 0.33 [95% CI 0.19-0.56]). However, no differences in maternal mortality and morbidity were observed between the two groups. The authors concluded that a policy of planned cesarean section is preferable for singleton fetuses in breech presentation at term, due to a reduction in perinatal/neonatal mortality or serious neonatal morbidity. They also noted that the benefit was more pronounced in countries with lower perinatal mortality rates [7]. A subsequent subgroup analysis found no difference in the prevalence of death or abnormal neurodevelopment at 2 years postpartum between vaginal and cesarean deliveries [8]. Furthermore, another study showed that maternal outcomes at 2 years postpartum were similar between planned cesarean section and planned vaginal birth for singleton breech fetuses at term[9].

Many other studies reported that planned vaginal delivery for breech presentation at term is safe when managed by skilled operators[10, 11]. An observational prospective study conducted in France and Belgium (*PREMODA* study), which included 8105 women with a breech-presenting fetus, found no significant difference in fetal and neonatal mortality or serious neonatal morbidity between the planned vaginal delivery and planned cesarean section groups (40 of 2502 [1.6%] *vs* 81 of 5573 [1.4%], OR 1.10 [95% CI 0.75-1.61]). Additionally, the study demonstrated that the rate of adverse perinatal and neonatal outcomes in this population was lower compared to the rates reported in the *Term Breech Trial*. The authors emphasized the importance of performing elective vaginal deliveries only in institutions where such deliveries are routinely performed, and where strict criteria are met before and during labor[10].

Despite ongoing debates, the number of cesarean deliveries for breech presentation has increased worldwide, while the expertise of obstetricians in breech vaginal deliveries has declined[12-14]. Cesarean section is a major surgical procedure, which inevitably carries risks, including anesthetic complications, hemorrhage, and infection; the risks are higher in emergency than in elective ones. Several studies have suggested that cesarean deliveries are associated with higher rates of maternal morbidity and mortality compared to vaginal deliveries[15, 16]. However, the *Term Breech Trial* did not find significant differences in maternal complications based on the planned mode of delivery, likely due to its limited power to evaluate maternal outcomes[7].

Selection criteria and contraindications for trial of labor in breech presentation

The question of whether elective cesarean section is preferable to planned vaginal delivery for breech presentation at term remains a challenging issue in obstetrics, particularly in countries where operators have extensive experience with breech deliveries. As a result, obstetricians are exploring ways to reduce cesarean section rates without compromising fetal safety, using various selection criteria for planned vaginal delivery.

Eight guidelines on breech management have been published. Notably, both the Dutch Society of Obstetricians and Gynecologists and the American College of Obstetricians and Gynecologists did not identify any specific contraindications for vaginal delivery. However, six other national guidelines have listed 11 contraindications. Among these, footling breech presentation is the only contraindication consistently mentioned in all six guidelines (table 1). A recent review in the literature found sufficient evidence to support only two contraindications for vaginal delivery: footling breech presentation and fetal growth restriction[17].

Table 1

	Guidelines*					
Contraindications	**RCOG**	**SOGC**	**RANZCOG**	**IOGRCPI**	**DSOG**	**CNGOF**
Footling breech presentation	+	+	+	+	+	+
Hyperextended fetal head	+	+	+	-	+	+
Fetal growth restriction	+	+	+	+	+	-
Estimated fetal weight >3.8 Kg	+	-	+	+	-	+
Cord presentation	-	+	+	-	+	-
Fetal anomaly likely to interfere with vaginal delivery	+	+	+	-	-	-
Antenatal fetal compromised	+	-	+	+	-	-
Estimated fetal weight > 4.0 Kg	-	+	-	-	+	-
Clinically inadequate maternal pelvis	-	+	-	-	-	+
Limited access to experienced personnel	+	-	-	+	-	-
Existing indication for cesarean section	+	-	-	+	-	-

Table 1 - Overview of contraindications for breech delivery in international guidelines with mentioned contraindications[17]

***RCOG** Royal College Obstetricians and Gynecologists, **SOGC** Society of Obstetricians and Gynecologists of Canada, **RANZCOG** Royal Australian New Zealand College Obstetricians and Gynecologists, **IOGRCPI** Institute of Obstetricians and Gynecologists Royal College of Physicians of Ireland, **DSOG** Danish Society of Obstetricians and Gynecologists, **CNGOF** French Society of Obstetricians and Gynecologists

The French College of Gynecologists and Obstetricians (CNGOF) defined the optimal criteria for deciding whether to attempt breech vaginal delivery. The recommended criteria include:

1) Normal pelvimetry.
2) Absence of hyperextension of fetal head (as confirmed by ultrasonography).
3) Absence of footling breech presentation.
4) Estimated fetal weight < 3800 g. While the available data are insufficient to establish whether routine estimation of fetal weight should be a criterion, the consensus is to avoid planned vaginal delivery when the estimated fetal weight is ≥ 3800 g.
5) Continuous electronic fetal heart rate monitoring for fetal surveillance during labor.
6) Patient's informed consent[18].

Other aspects considered in French Guidelines are:

- Complete breech presentation does not carry a higher risk of perinatal morbidity compared to frank breech presentation during trials of labor. However, it is associated with an increased risk of cesarean delivery during labor. Therefore, a complete breech presentation is not an absolute contraindication for planned vaginal delivery.
- Breech presentation in a small-for-gestational-age fetus is not an absolute contraindication for vaginal delivery.
- Nulliparity is not associated with a higher risk of perinatal morbidity in trials of labor, although it is associated with an increased risk of cesarean delivery during labor. As such, nulliparity is not an absolute contraindication for planned vaginal delivery.
- Rupture of the membranes at term before the onset of labor is not an absolute contraindication for a trial of labor[18].

The role of pelvimetry in patient selection

Vaginal delivery is considered widely influenced by the interaction of the bony pelvis and fetal dimensions. In the past, the shape of the bony pelvis was considered one of the main determinants of successful vaginal delivery[19], although modern obstetrics largely dismisses this correlation[19, 20].

Pelvimetry refers to the clinical or radiological assessment of the maternal pelvis and provides indirect measurement of various important obstetrical parameters. The concept of clinical pelvimetry dates back to 1675, when the relationship between pelvic dimensions and successful vaginal delivery was first described[21]. This method was later refined with the use of X-ray and, more recently, computed tomography (CT) and Magnetic Resonance Imaging (MRI). Due to the carcinogenic risks associated with in utero exposure to ionizing radiation, MRI has become the preferred modality for pelvimetry over X-rays[18].

Existing evidence suggests that pelvimetry does not offer significant prognostic value of cephalic presentation and cephalopelvic disproportion[20]. However, in breech presentation, pelvimetry may help to select the most appropriate mode of delivery[22]. Although there is no consensus on the exact measurements, modern obstetrics textbooks are largely based on historic pelvic measurements taken from Caucasian women, and only a few studies provide reference values to define the "normal" range for pelvimetry [23]. Despite these limitations, guidelines and expert opinions recommend adequate maternal pelvic dimensions as a criterion for selecting candidates for vaginal breech delivery. A randomized controlled trial demonstrated that MRI pelvimetry in breech presentation at term did not significantly reduce the overall cesarean section rate but improved the selection of delivery methods, with a notably lower rate of emergency cesarean sections[22]. The French clinical practice guideline on breech presentation states that "Women who want a trial of labor at term should be offered specific pelvic measurements to enable a joint decision about mode of delivery, because these measurements, although they do not modify the global cesarean rate, do make it possible to reduce the risk of cesarean delivery during labor…”.[18] The PREMODA study and the French Society of Obstetricians and Gynecologists (CNGOF) reported the following cutoff points for pelvic dimensions: an Obstetric Transverse Diameter (OTD) ≥ 12 cm, an Obstetric Conjugate Diameter (OCD) ≥ 10.5 cm, a Bispinous or Interspinous Diameter (BSD) ≥ 10 cm (figure 5).

Figure 5

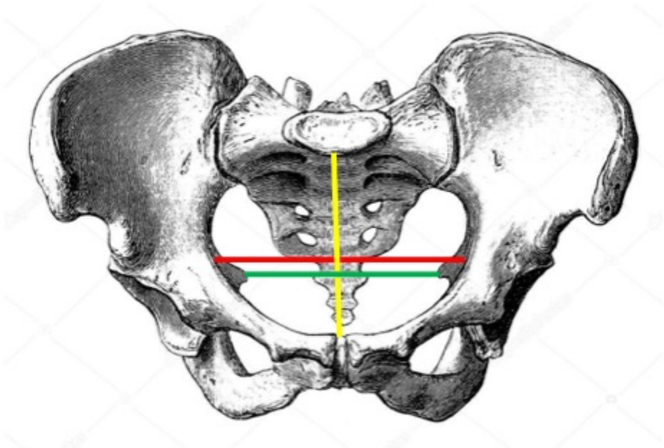

Figure 5 - Illustration of female pelvis. Red line represents the **obstetric transverse diameter (OTD)**, between the ileopectinal lines. Yellow line represents the **obstetric conjugate diameter (OCD)**, between the sacral promontory and the symphysis, and the green line represents the **Bispinous or Interspinous Diameter (BSD)**, between the ischial spines.

External cephalic version

If there is still space for debate on what is the best way to deliver a fetus in breech presentation at term, all the major international guidelines recommend offering external cephalic version (ECV) to women with a fetus in breech presentation at 37 weeks' gestation with the aim of reducing the rates of non-cephalic presentations and thus of Cesarean deliveries[24-26]. ECV is the manipulation of the fetus, through the maternal abdomen, to achieve a cephalic presentation. The success rate is approximately 50%[27]. Spontaneous version is rare at term (approximately 8% of primigravid women after 36 weeks' gestation). Spontaneous reversion to breech after a successful ECV is unusual, occurring in only 3% of cases. Furthermore, spontaneous conversion to a cephalic presentation after an unsuccessful ECV is seen in 3-7% of cases[28-30].

Several studies have attempted to define prediction models for successful ECV, but their clinical impact remains limited and challenging[31, 32]. In a meta-analysis, Kok et al. identified several factors associated with a higher likelihood of successful ECV. These include: multiparity (OR 2.5, 95% CI 2.3–2.8), nonengagement of the breech (OR 9.4, 95% CI 6.3–14), use of tocolysis (OR 18, 95% CI 12–29), a palpable fetal head (OR 6.3, 95% CI 4.3–9.2), and a maternal weight of less than 65 kg (OR 1.8, 95% CI 1.2–2.6)[33]. Additionally, sonographic factors, such as posterior placental location (OR 1.9, 95% CI 1.5–2.4), complete breech position (OR 2.3, 95% CI 1.9–2.8) and an amniotic fluid index greater than 10 (OR 1.8, 95% CI 1.5–2.1), have also been associated with higher success rate[34]. Limited data are available to suggest if estimated fetal weight affects success rates.

The role of ultrasound in the evaluation of maternal bony pelvis

Pelvimetry evaluated with CT and MRI allow clinicians to measure the bony pelvis both in sagittal and in transverse planes[35, 36]. However, their availability and costs limit their application in routine clinical practice.

On the other hand, ultrasound has potential advantages over MRI as it is highly and readily available in the obstetric settings, and it may represent a low-cost tool for the evaluation of maternal bony pelvis. Transperineal ultrasound (TPUS) is widely used for the evaluation of pelvic floor, and many studies demonstrated the usefulness of some sonographic parameters in the management of labor and delivery and in the evaluation of pelvic floor both in static and dynamic conditions (figure 6).

Figure 6

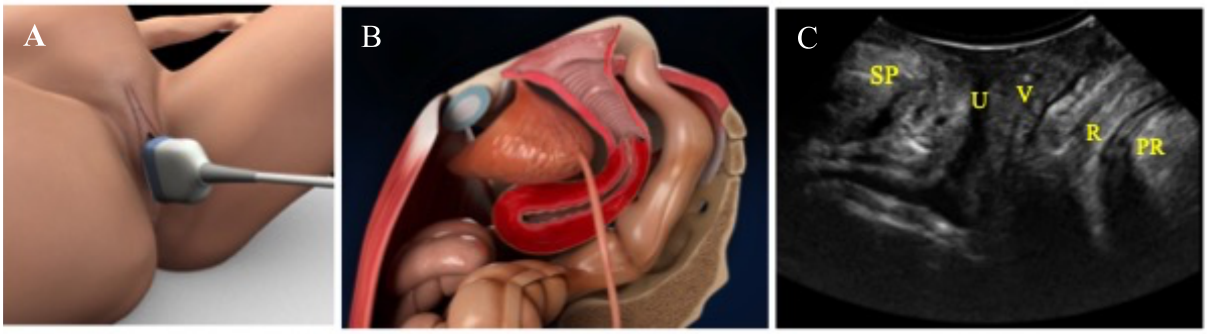

Figure 6 – **(A)** The image illustrates how to place the ultrasound transducer transperineally to visualize the mid-sagittal plane; **(B)** Graphic representation of pelvic floor muscles and pelvic organs; **(C)** Transperineal ultrasound in the mid-sagittal plane with the visualization of the symphysis pubis (SP), urethra (U), vagina (V), rectum (R), and puborectalis muscle (PR).

TPUS with 3D imaging techniques allows also the evaluation of a bony parameter, known as the subpubic arch angle (SPA)[37-39] (figure 7). The SPA is formed by the two inferior rami of the pubis and, as part of the pelvic outlet, provides indirect information about the shape of the maternal pelvis, potentially offering insight into relevant obstetric dimensions[19]. The correlation between SPA and mode of delivery for fetuses in cephalic presentation is not fully established. Some authors reported a correlation with duration of second stage but not with mode of delivery[40], others reported that SPA seems to predict the likelihood of an obstetric intervention[41]. Despite all studies with fetuses in cephalic presentations, as far as we know the correlation between fetal breech presentation and maternal pelvis has never been studied.

Figure 7

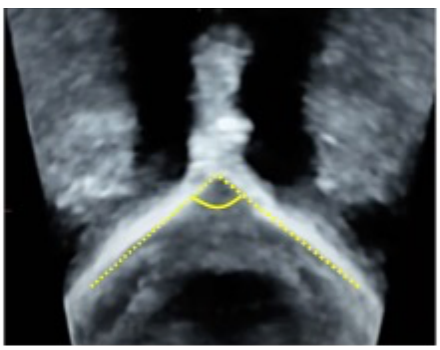

Figure 7 – 3D transperineal ultrasound with measurement of SPA, the angle formed by the two inferior rami of the pubis.

The role of ultrasound in the evaluation of pelvic floor

Pelvic floor is a musculotendinous sheet, formed predominantly by the levator ani muscle (LAM) (figure 8). The LAM has a complex function, which includes maintaining a resting tone, the ability to contract, and the ability to relax[42]. One of the main purposes of relaxation is childbirth.

Figure 8

Figure 8 - Illustration of levator ani muscle (LAM), a broad muscular sheet of variable thickness attached to the internal surface of the true pelvis. LAM is subdivided into parts accordingly to their attachments and viscera to which they are related, namely ileoccygeus, pubococcygeus, and ischiococcygeus.

The assessment of the pelvic floor anatomy and function is complex. Clinical assessment of the pelvic floor muscles is subjective with limited reproducibility. TPUS offers a reliable and reproducible tool for the evaluation of pelvic floor muscle integrity and function, in both static and dynamic conditions[43, 44]. 3D/4D TPU can reliably detect levator ani muscle avulsion and allows to evaluate LAM dimensions and function both statically and dinamically[45, 46] One of the main advantages of ultrasound is the ability to detect, even by 2D technique, both efficient contraction, and relaxation of the pelvic floor muscles[47-49]. In normal condition, pelvic floor dimensions, especially the anteroposterior diameter of the levator hiatus (APD), should be reduced at maximum pelvic floor contraction (PFMC) and increased with appropriate pushing[50] (figure 9). However, some women contract rather than relax their pelvic floor during pushing, a phenomenon known as LAM co-activation. This is clearly visible through a reduction in APD during pushing[51-53] (figure 10).

Figure 9

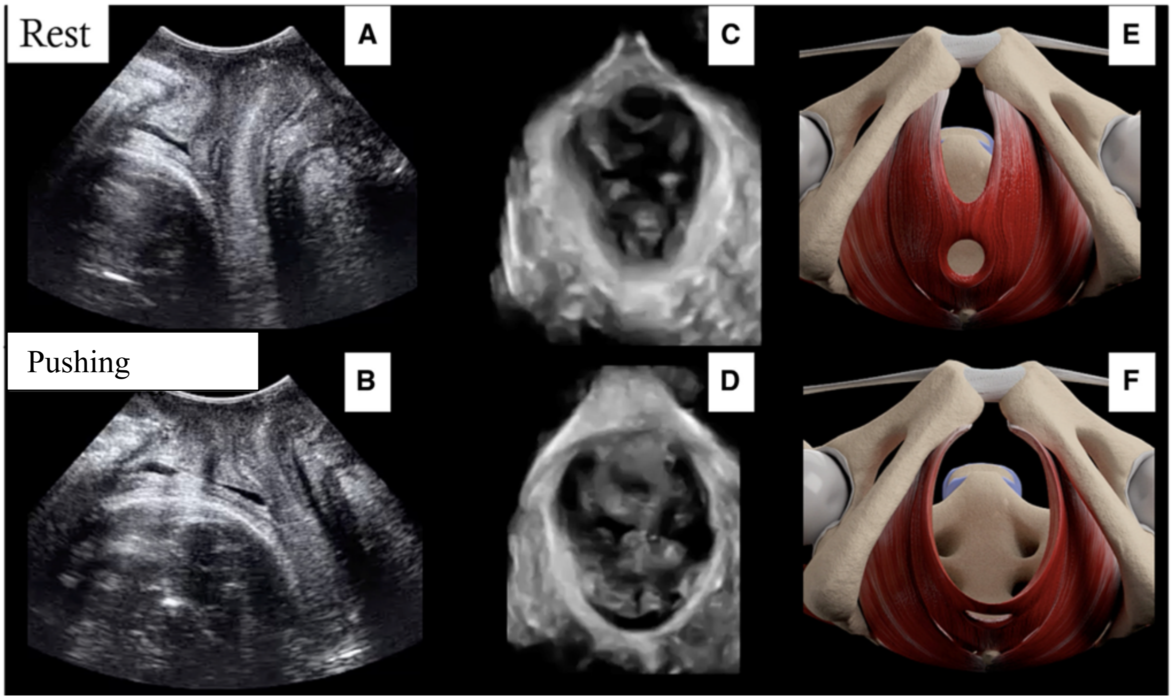

Figure 9 – An appropriate pushing maneuver is associated with the relaxation of the pelvic floor. This relaxation can be demonstrated through an increase in the anteroposterior diameter of the levator hiatus on 2D ultrasound images, from **A (rest)** to **B (pushing)**. Additionally, on 3D ultrasound using Omniview-VCI (GE Healthcare, Zipf, Austria) reconstruction, the hiatal area increases from **C (rest)** to **D (pushing)**. A graphic illustration further supports this observation, showing the changes in the pelvic floor dynamics from **E** to **F** during the pushing phase[53].

Figure 10

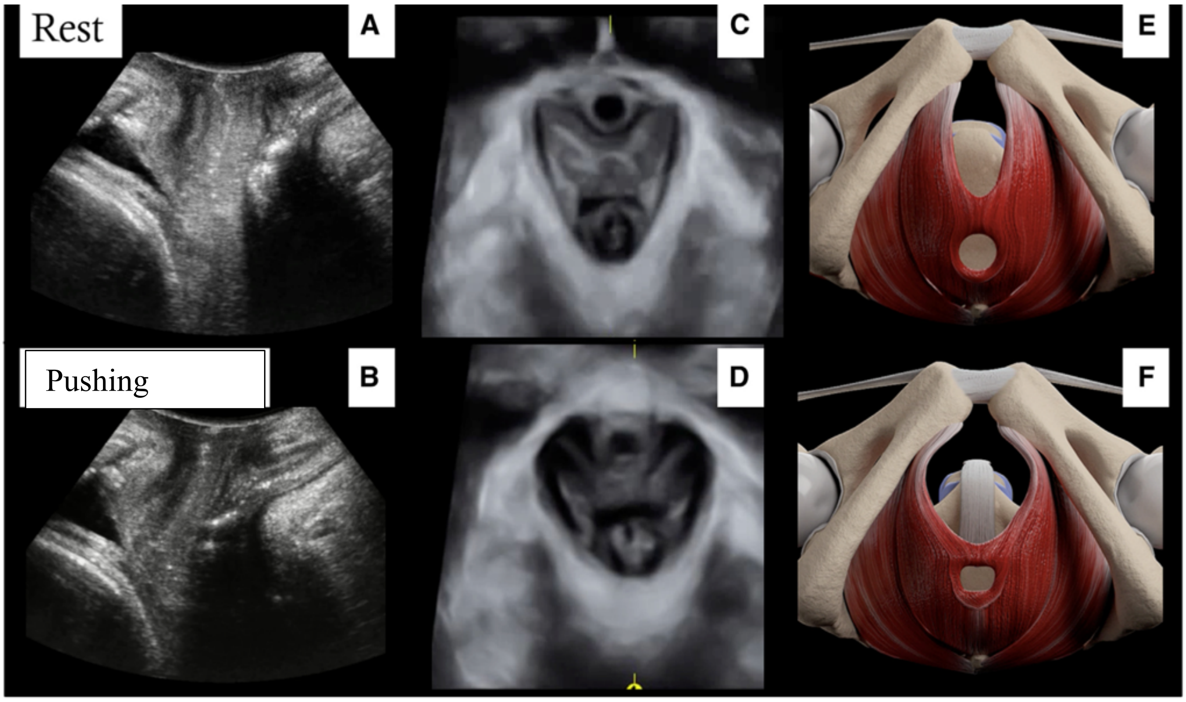

Figure 10 – Maternal pushing associated with levator ani muscle (LAM) coactivation can be demonstrated by a reduction in the anteroposterior diameter of the levator hiatus on both 2- and 3-D ultrasound images. Using Omniview-VCI (GE Healthcare, Zipf, Austria) reconstruction, the change in the pelvic floor can be observed from **A** and **C (rest)** to **B** and **D (pushing)**, with further clarification provided by a graphic illustration showing the shift from **E** to **F** during the pushing phase[53].

The effect of pelvic floor on labor outcomes for term fetuses in cephalic presentation has been extensively studied in recent years. It was demonstrated that when LAM co-activation is detected before the onset of labor, it is associated with an increased duration of the second stage of labor in nulliparous women at term[52, 53]. Several observational studies have found a correlation between larger levator hiatal dimensions and a higher likelihood of spontaneous vaginal delivery. However, other authors did not demonstrate a correlation between APD and mode of delivery. Although the association between hiatal dimensions and delivery mode is inconsistent in the published literature, the association between pelvic floor dimensions measured before the onset of labor and the duration of the second stage of labor has been found in almost all studies published[48, 52, 54]. Interestingly, Youssef et al. recently demonstrated that smaller pelvic floor dimensions and LAM co-activation at term before the onset of labor were associated with higher fetal head station, as shown by a narrower angle of progression, one of the most studied sonographic parameters for the evaluation of fetal head descent[55].

While the role of the pelvic floor in fetal presentation has never been evaluated, a randomized controlled trial assessing pelvic floor muscle training during pregnancy showed that breech presentation was less frequent in women who participated in the training, compared to those receiving standard care. In this study, all participants were individually instructed on pelvic floor anatomy and correct muscle contraction techniques. The training group participated in a specially designed exercise course, which included pelvic floor contractions and general exercises with a physiotherapist for one hour per week, spanning 12 weeks (from 20 to 36 weeks of pregnancy)[56, 57].

The correlation between maternal pelvis and pelvic floor with labor outcomes in women with a fetus in cephalic presentation at term has been extensively investigated. However, as breech presentation affects up to 4% of women at term, the correlation between maternal bony pelvis and pelvic floor with breech presentation remains underexplored.

Ultrasound offers a low-cost, reproducible and objective method for studying the anatomy and functionality of the maternal pelvic floor and bony pelvis, both in static and in dynamic conditions.

To date, however, the correlation between the maternal bony pelvis, pelvic floor (assessed with ultrasonography), and fetal breech presentation has never been investigated.

OBJECTIVES

The objectives of this study were threefold. In a cohort of nulliparous women at term gestation, the study aimed to:

1. Assess the correlation between subpubic arch angle (SPA) and fetal breech presentation.
2. Investigate the relationship between pelvic floor dimensions - both at rest, during pelvic floor muscle contraction (PFMC), and under maternal pushing - and fetal breech presentation.
3. Examine the correlation between levator ani muscle co-activation and fetal breech presentation

MATERIALS AND METHODS

This prospective observational study was conducted at the obstetrics and maternal-fetal medicine unit of Sant'Orsola University Hospital in Bologna, Italy, between June and December 2023. A non-consecutive series of women with singleton pregnancies and fetuses in cephalic or breech presentation at term (37-40 weeks) were recruited from the outpatient clinic or during hospitalization prior to labor. Exclusion criteria included transverse or oblique lie, previous uterine surgery, suspected fetal asphyxia, major fetal malformations, and prelabor rupture of membranes. Recruitment occurred only when an investigator experienced in 3D/4D transperineal ultrasound was available. All scans were performed using a Voluson Swift ultrasound machine (GE Medical Systems, Zipf, Austria) with a convex volumetric 4-8 MHz transducer covered by a sterile glove.

Transabdominal ultrasound for fetal presentation

A transabdominal ultrasound was performed on each participant to determine fetal lie and presentation[58]. Cephalic and breech presentations were diagnosed based on the position of the lowermost fetal part (head or breech, respectively). Breech presentations were classified as complete (buttocks and feet facing downward with folded legs), frank (buttocks facing downward), or footling (feet as the lowest structure in the birth canal)[59].

Three/Four Dimension (3D/4D) Transperineal ultrasound scans

For each participant, a static 3D volume was acquired at rest, followed by two dynamic 4D volumes: one during maximum pelvic floor muscle contraction (PFMC) and another during maximal maternal pushing. Participants were positioned in lithotomy position with an empty bladder and instructed to push freely, without restrictions on glottal closure. Prior to the acquisitions, women were provided with instructions on how to contract and push effectively, using visual feedback when necessary to ensure proper technique. The transducer was positioned translabially in the mid-sagittal plane (Figure 6). Volumes were acquired with a sweep angle of 80°, ensuring that the entire levator hiatus was visualized, including the symphysis pubis, urethra, vagina, anorectum, and puborectalis muscle[60]. Special attention was given to ensure the entire pubic symphysis was included in the volume for subsequent analysis of the subpubic arch angle (SPA). A linear reconstruction technique (OmniView; GE Medical Systems, Zipf, Austria), combined with a contrast-enhancing tool (Volume Contrast Imaging [VCI]; GE Medical Systems, Zipf, Austria), was used for all acquisitions. Using the OmniView-VCI technique, the minimal hiatal dimensions were identified by placing a line along the mid-sagittal plane, from the posteroinferior border of the pubic symphysis to the anterior margin of the puborectalis muscle at the anorectal angle. The OmniView line was set at a thickness of 1–2 cm, and the pelvic hiatus was automatically displayed on the right side of the screen. The three volumes (static 3D at rest, dynamic 4D during PFMC, and dynamic 4D during pushing) were saved for offline analysis (Figure 11).

Figure 11

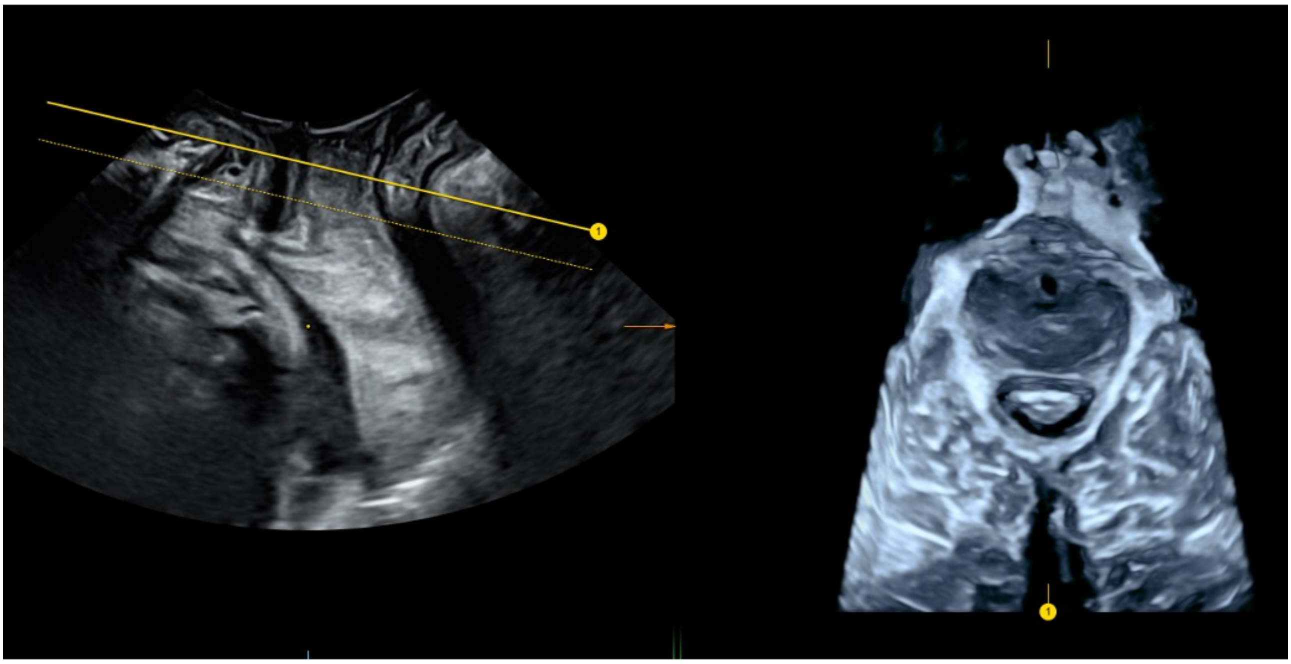

Figure 11 - Linear reconstruction technique (OmniView; GE Medical System, Zipf, Austria) combined with contrast-enhancing tool (Volume Contrast Imaging; VCI, GE Medical System, Zipf, Austria) was used for the acquisitions. The plane of minimal hiatal dimensions was obtained by placing a line on the mid-sagittal plane running from the posterior margin of the symphysis pubis to the anterior margin of the puborectalis muscle at the anorectal angle. The OmniView line was set at a thickness of 1–2 cm and the pelvic hiatus was displayed automatically on the right side of the screen.

Volume analysis

All ultrasound volumes were saved on the ultrasound machine and, upon completion of participant recruitment, anonymized and transferred to a PC with dedicated software (4DView 9.0; GE Medical Systems) for offline analysis. The following measures were obtained:

- *Subpubic arch angle (SPA):*

  The OmniView-VCI line was placed centrally along the pubic symphysis, with a thickness of 3 mm. The plane of the pubic rami was automatically displayed (Figure 12). The angle formed by the two pubic rami was measured using either the 3-point or the 2-line function (Figure 7).

Figure 12

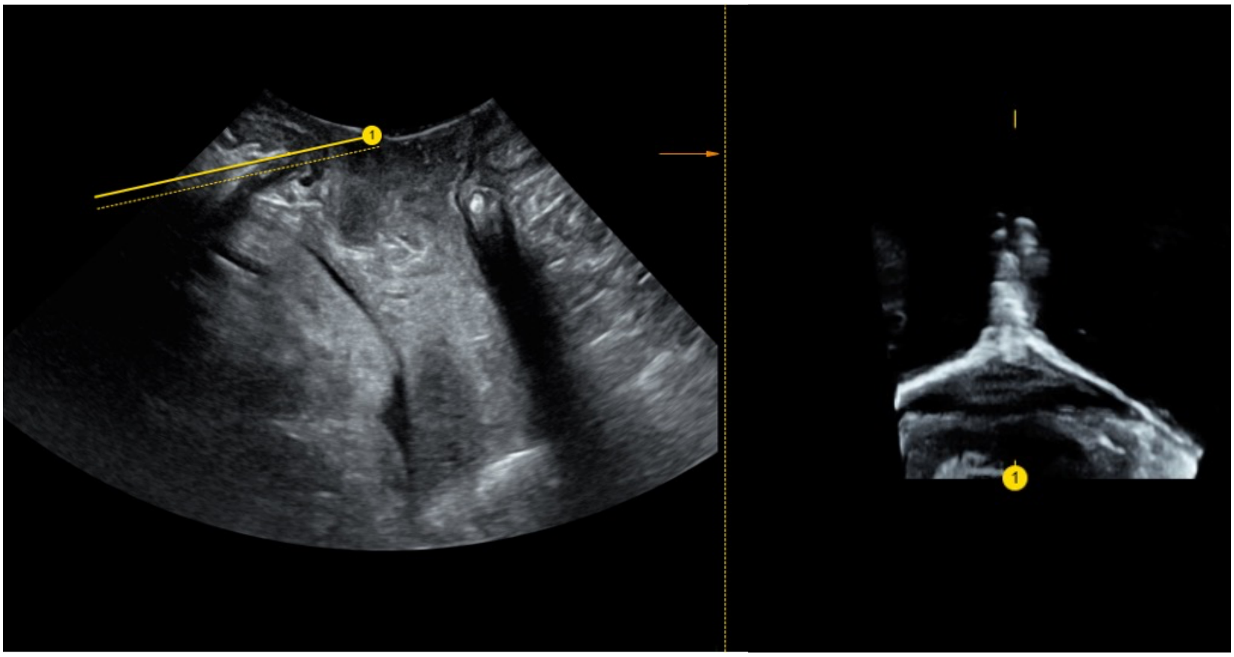

Figure 12 - OmniView-Volume Contrast Imaging (Omniview-VCI, GE Medical System, Zipf, Austria) technique for subpubic arch measurement. The line of the OmniView-VCI is depicted centrally along the pubic symphysis including a thickness of 3 mm. The plane of the pubic rami is then automatically displayed. The angle formed by the 2 pubic rami is then measured by the 3-point or the 2-line functions[39].

- *Anteroposterior diameter (APD) of the levator hiatus* (figure 13):

  APD was measured on the mid-sagittal plane (acquisition plane) as the distance between the posteroinferior border of the pubic symphysis and the anterior border of the puborectalis muscle.

- *Transverse diameter (TD) of the levator hiatus* (figure 13):

  TD was measured on the axial plane as the widest diameter of the levator hiatus from right to left.

- *Levator ani muscle hiatal area* (figure 13):

  Levator hiatal area was measured on the axial plane as the area bordered by the medial part of the levator ani muscle, symphysis pubis, and inferior pubic ramus.

SPA was measured only at rest, instead APD, TD and levator hiatal area were measured at rest, at maximum PFMC and pushing.

Figure 13

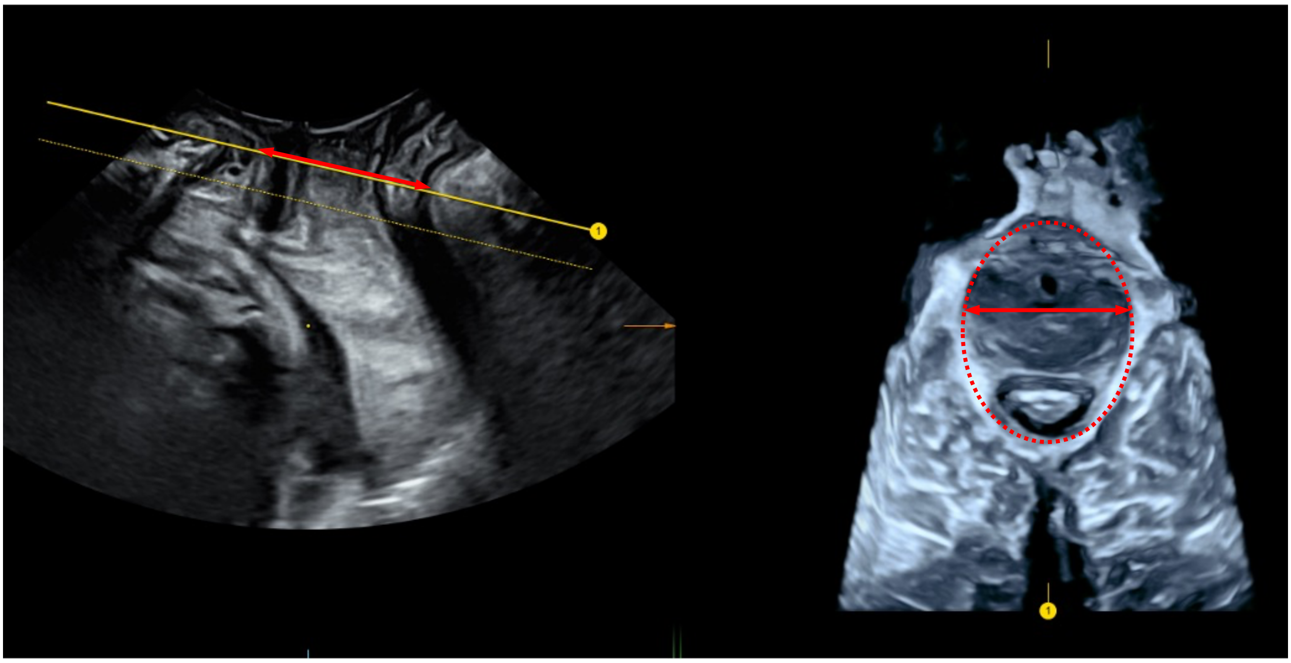

Figure 13 - OmniView-Volume Contrast Imaging (Omniview-VCI) technique. The plane of minimal hiatal dimensions was obtained, and the pelvic hiatus was displayed automatically on the right side of the screen. **Anteroposterior diameter (APD)** of the levator hiatus was measured on the mid-sagittal plane (acquisition plane) as the distance between the inferior border of the pubic symphysis and the anterior border of the puborectalis muscle (red line with arrows on the left image). **Transverse diameter (TD) of the levator hiatus** was measured on the axial plane as the widest diameter of the levator hiatus from right to left (red line with arrows on the right image). **Levator hiatal area** was measured on the axial plane as the area bordered by the medial part of the levator ani muscle, symphysis pubis, and inferior pubic ramus (dotted line on the right image).

For APD, absolute and proportional changes from rest to pushing were calculated using the following formulas:

$$\Delta APD = APD_{Pushing} - APD_{Rest}$$

$$\text{Proportional } \Delta APD = [(APD_{Pushing} - APD_{Rest})/APD_{Pushing}]\text{x}100$$

Levator ani muscle co-activation was considered present when APD during pushing was smaller than APD during rest.

Collection of maternal and neonatal data

Investigators retrieved the following maternal and neonatal data from the medical records: maternal age, ethnicity, height, weight, Body Mass Index (BMI), gestational age at recruitment, neonatal sex, and birthweight. Maternal and neonatal characteristics and all transperineal ultrasound (TPUS) measurements were compared between women with fetuses in cephalic presentation and those with fetuses in breech presentation. Additionally, the prevalence of the co-activation phenomenon was compared between the two groups.

Statistics

Means, standard deviations (SD), number of cases and frequencies were used as descriptive statistics. Differences between women with a fetus in cephalic *versus* breech presentation were assessed by unpaired two-tailed Student's t-test for continuous variables and Fisher Exact Test for categorical variables. Data were analyzed using 25.0 SPSS version (SPSS Inc., Chicago, IL, USA) and STATA 17 (StataCorp., College Station, TX, USA), and the significance level was set at 5%. This was a pilot study, so no sample size calculation was needed. As cephalic presentation is more frequent at term compared to breech presentation, we planned to enroll a higher number of women with a fetus in cephalic presentation with a ratio of 1:3 between breech and cephalic presentations.

Ethics

The local research ethics committees of our hospital approved the study protocol prior to the start of the study (reference number 788/2020/OSS/AOUBo). All study participants provided written informed consent prior to enrollment.

RESULTS

A total of 124 women were recruited for the study, including 93 with fetuses in cephalic presentation and 31 with fetuses in breech presentation. Table 2 presents the maternal and neonatal characteristics of the study population, both overall and by fetal presentation (cephalic vs. breech), as well as the measurements obtained at rest, during pelvic floor muscle contraction (PFMC), and during pushing.

The mean maternal age was 33.3 ± 4.6 years, the mean BMI was 27.4 ± 4.8 kg/m², and the mean gestational age at recruitment was 38.1 ± 1.0 weeks. The phenomenon of levator ani muscle (LAM) co-activation was observed in 23 women (18.4%), and the mean birthweight was 3220 ± 400 grams.

Among the women with breech presentation, BMI was significantly lower compared to those with cephalic presentation (25.9 ± 3.9 vs. 27.8 ± 5.0 kg/m², P = 0.03). No other significant differences in maternal or neonatal characteristics were observed between the two groups (Table 2).

Our findings indicate that a narrower subpubic arch angle (SPA) is associated with an increased risk of breech presentation in nulliparous women at term. Specifically, women with a breech-presenting fetus had a significantly narrower SPA compared to those with a cephalic-presenting fetus (100 ± 9° vs. 109 ± 15°, P < 0.001).

Regarding pelvic floor dimensions, women with a breech-presenting fetus had a smaller anteroposterior diameter (APD) during pushing compared to those with a cephalic-presenting fetus (52 ± 11 mm vs. 57 ± 9 mm, P = 0.03). Additionally, the increase in APD from rest to pushing was smaller in the breech group, both in absolute terms (2.2 ± 4.8 mm vs. 5.4 ± 5.9 mm, P < 0.01) and as a proportional change (3.7 ± 9.3% vs. 8.7 ± 9.8%, P = 0.02). No other significant differences in pelvic floor dimensions at rest, during PFMC, or during pushing were observed between the two groups.

The prevalence of LAM co-activation in the overall population was 18.5% (23/124). Notably, the prevalence of co-activation was more than two-fold higher in women with breech presentation compared to those with cephalic presentation (32.2% [10/31] vs. 13.9% [13/93], P= 0.02).

Table 2

	Total n=124	**Cephalic presentation, n=93**	**Breech presentation, n=31**	**P-value**
Maternal age (years)	33.3 ± 4.6	32.9 ± 4.5	34.6 ± 4.9	0.09
Ethnicity				
Caucasian	121 (97.6%)	91 (97.8%)	30 (96.8%)	0.16
African	2 (1.6%)	2 (2.2%)	0	
Asian	1 (0.8%)	0	1 (3.2%)	
Height (m)	1.66 ± 0.06	1.66 ± 0.06	1.66 ± 0.06	0.64
Weight (Kg)	75.1 ± 14.4	76 ± 14	72 ± 12	0.08
Body mass index, BMI (Kg/m^2)	27.4 ± 4.8	27.8 ± 5.0	25.9 ± 3.9	0.03
Gestational age (weeks)	38.1 ± 1.0	38.0 ± 1.0	38.4 ± 0.7	0.01
Rest				
SPA (°)	107 ± 14	109 ± 15	100 ± 9	<0.01
APD (mm)	51 ± 8	52 ± 7	50 ± 11	0.40
TD (mm)	39 ± 8	39 ± 9	38 ± 4.9	0.26
Levator hiatus area (cm^2)	15.8 ± 3.7	16.0 ± 3.5	15.3 ± 2.7	0.26
Pelvic floor muscle contraction (PFMC)				
APD (mm)	43 ± 8	43 ± 8	43 ± 9	0.71
TD (mm)	35 ± 5	36 ± 5	35 ± 5	0.83
Levator hiatus area (cm^2)	13.2 ± 4.8	13.3 ± 3.5	13.1 ± 6.4	0.89
Maternal pushing				
APD (mm)	56 ± 10	57 ± 9	52 ± 11	0.03
TD (mm)	39 ± 5	40 ± 5	39 ± 5	0.48
Levator hiatus area (cm^2)	18.1 ± 5.3	18.4 ± 4.6	17.6 ± 6.4	0.51
ΔAPD (mm)	4.5 ± 5.8	5.4 ± 5.9	2.2 ± 4.8	<0.01
Proportional ΔAPD (%)	7.4 ± 9.9	8.7 ± 9.8	3.7 ± 9.3	0.02

Levator ani muscle co-activation	23 (18.5%)	13 (13.9%)	10 (32.2%)	0.02
Neonatal sex				
Male	59 (47.6%)	47 (50.5%)	12 (38.8%)	0.25
Female	65 (52.4%)	46 (49.5%)	19 (61.2%)	
Neonatal birthweight (gr)	3223 ± 411	3253 ± 414	3137 ± 399	0.179

Table 2 - Population characteristics of all the124 women included in the study and according to the fetal presentation. Data are presented as mean ± standard deviation, or as n (%). APD, anteroposterior of levator ani muscle. SPA, subpubic arch angle
TD, transverse diameter of levator hiatus

DISCUSSION

In this study, we found that both maternal bony pelvic characteristics and pelvic floor relaxation contribute to the incidence of breech presentation in nulliparous women at term.

While maternal pelvimetry has long been recognized as an important tool in determining the best mode of delivery for breech fetuses, limited research has explored the role of ultrasound in this population[18, 61]. Previous studies utilizing MRI have identified a correlation between pelvimetric dimensions and the likelihood of successful vaginal delivery or the risk of emergency cesarean section in women planning vaginal breech delivery[22, 62]. However, the high cost, limited availability, and patient acceptability of MRI restrict its routine clinical use. In contrast, ultrasound offers several advantages, including bedside availability, real-time imaging, and the ability to capture both static and dynamic data during pregnancy[18, 37, 62].

Our study demonstrated that a narrower subpubic arch angle (SPA) is associated with a higher risk of breech presentation in nulliparous women at term. The SPA, formed by the inferior pubic rami, provides indirect information about the shape of the bony pelvis and has been widely studied in obstetrics. Albrich et al. suggested that narrower SPA is associated with prolonged labor[40], and Youssef et al. demonstrated that in low-risk nulliparous patients, SPA seems to predict the likelihood of an obstetric intervention[41]. Furthermore, Ghi et al. demonstrated that SPA measurement before labor may be helpful in predicting the risk of operative delivery due to prolonged or arrested labor among nulliparous women with large-for-gestational-age fetuses[63].

In addition to bony pelvic characteristics, our data suggest that women with breech-presenting fetuses may be less able to relax their pelvic floor effectively. This is supported by our finding that these women exhibited a smaller anteroposterior diameter (APD) of the levator hiatus during maternal pushing, a smaller increase in APD from rest to pushing, and a higher incidence of levator ani muscle (LAM) co-activation. LAM co-activation, a phenomenon in which the pelvic floor muscles fail to relax appropriately during pushing, was more than twice as prevalent in women with breech presentation compared to those with cephalic presentation.

Our study suggests that inadequate pelvic floor relaxation may play an etiological role in breech presentation, though we cannot definitively determine whether this is a cause or a consequence of breech presentation. These findings align with previous work suggesting that pelvic floor dysfunction may influence fetal positioning. Salvesen and Mørkved have conducted a randomized controlled trial (RCT) in which 301 healthy nulliparous women were randomized to receiving a pre-designed training program with a physiotherapist including pelvic floor exercises for 60 minutes once per week for a period of 12 weeks between the 20th and 36th week of pregnancy (n = 148). The control group (n=153) did not receive training but were not discouraged from doing pelvic floor muscle exercises on their own trained. Interestingly in the training group only one woman had a breech presentation at term in comparison to 9 women in the control group (P=0.01)[57]. The authors explained this almost 9-fold higher prevalence of breech presentation as a possible chance finding. Although our study cannot exclude this explanation, it definitely raises doubts on whether pelvic floor education and training can lead to better pelvic floor relaxation and consequently less incidence of breech presentation. As demonstrated by a more recent RCT by Del Forno et. al pelvic floor physiotherapy improves pelvic floor relaxation as revealed by larger levator ani muscle hiatal dimensions in comparison with controls, in women with deep infiltrating endometriosis and superficial dyspareunia [64].

In summary, our findings indicate that maternal pelvic characteristics, particularly the subpubic arch angle (SPA), along with the ability to relax the pelvic floor, may significantly influence the likelihood of breech presentation in nulliparous women at term. The observed correlation between a narrower SPA and higher breech presentation rates highlights the critical role of pelvic morphology in predicting labor outcomes. Additionally, our data point to inadequate pelvic floor relaxation as a potential contributor to breech presentation, though further studies are needed to clarify the precise causal mechanisms. Preliminary evidence from randomized controlled trials (RCTs) also suggests that pelvic floor physiotherapy may offer potential as a preventive strategy for breech presentation. Longitudinal research examining the impact of pelvic floor training on breech rates could provide valuable insight into its effectiveness. Additionally, expanding research to include a diverse population of women with varying characteristics may improve the generalizability of our findings. Ultimately, this research could contribute to the optimization of delivery methods and the reduction of associated risks, ensuring better outcomes for both mothers and their infants.

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