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Published Version:
Youssef A., Brunelli E., Montaguti E., Di Donna G., Dodaro M.G., Bianchini L., et al. (2020). Transperineal ultrasound assessment of maternal pelvic floor at term and fetal head engagement. ULTRASOUND IN OBSTETRICS & GYNECOLOGY, 56(6), 921-927 [10.1002/uog.21982].

Availability:
This version is available at: https://hdl.handle.net/11585/792478 since: 2021-01-28

Published:
DOI: http://doi.org/10.1002/uog.21982

Ultrasound Obstet Gynecol 2020; **56**: 921–927
Published online in Wiley Online Library (wileyonlinelibrary.com). **DOI:** 10.1002/uog.21982

Transperineal ultrasound assessment of maternal pelvic floor at term and fetal head engagement

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KEYWORDS: angle of progression; coactivation; fetal head engagement; labor; levator ani muscle; pelvic floor; second stage; transperineal ultrasound

CONTRIBUTION

What are the novel findings of this work?
Levator ani muscle coactivation and smaller pelvic floor dimensions in nulliparous women at term are associated with higher fetal head station on transperineal ultrasound.

What are the clinical implications of this work?
The results of the present study increase our understanding of the effect of pelvic floor static and dynamic dimensions on the mechanism of fetal head engagement and labor. Further studies exploring potential interventions aimed at improving pelvic floor relaxation may have a significant impact on the outcome of labor.

ABSTRACT

Objectives *To evaluate the association between pelvic floor dimensions in nulliparous women at term and fetal head engagement, as assessed by transperineal ultrasound.*

Methods *This was a prospective observational study of nulliparous women at term. Before the onset of labor, transperineal ultrasound was used to measure the anteroposterior diameter (APD) of the levator hiatus and the angle of progression (AoP) at rest, on maximum pelvic floor muscle contraction and on maximum Valsalva maneuver (before and after visual feedback). We assessed the correlation between pelvic floor static and dynamic dimensions (levator hiatal APD and levator ani muscle coactivation) and AoP, which is an objective index of fetal head engagement.*

Results *In total, 282 women were included in the analysis. Among these, 211 (74.8%) women had a vaginal delivery while 71 (25.2%) had a Cesarean delivery. AoP was narrower in the Cesarean-delivery group at rest, on maximum pelvic floor muscle contraction and on maximum Valsalva, whereas no differences in levator hiatal APD were found between the two groups. We found a negative correlation between levator hiatal APD at rest, on maximum pelvic floor muscle contraction and on maximum Valsalva and the duration of the second stage of labor. There was a positive correlation between AoP and levator hiatal APD on maximum Valsalva maneuver after visual feedback ($r = 0.15$, $P = 0.01$). Women with levator ani muscle contraction on Valsalva maneuver (i.e. coactivation), both pre and post visual feedback, had a narrower AoP at rest and on maximum Valsalva. After visual feedback, women with levator ani muscle coactivation had a longer second stage of labor than did those without (80.8 ± 61.4 min vs 62.9 ± 43.4 min ($P = 0.04$)).*

Conclusions *Smaller pelvic floor dimensions and levator ani muscle coactivation are associated with higher fetal head station and with a longer second stage of labor in nulliparous women at term. Copyright © 2020 ISUOG. Published by John Wiley & Sons Ltd.*

INTRODUCTION

The use of transperineal ultrasound (TPU) has been increasing over the past few years. Many studies, both in obstetrics and gynecology, have demonstrated that TPU can provide valuable information for the clinician. In gynecology, TPU is a reliable and reproducible tool for static and dynamic assessment of pelvic floor morphology and biometry[1–6]. In addition to providing important information in urogynecological patients, TPU has considerably improved our understanding of the relationship between labor and pelvic floor disorders[2,3,7–12]. On the other hand, in obstetrics, TPU before and during labor

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Accepted: 14 January 2020

is useful in certain clinical situations as a complementary tool to clinical examination[13–22]. In particular, TPU offers an objective, accurate and reproducible method for the evaluation of fetal head engagement[13–19]. The angle of progression (AoP) is one of the most reproducible and studied TPU indices of fetal head station and engagement[15,23–28].

Recently, several studies have found a correlation between pelvic floor dimensions and levator ani muscle (LAM) coactivation at term and the outcome of labor[29–33]. The AoP at term has a strong association with the risk of Cesarean delivery and with duration of labor[15,23,26,34–37], but the correlation between fetal head engagement and pelvic floor dimensions has not been assessed previously.

The aim of the present study was to evaluate the association between the anteroposterior diameter (APD) of the levator hiatus and LAM coactivation in nulliparous women at term and the AoP, as assessed by TPU.

PATIENTS AND METHODS

This was a prospective observational study conducted between January 2018 and March 2019 in Sant'Orsola Malpighi University Hospital, University of Bologna, Bologna, Italy. We recruited a non-consecutive series of nulliparous women at term with a singleton pregnancy and the fetus in cephalic presentation. Women were recruited when one of the investigators with more than 2 years of experience in TPU was present in the outpatient clinic for the purpose of the study. Exclusion criteria included previous uterine surgery, fetal congenital malformation and women with regular uterine contractions.

After recruitment and before the onset of labor, one of the investigators (A.Y., E.B., E.M. or G.D.) performed a TPU examination using a Voluson E10 or Voluson P8 Ultrasound System with SonoL&D software (GE Healthcare, Zipf, Austria) with a convex transducer covered by a sterile glove. All investigators performing TPU were blinded to the clinical examination results. TPU was performed as described previously[32,33]. The midsagittal view was obtained, visualizing the following landmarks: pubic symphysis, fetal head, rectum and puborectalis muscle (Figure 1). On the midsagittal view, two parameters were measured: the APD of the levator hiatus and the AoP. Levator hiatal APD was measured at the level of minimal hiatal dimensions from the posteroinferior border of the pubic symphysis to the anterior border of the puborectalis muscle (Figures 2 and 3). The AoP (also called the angle of fetal head descent) is the angle between the long axis of the pubic symphysis and a line passing through the lowermost border of the pubic symphysis tangentially to the fetal head (Figures 2 and 3). All TPU measurements were performed under resting conditions, on maximum pelvic floor muscle contraction (Figure 2) and on maximum Valsalva maneuver (Figure 3). TPU on maximum Valsalva was performed twice: once following only verbal explanation of the maneuver, and once following visual feedback. During visual feedback, each woman was allowed to watch the ultrasound screen in order to follow the movement of the puborectalis muscle during the Valsalva maneuver. An increase in levator hiatal APD on Valsalva indicated appropriate relaxation of the pelvic floor with pushing, while a decrease in levator hiatal APD during Valsalva indicated simultaneous undesired LAM contraction. As reported previously, we diagnosed LAM coactivation when the APD of the levator hiatus on Valsalva maneuver was less than that at rest[38]; birth attendants were blinded to the results of TPU. We also measured the duration of the second stage of labor, defined as the time from full cervical dilatation to delivery. In our center, the maximum time allowed for the second stage of labor in the first delivery is 3 h without and 4 h with epidural analgesia. We have no policy limiting the pushing technique (coached *vs* spontaneous), which is usually left to the preference and experience of the birth attendant.

Following delivery, one of the investigators reviewed the women's medical records and recorded the following data: maternal age and body mass index (BMI), gestational age, use of epidural analgesia, neonatal Apgar score, mode of delivery, birth weight and duration of the second stage of labor.

Statistical analysis

All continuous variables showed a Gaussian distribution on P-plot examination, at least between the 10th and

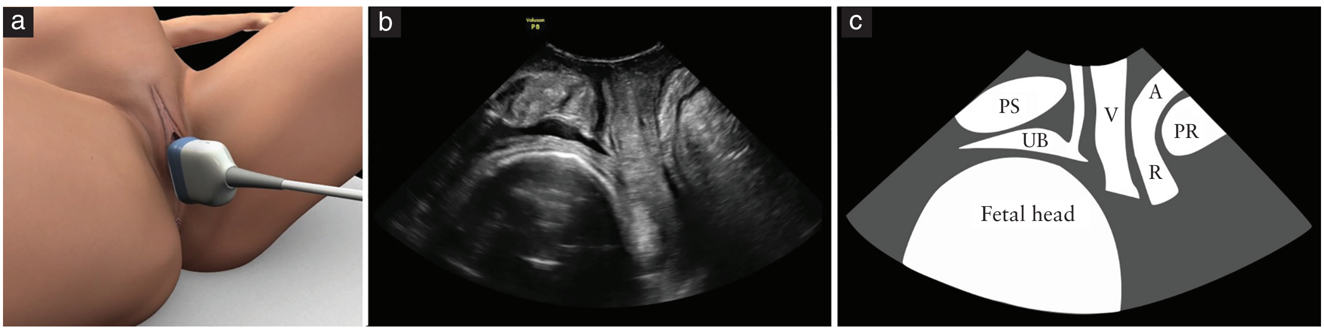

Figure 1 Transperineal ultrasound technique used in the present study, showing convex transducer placement in the midsagittal plane (a), corresponding ultrasound image (b) and schematic illustration of visualized structures (c), including pubic symphysis (PS), urinary bladder (UB), fetal head, vagina (V), rectum (R), anus (A) and puborectalis muscle (PR).

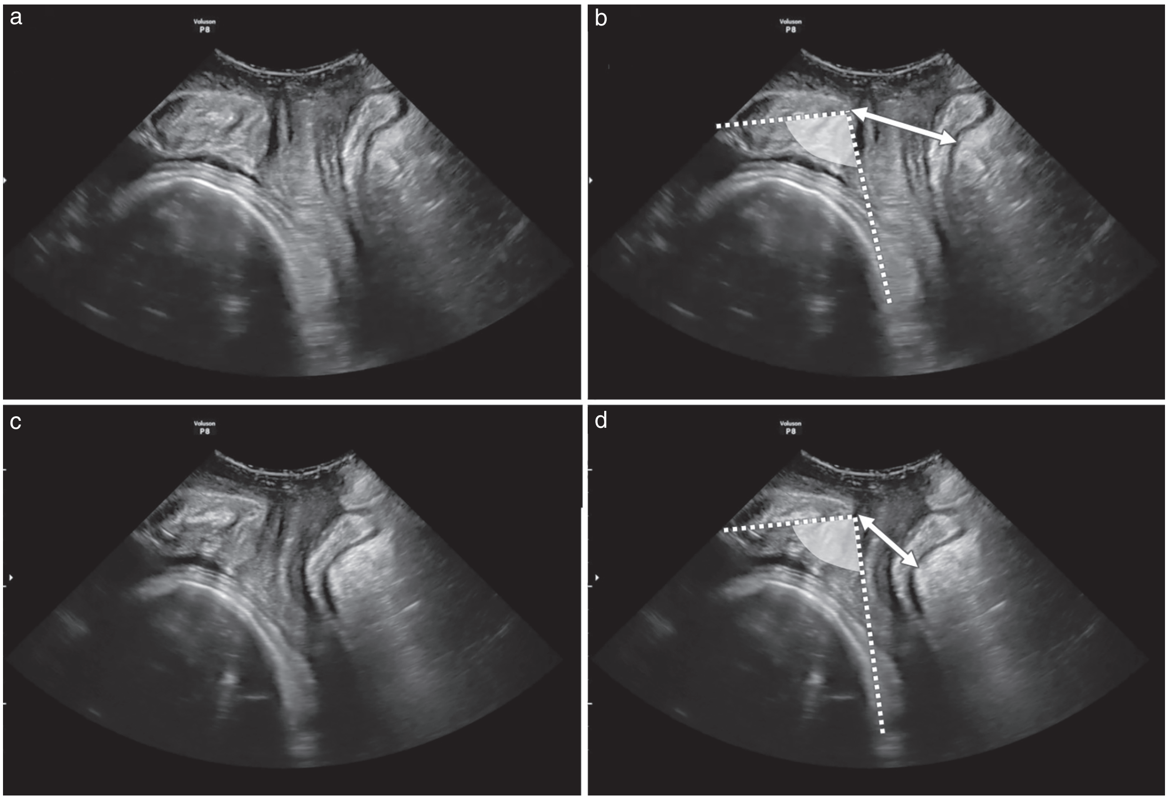

Figure 2 Ultrasound images showing fetal head and pelvic floor changes between rest (a,b) and maximum pelvic floor muscle contraction (c,d). Note reduction in angle of progression (between dotted lines) and in anteroposterior diameter of levator hiatus (arrows).

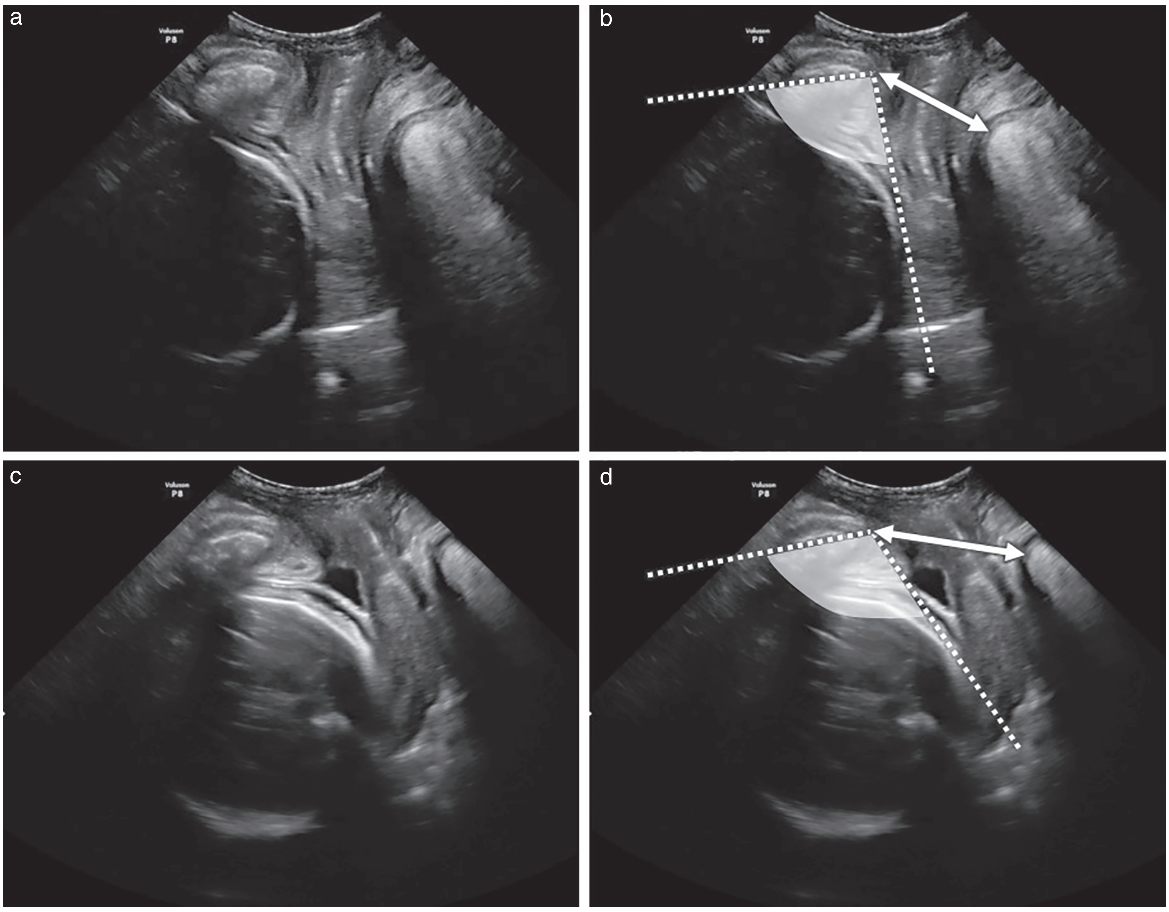

Figure 3 Ultrasound images showing fetal head and pelvic floor changes between rest (a,b) and maximum Valsalva maneuver (c,d). Note increase in angle of progression (between dotted lines) and in anteroposterior diameter of levator hiatus (arrows).

90th centiles, and the Kolmogorov–Smirnov test showed no significant deviation ($P > 0.05$). Mean, SD and frequencies were used as descriptive statistics. Differences between women who delivered vaginally and those who had a Cesarean delivery, and between women with and those without LAM coactivation, were assessed using the unpaired two-tailed Student's *t*-test and Fisher's exact test. Pearson's correlation was used to assess the significance of the association between continuous variables, which included APD of the levator hiatus, AoP and duration of the second stage of labor. Statistical analysis was performed using SPSS version 21.0 (SPSS Inc., Chicago, IL, USA), and two-tailed $P < 0.05$ were considered statistically significant.

The study was approved by the Ethics Committee of the Sant'Orsola Malpighi University Hospital, Bologna, Italy, on 8 November 2016 (reference # 139/2016/U/Oss). All study participants signed informed consent before being enrolled in the study.

RESULTS

Overall, 321 nulliparous women at term were approached in our outpatient clinic, of whom 290 (90.3%) agreed to participate in the study. Eight women did not deliver in our hospital and were thus excluded from the final analysis.

The characteristics of the 282 women included in the study are shown in Table 1. Delivery was vaginal in 211 (74.8%) women (by vacuum extraction in 52 (18.4%)) and by Cesarean in 71 (25.2%) women. The primary indication for Cesarean delivery was pathological fetal heart trace in 43 (15.2%) women and dystocia in 28 (9.9%) women. The primary indication for vacuum delivery was pathological fetal heart trace in 36 (12.8%) women and dystocia in 16 (5.7%) women.

Women in the Cesarean-delivery group were older, had a higher BMI and had lower neonatal Apgar scores at 1 and 5 min than did those in the vaginal-delivery group. The AoP was narrower in the Cesarean-delivery group at rest, on maximum pelvic floor muscle contraction and on maximum Valsalva when compared with the vaginal-delivery group. No significant differences between the two groups were found with regard to the APD of the levator hiatus or the rate of LAM coactivation. On Pearson's analysis, we found a significant correlation between AoP and levator hiatal APD on maximum Valsalva maneuver after visual feedback (Pearson's $r = 0.15$, $P = 0.01$). The larger the APD of the levator hiatus, the lower (more engaged) was the fetal head. This association was not significant at rest (Pearson's $r = 0.03$, $P = 0.66$), on maximum pelvic floor muscle contraction (Pearson's $r = 0.09$, $P = 0.09$) or on maximum Valsalva maneuver before visual feedback (Pearson's $r = 0.11$, $P = 0.05$).

Table 2 shows the correlation between TPU parameters and duration of the second stage of labor. A negative correlation was found between levator hiatal APD at rest, on maximum pelvic floor muscle contraction and on maximum Valsalva and duration of the second stage of labor. No association was found between AoP and duration of the second stage of labor.

LAM coactivation was diagnosed in 91 (32.3%) and 80 (28.4%) women before and after visual feedback, respectively. As shown in Table 3, women with coactivation, both pre and post visual feedback, had a narrower AoP at rest and on maximum Valsalva. Moreover, women with coactivation post visual feedback had a longer second

Table 1 Characteristics of 282 women included in study at term, overall and according to mode of delivery

Characteristic	*Total population* (n = 282)	*Mode of delivery*		
		Vaginal (n = 211)	*Cesarean* (n = 71)	P*
Maternal age (years)	33.0 ± 4.9	32.4 ± 4.8	34.9 ± 4.8	< 0.01
BMI (kg/m^2)	26.9 ± 3.8	26.6 ± 3.7	27.8 ± 3.7	0.01
Gestational age at scan (weeks)	40.4 ± 1.0	40.4 ± 1.0	40.5 ± 1.0	0.82
Epidural analgesia	181 (64)	117 (55)	64 (90)	< 0.01
Anteroposterior diameter of levator hiatus (cm)				
At rest	5.1 ± 0.7	5.1 ± 0.7	5.1 ± 0.6	0.69
On maximum pelvic floor muscle contraction	4.1 ± 0.6	4.2 ± 0.6	4.1 ± 0.5	0.50
On maximum Valsalva pre visual feedback	5.5 ± 1.0	5.5 ± 1.1	5.5 ± 0.8	0.88
On maximum Valsalva post visual feedback	5.7 ± 1.1	5.7 ± 1.2	5.7 ± 0.9	0.78
Angle of progression (°)				
At rest	95.4 ± 14.9	96.9 ± 14.5	90.7 ± 15.2	< 0.01
On maximum pelvic floor muscle contraction	91.3 ± 13.9	92.2 ± 14.1	88.4 ± 13.5	0.04
On maximum Valsalva pre visual feedback	103.3 ± 17.8	104.9 ± 17.7	98.2 ± 17.2	0.01
On maximum Valsalva post visual feedback	105.9 ± 18.8	107.7 ± 18.5	100 ± 18.65	0.01
Birth weight (g)	3349 ± 401	3340 ± 385	3376 ± 448	0.51
1-min Apgar score	8.8 ± 0.8	8.9 ± 0.7	8.6 ± 1.0	0.01
5-min Apgar score	9.8 ± 0.5	9.9 ± 0.4	9.7 ± 0.6	0.02
Levator ani muscle coactivation				
Pre visual feedback	91 (32)	71 (34)	20 (28)	0.46
Post visual feedback	80 (28)	60 (28)	20 (28)	1.00

Data are given as mean ± SD or *n* (%). *Student's *t*-test for continuous data and Fisher's exact test for categorical data. BMI, body mass index.

stage of labor. No other differences were noted between the two groups.

DISCUSSION

In this study we found a positive correlation between the APD of the levator hiatus and fetal head engagement, as assessed by TPU. In our studied population, larger APD of the levator hiatus on maximum Valsalva maneuver after visual feedback was associated with a lower fetal head in the birth canal, as measured using the AoP, which is an objective and reproducible TPU parameter.

Another interesting finding is the association between LAM contraction, rather than relaxation, on Valsalva maneuver (coactivation) and narrower AoP, reflecting higher fetal head station. In particular, women with coactivation had a less engaged fetal head at rest and on maximum Valsalva maneuver. On the basis of our findings, we speculate that higher pelvic floor tone and lack of adequate relaxation may represent higher resistance to descent of the fetal head. Indeed, recent studies support the association between pelvic floor muscle hypertone and LAM coactivation. It has been shown that women with deep infiltrating endometriosis, who are known to have a considerably higher risk of pelvic floor hypertone, have almost a three-fold higher risk of LAM coactivation[39,40]. We also confirmed an association between LAM coactivation after visual feedback and longer second stage of labor.

Table 2 Correlation of anteroposterior diameter (APD) of levator hiatus and angle of progression (AoP) with duration of second stage of labor in 212 women at term

Variable	*Pearson's* r	P
APD (in cm)		
At rest	−0.27	< 0.01
On maximum pelvic floor muscle contraction	−0.18	< 0.01
On maximum Valsalva pre visual feedback	−0.24	< 0.01
On maximum Valsalva post visual feedback	−0.20	< 0.01
AoP (in °)		
At rest	−0.09	0.18
On maximum pelvic floor muscle contraction	−0.09	0.21
On maximum Valsalva pre visual feedback	−0.10	0.16
On maximum Valsalva post visual feedback	−0.11	0.12

Duration of second stage of labor was measured in minutes.

Previous studies have shown that pelvic floor dimensions can affect the outcome of labor, especially the duration of the second stage[31,41]. Recently, two studies showed that LAM coactivation is associated with a longer second stage of labor, but not with mode of delivery[32,33], findings that were confirmed by the present study.

Kahrs *et al.*[42,43] performed a multicenter study on the use of ultrasound before vacuum delivery. Recently, they performed a secondary analysis of their data assessing fetal head descent during active pushing and found that a lack of fetal descent during active pushing was associated with longer duration of operative vaginal delivery[44]. Interestingly, in some women, the fetal head was higher in the birth canal during maternal pushing than at rest. The authors speculated that this may be due to LAM coactivation but, since they did not assess pelvic floor dimensions, they could not confirm or refute their theory.

An association between lower fetal head station on TPU and outcome of labor has been demonstrated in many studies. Indeed, a narrower AoP (indicating a higher fetal head station and thus less engagement) has been shown consistently to be associated with a higher risk of Cesarean

Table 3 Characteristics of 282 women at term, according to levator ani muscle coactivation pre and post visual feedback

	Pre visual feedback			*Post visual feedback*		
Characteristic	*No coactivation (n = 191)*	*Coactivation (n = 91)*	P*	*No coactivation (n = 202)*	*Coactivation (n = 80)*	P*
Maternal age (years)	33.1 ± 4.9	32.9 ± 4.8	0.83	32.9 ± 5.0	33.1 ± 4.6	0.81
BMI (kg/m^2)	26.7 ± 3.8	27.3 ± 3.7	0.16	26.8 ± 3.8	27.2 ± 3.7	0.41
Gestational age at scan (weeks)	40.3 ± 0.9	40.6 ± 1.1	0.07	40.4 ± 0.9	40.5 ± 1.1	0.53
Epidural analgesia	121 (63)	60 (66)	0.69	126 (62)	55 (69)	0.34
Anteroposterior diameter of levator hiatus (cm)						
At rest	5.1 ± 0.7	5.2 ± 0.6	0.19	5.1 ± 0.7	5.1 ± 0.6	0.82
On maximum pelvic floor muscle contraction	4.1 ± 0.6	4.1 ± 0.5	0.91	4.2 ± 0.6	4.1 ± 0.5	0.10
On maximum Valsalva	5.8 ± 0.9	4.8 ± 0.6	< 0.001	6.1 ± 1.0	4.7 ± 0.6	< 0.001
Angle of progression (°)						
At rest	96.9 ± 13.9	92.2 ± 16.1	0.02	96.6 ± 14.3	92.2 ± 15.9	0.02
On maximum pelvic floor muscle contraction	92.3 ± 13.0	89.0 ± 15.7	0.08	92.0 ± 13.2	89.5 ± 15.8	0.20
On maximum Valsalva	104.9 ± 17.4	99.9 ± 18.4	0.03	107.7 ± 18.5	101.3 ± 18.6	0.01
Duration of second stage of labor (min)†	66 ± 46	70 ± 56	0.53	63 ± 43	81 ± 61	0.04
Birth weight (g)	3344 ± 407	3360 ± 392	0.76	3357 ± 417	3331 ± 361	0.62
1-min Apgar score	8.8 ± 0.8	8.9 ± 0.7	0.72	8.8 ± 0.8	8.9 ± 0.7	0.79
5-min Apgar score	9.8 ± 0.4	9.8 ± 0.5	0.49	9.8 ± 0.4	9.8 ± 0.5	0.50

Data are given as mean ± SD or *n* (%). *Student's *t*-test for continuous data and Fisher's exact test for categorical data. †212 women. BMI, body mass index.

delivery, longer duration of labor, failure of instrumental delivery and failure of induction of labor[15,23,34,35,45]. In the present study, we confirmed that a narrower AoP at term is associated with a higher risk of Cesarean delivery in nulliparous women. This association may be useful for helping to improve the management of labor (for example, avoiding a prolonged second stage of labor in women at very high risk for Cesarean delivery). However, the accuracy of TPU before the onset of labor as a single parameter is not yet good enough for clinical application. Future studies integrating TPU with other parameters, such as fetal biometry or pelvic floor dimensions, may lead to a clinically useful predictive model.

The phenomenon of LAM coactivation is quite common, being present in almost one in every three nulliparous women[32,33,38], but it remains largely understudied[38]. Only recently has its clinical impact on the outcome of labor been evaluated[32,33]. As LAM coactivation is recognizable before delivery, there may be an opportunity to help women to improve their pelvic floor relaxation before the onset of labor. Whether women with LAM coactivation will benefit from an antenatal obstetric intervention aimed at achieving more efficient pelvic floor relaxation remains to be elucidated.

Previous studies aimed at improving women's pushing capability have been published, with inconsistent results. Antenatal pelvic floor education has been assessed. Salvesen and Mørkved[46] found that a structured pelvic floor training program was associated with a shorter second stage of labor and Youssef *et al.*[35] showed that visual feedback using ultrasound in nulliparous women before the onset of labor can help women push more efficiently. On the other hand, Phipps *et al.*[47] failed to identify a positive clinical impact of antenatal education using observation of the perineum and vaginal examination. Similar contradictory results have been found in studies assessing intrapartum interventions aimed at optimizing maternal pushing. A recent small randomized controlled trial found that women who underwent ultrasound coaching had a shorter second stage of labor than did controls[48]. This finding, however, was not confirmed by others[49]. We believe that the main reason for these conflicting results is the recruitment of an unselected population. Most women are able to relax their pelvic floor and push efficiently. Therefore, the majority of women do not need any help or intervention before or during labor. In view of our results, we suggest that women with LAM coactivation may be ideal candidates for future studies evaluating both antenatal and intrapartum interventions aimed at optimizing maternal pushing.

The main strength of the present study is its originality. No previous studies have assessed the correlation between pelvic floor static and dynamic dimensions and fetal head engagement. Another strength is that all of the caregivers managing labor were blinded to the TPU results.

The main weakness of the study is that we could not confirm whether smaller pelvic floor dimensions are the cause or the result of higher fetal head station. We acknowledge that, based on the present data, it is impossible to deduce this with absolute certainty.

In conclusion, we have shown that smaller pelvic floor dimensions and LAM contraction on Valsalva maneuver (i.e. coactivation) are associated with higher fetal head station and with a longer second stage of labor in nulliparous women at term.

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