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ORIGINAL CLINICAL ARTICLE

Evaluation of levator ani muscle throughout the different stages of labor by transperineal 3D ultrasound

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OBJECTIVE: Description and assessment by 3-D transperineal ultrasound of modifications suffered by pelvic floor muscles during the passage of the fetal head through the birth canal during the second stage of labor, as well as the identification of the precise moment in which levator ani muscle avulsion takes place.

MATERIALS AND METHODS: Patients included were 35 primigravidae, recruited during the first stage of labor, with at term pregnancy (37-42 weeks), without serious maternal-fetal pathology and cephalic presentation. A prospective observational study of 35 primigravidae, recruited during the first stage of labor, with at term pregnancy (37-42 weeks), with fetus in cephalic presentation and without serious maternal-fetal pathology. Sonographic evaluation was carried out by 3-D transperineal ultrasound during the first and second stages of labor (with fetal head in 1st, 2nd-3rd and 4th planes of Hodge), immediately postpartum and 6 months postpartum. Ultrasound parameters studied were antero-posterior and transverse diameters, as well as levator hiatus area and levator ani muscle thickness and area.

RESULTS: Twenty-one patients were studied (15 spontaneous deliveries; 6 instrumental deliveries). When measured with fetal head in the 4th plane of Hodge, a significant increase both in the levator hiatus area ($15.39\ cm^2/15.68\ cm^2/20.96\ cm^2/42.55\ cm^2/22.92\ cm^2/18.18\ cm^2$; $P < 0.0005$) and in the levator ani muscle area ($8.78\ cm^2/9.18\ cm^2/9.69\ cm^2/15.07\ cm^2/11.33\ cm^2/12.36\ cm^2$; $P < 0.0005$) was identified. Four cases of unilateral right avulsion (two vacuum and two forceps deliveries) were identified.

CONCLUSIONS: We conclude that the phase of delivery that causes a major increase in the area of the levator hiatus area and in the levator ani muscle area is when the fetal head reaches the 4th plane of Hodge. Furthermore, data in our paper indicates that the exact moment in which the avulsion of the levator ani muscle is produced is when the bulging of the fetal head on the maternal perineum occurs.

KEYWORDS
labor, levator ani muscle, pelvic floor, transperineal 3D ultrasound

1 | INTRODUCTION

Although throughout the pregnancy there is a strain on the gravid uterus and hormonal changes that produce a remodeling of the connective tissue of pelvic floor muscles,[1] it seems to be the passage of the fetus through the birth canal that causes muscle injury of the pelvic floor.[2–4] The most common injury reported following vaginal delivery is levator ani muscle avulsion, that is, separation of the muscle insertion from the inferior pubic ramus.[3,4] This injury occurs in 10-36% after spontaneous vaginal delivery[1,3] in 35-64% of forceps assisted deliveries[1,5,6] and in 34% of vacuum assisted ones.[7]

Savabik describes a significant distension of the levator hiatus area during vaginal delivery (from 6-35 cm^2 to 68 cm^2) which implies a distension of the muscle of 25-245%.[8]

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Several authors have described how the injury of levator ani muscle probably occurs due to the bulging of the fetal head on the maternal perineum.[2–4] Ashton-Miller carried out a simulation on how pelvic floor muscles distend during vaginal delivery, setting the maximum distension point at the moment of delivery of the fetal head.[9] However, no previous studies have carried out an ultrasound evaluation of the changes that occur on pelvic floor muscles as the fetal head descends through the birth canal. Regarding this, the identification by ultrasound of the exact moment in which the avulsion of levator ani muscle occurs has not yet been described either.

Our aim is to assess by 3-D transperineal ultrasound changes suffered by pelvic floor muscles during the passage of the fetal head through the birth canal during the second stage of labor, trying to identify the precise moment in which levator ani muscle avulsion takes place.

2 | MATERIALS AND METHODS

A prospective observational study carried out between March 1, 2015 and October 31, 2015, with patients recruited in the maternity unit of Valme University Hospital in Seville (Spain). The study was approved by the Andalusian board of biomedicine ethics committee, with code 3004/2012.

Patients included were 35 primigravidae, recruited during the first stage of labor, with at term pregnancy (37–42 weeks), without serious maternal-fetal pathology and cephalic presentation. The patients gave written informed consent before the study began. Obstetric data collected were as follows: maternal age, gestational age, epidural anesthesia and its duration, first and second stage of labor durations, type of delivery, episiotomy, perineal tears, and fetal birth weight.

Deliveries were carried out by obstetricians from the maternity unit of Valme University Hospital in Seville (Spain) with a minimum experience of 3 years in obstetric practice. We performed birth assistance with restrictive episiotomy and obstetrician instruments (vacuum or forceps) whenever necessary.

Sonographic evaluation was carried out by transperineal 3-D ultrasound during the first and second stages of labor, immediate postpartum and 6 months postpartum. During labor, volume captures were taken as follows: three during the first stage of labor (2-10 cm of dilatation), three during the second stage, with the fetal head in the first plane of Hodge, three with the fetal head in second or third plane of Hodge,

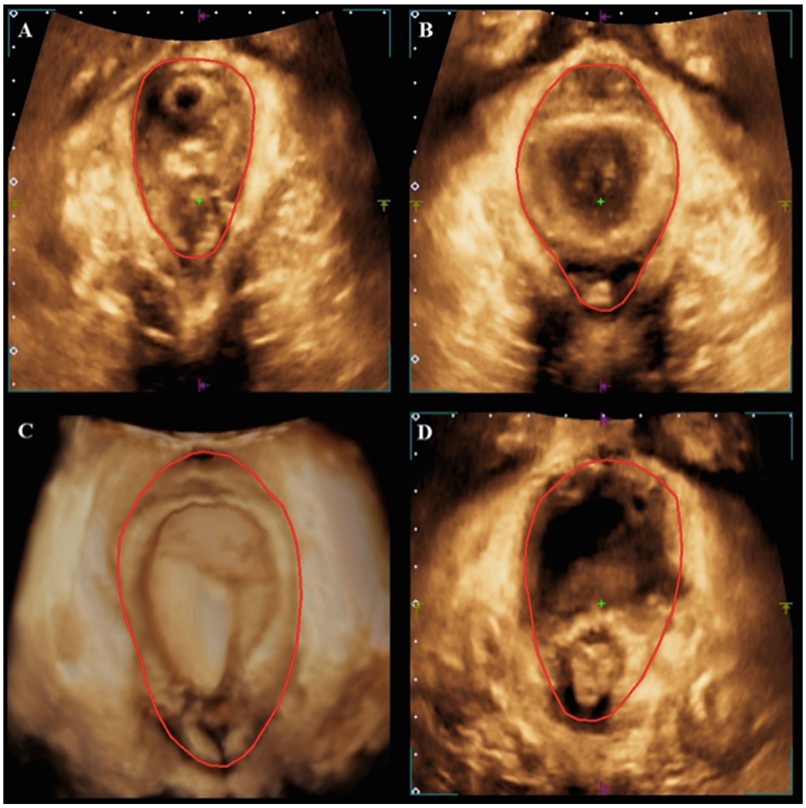

FIGURE 1 The solid line shows modifications in the levator hiatus area as the descent of the fetal head takes places. A: Levator hiatus area with fetal head in the 1st plane of Hodge. B: Levator hiatus area with the fetal head in 2nd-3rd plane of Hodge and caput succedaneum reaching PMD. C: Levator hiatus area with the fetal head in 4th plane of Hodge; fetal head has reached PMD in an occipito-anterior position, allowing visualization of fetal skull and cranial sutures; at this level, compression of the urethra and anus by the fetal head can be appreciated. D: Significant alteration of levator hiatus area in immediate postpartum

and three with fetal head in fourth plane of Hodge prior to delivery. Three more captures were taken in the immediate postpartum before the patient abandoned the delivery room (Fig. 1A–D). The last sonographic evaluation with another three volume captures was performed 6 months after the delivery. All analyses of the ultrasound volumes were performed offline.

The ultrasound evaluation was focused on the analysis of the plane of minimum dimensions (PMD),[10] measuring antero-posterior and transverse diameters and levator hiatus areas.[10] Levator ani muscle analysis was performed taking six measurements of muscle thickness and the determination of its area.[11] All of measurements were taken from the PMD. Muscle thickness measurements were taken from the anterior third (at the point pubic insertion of the levator ani muscle), middle third (central region of levator ani muscle), and posterior third of the muscle (at the anal canal level) (Fig. 2). The diagnosis of avulsion was established 6 months after delivery using multiview mode.[12] In the multi-view ultrasound, complete avulsion was defined as an abnormal insertion of levator ani muscle in the lower pubic branch, identified in all three central slices, that is, in the PMD and the 2.5 and 5.0 mm slices cranial to this.[12]

The sonographic evaluation was performed by a single examiner with more than 5 years of dedication to obstetric ultrasound and specific training in 3/4D imaging. A 500 Toshiba Aplio (Toshiba Medical Systems Corp., Tokyo, Japan) with an abdominal ultrasound probe PVT-675MV 3D was used for the assessment. Image acquisition was carried out with patients in dorsal lithotomy position.

We determined means and standard deviations for numeric variables and percentages for qualitative variables. Confidence internals for averages and percentages with 95% confidence were carried out. Spearmańs correlation rank coefficients were used to establish the relations between numeric variables, since normality could not be verified. General linear model repeated measure was used to compare numeric variables throughout the different stages of labor. Statistical analysis was performed with SPSS Statistics software program version 23.

3 | RESULTS

Out of the initial sample, 21 patients had a vaginal delivery in which all ultrasound images needed at the different stages of labor could be taken. Fourteen were excluded due to: five intrapartum caesarean sections (one due to fetal distress and four because of failure to progress) and nine due to failure in the acquisition of captures in all stages of labor.

Table 1 presents general data of the patients included. Out of the 21 patients studied, six ended in instrumental deliveries (two forceps, four vacuum) indicated to shorten second stage of labor.

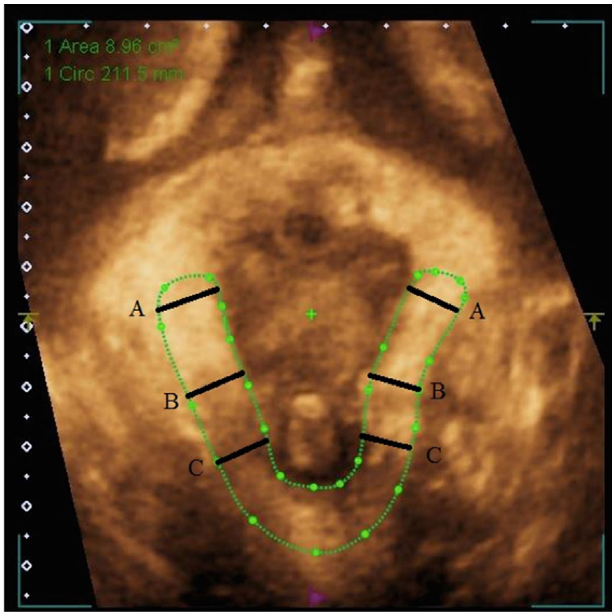

FIGURE 2 Mean measurements of levator ani muscle. Dotted line: levator ani muscle area. Line A: Levator ani muscle thickness measured at its anterior third. Line B: Levator ani muscle thickness measured at its middle third. Line C: Levator ani muscle thickness measured at its posterior third

The measurements obtained from the PMD at the different stages of the second stage of labor are listed in Table 2. Statistically significant differences ($P < 0.0005$) were observed in the levator hiatus area and in antero-posterior and transverse diameters in the levator hiatus. All three measurements—levator hiatus area, antero-posterior and transverse diameters of the levator hiatus- were greater in those images corresponding to the stage in which the fetal head was in the 4th plane of Hodge. Figure 3 presents the changes that took place in the area of the levator hiatus of each patient, observing how in all patients, levator hiatus area was greater when the fetal head had reached the 4th plane of Hodge. In addition, four cases of unilateral right avulsion (two vacuum deliveries and forceps deliveries two) were identified.

The mean levator ani muscle thickness (measured in its anterior, middle, and posterior thirds) and the average area of levator ani muscle measured during labor are shown in Table 2. Statistically significant differences (P <0.0005) were found between thickness measurements taken at the different stages of labor. The same happened with the levator ani muscle area, with statistically significant differences being observed between the measurements of the area in cm^2 taken in at the different stages of labor (8.78 ± 1.35, 9.18 ± 1.75, 9.69 ± 1.29, 15.07 ± 2.95, 11.33 ± 2.11, 12.36 ± 1.98; $P < 0.0005$, respectively). Figure 4 presents modifications in the levator ani muscle area in the different patients studied. When analyzing the relationship between fetal weight at birth and levator hiatus area and levator ani muscle area (Spearmańs correlation

TABLE 1 General characteristics of study population (n:21)

	Media (±DT) o%	IC 95%
Mean maternal age (years)	27.86 (±6.02)	25.12-30.60
Gestational age (weeks)	39.00 (±1.38)	38.37-39.63
Epidural analgesia	90.50% (19/21)	79.60-100
Epidural period (minutes)	365.26 (±104.46)	314.91-415.61
Lenght of first stage of labor (minutes)	337.38 (±130.84)	277.82-396.94
Lenght of second stage of labor (minutes)	108.86 (±25.58)	97.21-120.50
Episiotomy	33.3% (7/21)	18.13-73.76
Perineal tears	38.1% (8/21)	17.33-18.47
High grade perineal tears	50% (4/8)	15.35-84.65
Weight at birth (gr)	3189.05 (±379.13)	3016.47-3361.63
Mean APGAR score at 1 min	9.1 (±0.91)	8.39-9.81
Mean APGAR score at 5 min	9.96 (±0.03)	9.93-9.99
Umbilical artery pH at birth	7.26 (±0.37)	7.06
Admission to Neonatology Unit	0	0

rank coefficient 0.10 and 0.24, respectively), no statistically significant differences were observed.

4 | DISCUSSION

During labor, women's pelvic floors must undergo modifications in order to allow fetal passage through the birth canal. The study of this adaptation process has determined that the levator ani muscle is the element which suffers a higher degree of strain during this process, with a stretch ratio ([tissue length under strain]/[original tissue length]) of 3.26.[13]

Due to this, the levator ani muscle is the pelvic floor muscle which has a higher risk of being injured during the second stage of labor. However, these statements are based on 3D geometric models,[14] with the limitations these entail and which include the equalization of the fetal head to a perfect sphere or the fact of not taking into account the different strains suffered by the tissues during labor.[13,14] In subsequent studies, ultrasound and MRI images of the fetal head and pelvic floor muscles have been used in order to recreate this as accurately as possible. The adaptation of the fetus as it passes through the levator ani muscle,[15] revealing how levator ani muscle represents an obstacle to the descent of the fetal head, thus increasing the risk of pelvic floor injuries.[16]

In our study, we aimed to carry out an assessment in real time of the adaptability of levator ani muscle throughout the different stages of labor. Blasi et al.[17] had already analyzed the adaptation of levator ani muscle during vaginal delivery by translabial 3D ultrasound, stating that it is a feasible, low cost technique, and which involves minimum discomfort to the patient. Blasi's study[17] was based on the performance of two ultrasound evaluations, one before full dilation is completed and one in full dilatation conditions, and before fetal extraction takes place. However, this author did not evaluate the engagement of the fetal head in the birth canal.

TABLE 2 Levator hiatus and levator ani muscle ultrasound measurements taken from PMD as the fetal head progresses throughout the different stages of labor (first stage of labor, second stage of labor, immediate postpartum, and 6 months after delivery)

	Media (±DT)						
		Second stage of labor					
	First stage of labor	1st plane of hodge	2nd-3rd plane of hodge	4th Plane of Hodge	Postpartum	6 months after delivery	*P*
Levator hiatus antero-posterior diameter (mm)	61.21 (±7.67)	60.51 (±6.87)	70.04 (±8.48)	86.29 (±5.45)	72.21 (±10.24)	65.05 (±7.84)	<0.0005
Levator hiatus latero-lateral diameter (mm)	37.52 (±4.23)	36.44 (±3.13)	40.49 (±5.55)	61.09 (±8.27)	44.09 (±6.89)	40.58 (±7.01)	<0.0005
Levator hiatus area (cm^2)	15.39 (±4.52)	15.68 (±4.10)	20.96 (±5.71)	42.55 (±7.29)	22.92 (±6.49)	18.18 (±5.43)	<0.0005
Levator ani muscle area (cm^2)	8.78 (±1.35)	9.18 (±1.75)	9.69 (±1.29)	15.07 (±2.95)	11.33 (±2.11)	12.36 (±1.98)	<0.0005
Right anterior third levator ani muscle thickness (mm)	8.01 (±1.34)	8.28 (±1.28)	7.54 (±0.80)	8.51 (±2.03)	9.74 (±2.76)	9.15 (±2.19)	0.001
Right middle third levator ani muscle thickness (mm)	7.94 (±1.13)	8.37 (±1.01)	7.46 (±0.93)	8.36 (±1.77)	8.84 (±1.89)	9.06 (±2.26)	0.005
Right posterior third levator ani muscle thickness (mm)	8.02 (±1.20)	8.34 (±1.12)	7.57 (±0.75)	8.75 (±1.58)	9.00 (±1.42)	8.89 (±2.01)	0.001
Left anterior third levator ani muscle thickness (mm)	7.82 (±1.30)	7.62 (±1.18)	7.11(±1.10)	8.73 (±1.40)	9.00 (±1.66)	9.01 (±2.54)	<0.0005
Left middle third levator ani muscle thickness (mm)	7.47 (±0.95)	7.18 (±1.05)	6.68 (±1.16)	8.39 (±1.34)	8.34 (±1.24)	9.19 (±1.98)	<0.0005
Left posterior third levator ani muscle thickness (mm)	7.05 (±0.55)	7.15 (±0.61)	6.63 (±1.05)	8.21 (±1.10)	8.01 (±1.20)	9.23 (±1.94)	<0.0005

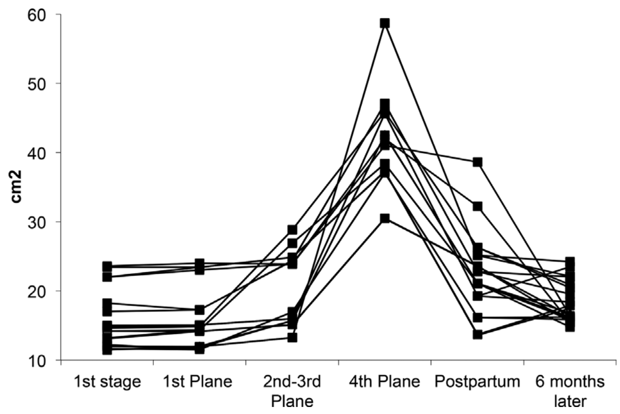

FIGURE 3 Changes in levator hiatus area (cm^2) per patient taken in the different stages of labor. We study levator hiatus area (cm^2) as the fetal head progresses throughout the 1st and 2nd stages of labor (with fetal head in 1st, 2nd-3rd and 4th planes of Hodge), immediate postpartum and 6 months after the delivery

In our study, we have assessed the modifications suffered by the levator hiatus area as the fetal head descends through the different planes of Hodge. Thus, it can be seen how levator hiatus presents a maximum area at the moment in which the fetal head reaches the 4th plane of Hodge (Fig. 3). This fact is reflected in Figure 4, where the modifications the hiatus area suffers during the descent of the fetal head can be seen. In the capture taken in the 1st plane of Hodge (Fig. 4), the fetal head is above the PMD and the hiatus is practically unchanged, remaining as it was during the first stage of labor (Fig. 3). When the fetal head is at the 2nd-3rd plane of Hodge (Fig. 4), fetal caput can reach the level of PMD, causing just a slight modification of the area of the levator hiatus. However, it is when the fetal head reaches the 4th plane of Hodge (Fig. 4), and therefore is passing through the PMD,[18] that both the levator hiatus area (Fig. 3) and the levator ani muscle area (Fig. 4) reach their highest value.

Regarding the injuries the levator ani muscle can suffer in caesarean section deliveries, Albrich et al.[19] reported four cases of levator ani muscle defects after intrapartum caesarean section. Based on these findings, he states that both cervical dilation and the descent of the fetal head can cause pelvic floor muscle and nerve damage. However, regarding this, Dietz points out that the lesions identified by Albrich could correspond to unresolved hematomas or even congenital anomalies.[20] Aydin et al.[21] describe a defect rate of 40.2% after intrapartum cesarean section, although note significant limitations to these results due to the absence of an accurate description of what levator ani muscle injury implies.

Other authors have focused on the modifications the pelvic floor suffers in cases of cesarean section deliveries. These authors state that changes in the matrix of connective tissue, damage to the pelvic floor fascia, and nerve damage can be produced, but that avulsions of levator ani muscle will not be detected in these cases.[22–28]

According to the results of our study and taking into account the fact that we have not been able to visualize by ultrasound the exact moment in which avulsion of the levator ani muscle is produced, we conclude that avulsion occurs just before the delivery of the fetal head. Moreover, we establish that the phase of delivery that causes a major increase in the levator hiatus area and in the levator ani muscle area, is that in which the fetal head reaches the 4th plane of Hodge.

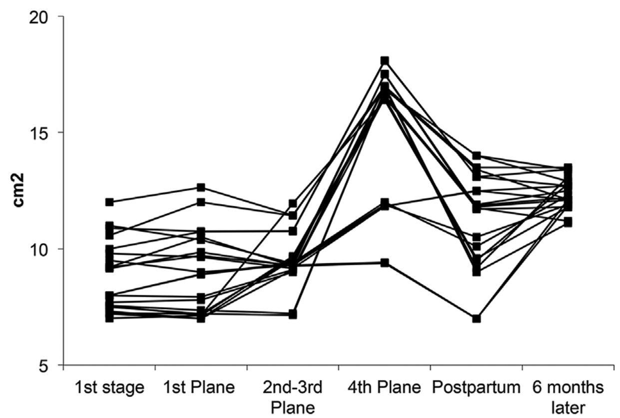

FIGURE 4 Graphic representation of levator ani muscle area measurements (cm^2) taken at the different stages of labor from each patient in the study group

POTENTIAL CONFLICTS OF INTEREST

None to disclose.

REFERENCES

1. Shek KL, Dietz HP. The effect of childbirth on hiatal dimensions. *Obstet Gynecol*. 2009;113:1272–1278.
2. DeLancey JO, Kearney R, Chou Q, Speights S, Binno S. The appearance of levator ani muscle abnormalities in magnetic resonance images after vaginal delivery. *Obstet Gynecol*. 2003;101:46–53.
3. Dietz HP, Lanzarone V. Levator trauma after vaginal delivery. *Obstet Gynecol*. 2005;106:707–712.
4. Tunn R, Paris S, Fischer W, Hamm B, Kuchinke J. Static magnetic resonance imaging of the pelvic floor muscle morphology in women with stress urinary incontinence and pelvic prolapse. *Neurourol Urodyn*. 1998;17:579–589.
5. Shek K, Dietz HP. Intrapartum risk factors for levator trauma. *BJOG*. 2010;117:1485–1492.
6. Krofta L, Otcenasek M, Kasikova E, Feyereisl J. Pubococcygeus-puborectalis trauma after forceps delivery: evaluation of the levator ani muscle with 3D/4D ultrasound. *Int Urogynecol J Pelvic Floor Dysfunct*. 2009;20:1175–1181.
7. García-Mejido JA, Gutierrez L, Fernández-Palacin A, Aquise A, Sainz JA. Levator ani muscle injures associated with vaginal vacuum assisted delivery determined by 3/4D transperineal ultrasound. *J Matern Fetal Neonatal Med*. 2016;21:1–6.
8. Svabík K, Shak KL, Dietz HP. How much does the levator hiatus have to stretch during childbirth? *BJOG*. 2009;116:1657–1662.
9. Ashton-Miller JA, DeLancey JO. Functional anatomy of the female pelvic floor. *Ann NY Acad Sci*. 2007;1101:266–296.

10. Falkert A, Endress E, Weigl M, Seelbach-Göbel B. Three-dimensional ultrasound of the pelvic floor 2 days after first delivery: influence of constitutional andobstetric factors. *Ultrasound Obstet Gynecol*. 2010;35:583–588.
11. Dietz HP, Shek C, Clarke B. Biometry of the pubovisceral muscle and levator hiatus by three-dimensional pelvic floor ultrasound. *Ultrasound Obstet Gynecol*. 2005;25:580–585.
12. Dietz H, Bernardo M, Kirby A, Shek K. Minimal criteria for the diagnosis of avulsion of the puborectalis muscle by tomographic ultrasound. *Int Urogynecol J*. 2010;22:699–704.
13. Lien KC, Mooney B, DeLancey JO, Ashton-Miller JA. Levator ani muscle stretch induced by simulated vaginal birth. *Obstet Gynecol*. 2004;103:31–40.
14. Ashton-Miller JA, Howard D, DeLancey JO. The functional anatomy of the female pelvic floor and stress continence control system. *Scand J Urol Nephrol Suppl*. 2001;207:1–7.
15. Silva ME, Oliveira DA, Roza TH, Brandao S, Parente MP, Mascarenhas T, et al. Study on the influence of the fetus head molding on the biomechanical behavior of the pelvic floor muscles, during vaginal delivery. *J Biomech*. 2015;48:1600–1605.
16. Parente MP, Natal Jorge RM, Mascarenhas T, Silva-Filho AL. The influence of pelvic muscle activation during vaginal delivery. *Obstet Gynecol*. 2010;115:804–808.
17. Blasi I, Fuchs I, D́Amico R, Vinci V, La Sala GB, Mazza V, et al. Intrapartum translabial three- dimensional ultrasound visualization of levator trauma. *Ultrasound Obstet Gynecol*. 2011;37:88–92.
18. Fuchs I, Tutschek B, Henrich W. Visualization of the fetal fontanels and skull sutures by three-dimensional translabial ultrasound during the second stage of labor. *Ultrasound Obstet Gynecol*. 2008;31:484–486.
19. Albrich SB, Laterza RM, Skala C, Salvatore S, Koelbl H, Naumann G. Impact of mode of delivery on levator morphology: a prospective observational study with three-dimensional ultrasound early in the postpartum period. *BJOG*. 2012;119:51–60.
20. Aydin S, Tuncel MA, Aydin CA, Ark C. Do we protect the pelvic floor with non-elective caesarean? A study of 3D/4D pelvic floor ultrasound immediately after delivery. *J Obstet Gynaecol Res*. 2014;4:1037–1045.
21. Peschers UM, Schaer GN, DeLancey JO, Schuessler B. Levator ani function before and after childbirth. *Br J Obstet Gynaecol*. 1997;104:1004–1008.
22. Sze EH, Sherard GB, Dolezal JM. Pregnancy, labor, delivery, and pelvic organ prolapse. *Obstet Gynecol*. 2002;100: 981–986.
23. Dolan LM, Hosker GL, Mallett VT, Allen RE, Smith AR. Stress incontinence and pelvic floor neurophysiology 15 years after the first delivery. *BJOG*. 2003;110:1107–1114.
24. Lee SJ, Park JW. Follow-up evaluation of the effect of vaginal delivery on the pelvic floor. *Dis Colon Rectum*. 2000;43: 1550–1555.
25. Tunn R, Delancey JO, Howard D, Ashton-Miller JA, Quint LE. Anatomic variations in the levator ani muscle, endopelvic fascia, and urethra in nulliparas evaluated by magnetic resonance imaging. *Am J Obstet Gynecol*. 2003;188:116–121.
26. Tunn R, DeLancey JO, Howard D, Thorp JM, Ashton-Miller JA, Quint LE. MR imaging of levator ani muscle recovery following vaginal delivery. *Int Urogynecol J Pelvic Floor Dysfunct*. 1999;10:300–307.
27. Snooks SJ, Setchell M, Swash M, Henry MM. Injury to innervation of pelvic floor sphincter musculature in childbirth. *Lancet*. 1984;2:546–550.
28. Novellas S, Chassang M, Verger S, Bafghi A, Bongain A, Chevallier P. MR features of the levator ani muscle in the immediate postpartum following caesarean delivery. *Int Urogynecol J*. 2010;21:563–568.

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