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# Biometry of the pubovisceral muscle and levator hiatus by three-dimensional pelvic floor ultrasound

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**KEYWORDS:** 3D; levator ani; pelvic floor; perineal ultrasound; prolapse; translabial ultrasound

## ABSTRACT

***Objective*** *Until recently, magnetic resonance was the only imaging method capable of assessing the levator ani* in vivo. *Three-dimensional (3D) ultrasound has recently been shown to be able to demonstrate the pubovisceral muscle. The aim of this study was to define the anatomy of the levator hiatus in young nulliparous women with the help of 3D ultrasound.*

***Methods*** *In a prospective observational study, 52 nulligravid female Caucasian volunteers (aged 18–24 years) were assessed by two-dimensional (2D) and 3D translabial ultrasound after voiding whilst supine. Pelvic organ descent was assessed on Valsalva maneuver. Volumes were acquired at rest and on Valsalva maneuver, and biometric indices of the pubovisceral muscle and levator hiatus were determined in the axial and coronal planes.*

***Results*** *In the axial plane, average diameters of the pubovisceral muscle were 0.4–1.1 cm (mean 0.73 cm). Average area measurements were 7.59 (range, 3.96–11.9) cm$^2$. The levator hiatus at rest varied from 3.26 to 5.84 (mean 4.5) cm in the sagittal direction, and from 2.76 to 4.8 (mean 3.75) cm in the coronal plane. The hiatus area at rest ranged from 6.34 to 18.06 (mean 11.25) cm$^2$ increasing to 14.05 (6.67–35.01) cm$^2$ on Valsalva maneuver ($P = 0.009$). There were significant correlations between pelvic organ mobility and hiatus area at rest ($P = 0.018$ to $P < 0.001$) and on Valsalva maneuver (all $P < 0.001$).*

***Conclusions*** *Biometric indices of the pubovisceral muscle and levator hiatus can be determined by 3D ultrasound. Significant correlations exist between hiatal area and pelvic organ descent. These data provide support for the hypothesis that levator ani anatomy plays an independent role in determining pelvic organ support. Copyright © 2005 ISUOG. Published by John Wiley & Sons, Ltd.*

## INTRODUCTION

The levator ani muscle is thought to play a significant role in the pathogenesis of incontinence and prolapse[1]. Until recently, magnetic resonance was the only imaging method capable of assessing the levator ani *in vivo*[2], and both normal anatomy[3] and levator trauma[4–7] have been demonstrated using this technology. However, magnetic resonance imaging (MRI) has not been adopted in clinical practice, the main reason being cost and access problems. The nature of MRI impedes research in the field as recruitment of patients may be difficult not just due to cost and logistical problems, but also due to psychological issues, e.g. in pregnancy. In addition, MRI is contraindicated in patients with metallic implants, and such implants are not uncommonly found in women presenting for the investigation of pelvic floor disorders.

The advent of three-dimensional (3D) pelvic floor ultrasound now enables us to evaluate the levator ani with much less cost to the health care provider and minimal discomfort to the patient[8,9]. While spatial resolution may be inferior, ultrasound allows a degree of dynamic multiplanar imaging, which is almost impossible using current MRI technology. This study was designed to define a number of parameters describing levator anatomy on 3D ultrasound, to establish test-retest variability for those parameters, and to correlate levator biometry with pelvic organ descent as determined by two-dimensional (2D) ultrasound[10] in a group of young women recruited for a twin study of pelvic floor function. Significant pelvic organ descent in young women is not uncommon, as recently shown both by clinical examination[11] and on 2D pelvic floor ultrasound[12].

## METHODS

Fifty-two nulligravid female Caucasian volunteers between 18 and 24 years of age were invited to a pelvic

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floor assessment. They were recruited through the Australian Twin Registry as part of a twin study of pelvic floor function. After an interview covering symptoms of pelvic floor dysfunction and a family history of such symptoms and/or surgical intervention, 3D translabial ultrasound was performed after voiding whilst the patient was in the supine position, using a GE Kretz Voluson 730 system (GE Kretztechnik GmbH, Zipf, Austria) with 7–4-MHz 3D ultrasound transducer. Automatic image acquisition took about 3–5 seconds, and the main transducer axis was oriented in the mid-sagittal plane. The acquisition angle was set at the transducer maximum of 70°. Volumes were acquired at rest and during Valsalva, after the efficacy of both maneuvers had been ascertained by 2D imaging in the mid-sagittal plane.

In the mid-sagittal plane (shown in Figure 1), pelvic organ descent on Valsalva maneuver was measured using the positions of the most dependent part of the bladder, the most inferior parts of the cervix and rectal ampulla relative to the inferior margin of the symphysis pubis. These measurements were obtained just prior to volume acquisition. The methodology for assessing pelvic organ descent on Valsalva maneuver has been described in detail elsewhere[10] and has been found to correlate well with clinical measures of descent[10]. In order to improve compliance, and due to the fact that a significant number of our patients had not experienced a vaginal examination before, we decided to omit a clinical prolapse assessment.

Since there is disagreement regarding nomenclature of the inferior aspects of the levator ani, we have used the term ‘puboviscer al muscle’ as synonymous with the term ‘puborectalis’ or ‘pubococcygeus/puborectalis’ as defined by DeLancey[1]. The two components of the puboviscer al muscle cannot be distinguished on imaging, neither on MRI nor on ultrasound. However, both methods are able to define the muscle well relative to surrounding soft tissue. In the case of pelvic floor ultrasound, this is due to the high echogenicity of muscle fibers running roughly in the axial plane, i.e. perpendicular to the incident beam. While the more cranial aspects of the levator (i.e. the iliococcygeus) are invisible due to poor resolution at depths over 6–8 cm, the area of the levator hiatus is situated at a depth of 2–4 cm from the perineum and well within the effective range of 7–4-MHz transducers such as those routinely used for transabdominal 3D imaging. Figure 1 shows the location of the planes used for determining hiatal diameters and areas (single line) as well as levator thickness and area (double line). The plane of minimal hiatal dimensions is identified in the mid-sagittal plane, evident as the minimal distance between the hyperechogenic posterior aspect of the symphysis pubis and the hyperechogenic anterior border of the puboviscer al muscle just posterior to the anorectal muscularis (represented by the single oblique line in Figure 1). With the GE Kretz 4D View software package (GE Kretztechnik GmbH, Zipf, Austria) used for 3D analysis, this plane is defined in the mid-sagittal orthogonal plane, which then allows representation of exactly this cross-section of the volume in the axial or ‘C’ plane.

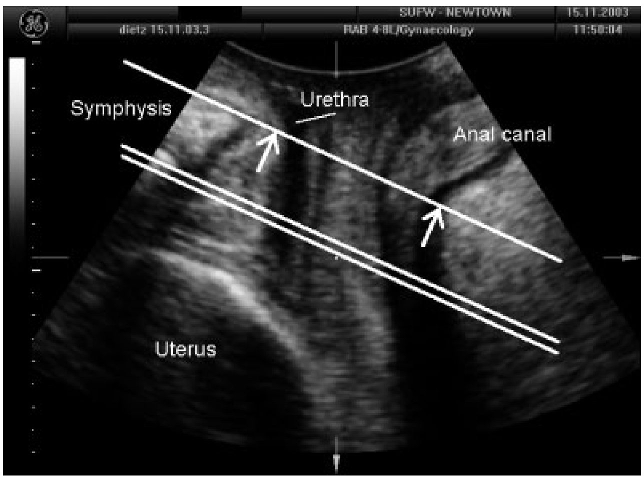


**Figure 1** Mid-sagittal translabial two-dimensional pelvic floor ultrasound, showing the location of planes used for determining hiatal diameters and areas (single line) as well as puboviscer al muscle thickness and area (double line). The plane of minimal hiatal dimensions is identified in the mid-sagittal plane, evident as the minimal distance between the hyperechogenic posterior aspect of the symphysis pubis (left arrow) and the hyperechogenic anterior border of the puboviscer al muscle just posterior to the anorectal muscularis (right arrow).

Maximum levator thickness is determined by slowly moving the plane of minimal hiatal dimensions cranially until the plane of maximal thickness of the puboviscer al muscle is reached. This is usually located about 1–1.5 cm above the actual levator hiatus (double line in Figure 1).

The following parameters were assessed for this study. In the axial view, we measured maximum diameters of the puboviscer al muscle in two locations bilaterally and determined muscle area by tracing its outline at the level of maximal muscle thickness. The plane of minimal anteroposterior (AP) diameters was identified in the mid-sagittal image (Figure 1); the axial plane at this level was then utilized to determine the minimum AP and lateral diameters of the levator hiatus as well as the hiatal area. In the coronal plane, the distance between perineal skin and puboviscer al muscle was determined, as was its diameter perpendicular to the perineal surface and its area at a level just anterior to the anorectal junction. Figure 2 shows the puboviscer al muscle loop in the axial plane, demonstrating measurement of levator thickness (left) and area (right). Figure 3 shows the levator hiatus in the axial plane at the level of minimal AP dimensions, 1–1.5 cm below the plane used for muscle diameter and area measurements.

Ethics Committee approval had been obtained for the parent study, which was part of twin research into the heritability of pelvic floor disorders (QIMR P434 (H0202-01-004)). All women gave informed written consent. They received a shopping voucher worth A$100.00 for their participation as is usual in twin research. Statistical analysis was performed after normality testing (histogram

 

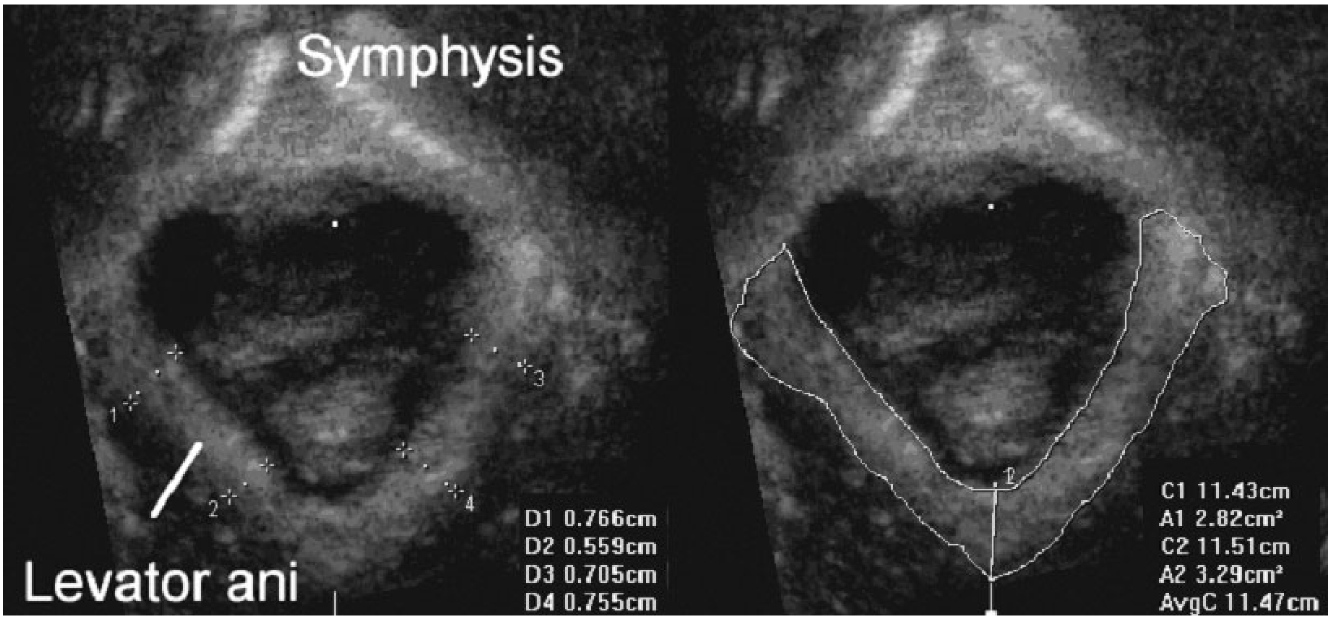


**Figure 2** Measurement of pubovisceral muscle thickness (left) and area (outlined on the right) in the axial plane, obtained by translabial ultrasound with the woman in the supine position and after voiding. Ventral is superior, dorsal is inferior; the patient's right is left on each of the two images. The view obtained is equivalent to a view of the perineum from below, with the patient in the lithotomy position.

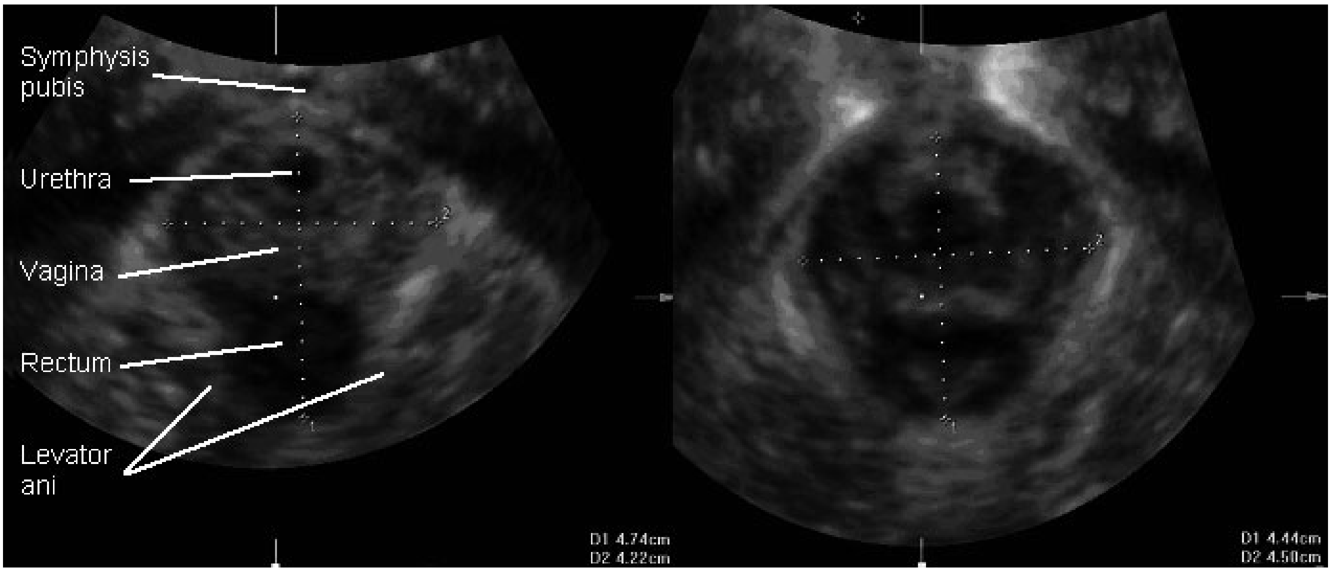


**Figure 3** Levator hiatus at rest (left) and on Valsalva maneuver (right), oblique axial plane at the level of minimal anteroposterior hiatal distance.

analysis and/or Kolmogorov–Smirnov testing), using Minitab Version 13 (Minitab Inc., State College, PA, USA). Pearson's correlation coefficient ($r$) was used to compare normally distributed continuous variables. Repeatability measures were obtained on SPSS (SPSS Inc., Chicago, IL, USA) for all the above parameters in a test-retest series comprising 20 volume datasets assessed by H.P.D. and C.S. in blinded fashion. $P < 0.05$ was considered statistically significant.

## RESULTS

All participants in this study were nulligravid and Caucasian. The mean age was 20.4 (range, 18–24) years, mean body mass index was 23.5 (range, 18.8–33.6). All 52 young women recruited for this study did not have symptoms of prolapse. Three reported stress incontinence and one reported urge incontinence more than once a month. None had a history of pelvic or pelvic floor surgery or physiotherapy intervention for a pelvic floor disorder. Fifteen women (29%) reported knowledge of pelvic floor muscle exercises, and 12 (23%) stated that they consciously contracted the pelvic floor at times. Six (12%) reported regular straining at stool, and nine (17%) described frequent constipation.

2D pelvic floor imaging was performed in all 52 women. On Valsalva, bladder descent was measured to a mean of 12.1 (range, 28.5 above to 10.0 below) mm above the symphysis pubis, uterine descent to a mean of 29.1 (range, 51.0 to 6.0 above) mm above the symphysis pubis, and rectal descent to a mean of 4.6 (range, 43.0 above to 22.0 below) mm above the symphysis pubis.

Of 52 sets of 3D ultrasound volumes, three were excluded from formal analysis since the volumes were technically inadequate (mostly obtained during the initial phase of the study), leaving 49 datasets for measurements taken at rest. In 11 women, datasets on Valsalva maneuver were incomplete due to suboptimal volume acquisition (i.e. incomplete imaging of the whole pubovisceral muscle). Consequently, hiatal area on Valsalva maneuver was available for 38 women only.

Repeatability indices for biometric parameters of the puboviscеral muscle and the levator hiatus were determined in a test-retest series of 20 women. Intraclass correlation coefficient (ICC) values ranked between 0.44 and 0.82 (absolute agreement definition), with best agreement shown for measures of the levator hiatus (0.70 for transverse hiatal diameter, 0.82 for the sagittal hiatal diameter and 0.74 for hiatal area) (Table 1).

Table 2 shows the results of measurements in the axial and coronal planes. There were no significant or near-significant correlations between the above biometric indices and levator function as quantified by cranioventral displacement of the bladder neck on pelvic floor contraction (e.g. total muscle area in the axial plane vs. displacement, $r = 0.09$, non-significant (NS), and hiatus area vs. displacement, $r = 0.08$, NS). However, there were statistically significant correlations between measures of pelvic organ mobility and hiatal area at rest and on Valsalva. Table 3 shows results of Pearson's statistics, correlating hiatal area at rest and on Valsalva maneuver with pelvic organ descent as determined by translabial ultrasound in the mid-sagittal view. Correlations are negative as higher values for those parameters signify a higher organ position (less descent) on Valsalva. The larger the hiatal area, the lower the position of pelvic organs on Valsalva, i.e. the more descent. In all cases, more marked pelvic organ descent was associated with a larger hiatal area on Valsalva.

**Table 1** Intraclass correlation coefficients for parameters of puboviscеral muscle and levator hiatal anatomy on 3D pelvic floor ultrasound (test-retest series, $n = 20$)

| *Parameter* | *ICC* | *95% CI* |
|---|---|---|
| Puboviscеral muscle diameter (axial) | 0.52 | 0.12–0.74 |
| Puboviscеral muscle area (axial) | 0.44 | 0.02–0.70 |
| Levator hiatus at rest (AP diameter) | 0.82 | 0.63–0.92 |
| Levator hiatus at rest (LR diameter) | 0.70 | 0.38–0.86 |
| Hiatal area at rest | 0.74 | 0.49–0.87 |
| Hiatal area on Valsalva | 0.50 | 0.23–0.70 |
| Puboviscеral muscle diameter (coronal) | 0.54 | 0.16–0.75 |
| Puboviscеral muscle area (coronal) | 0.45 | 0.00–0.70 |

AP, sagittal (anteroposterior); ICC, intraclass correlation coefficient; LR, coronal (left to right).

**Table 2** Biometric indices of the puboviscеral muscle and levator hiatus determined in the axial and coronal planes

| *Parameter* | *Mean* | *SD* |
|---|---|---|
| Puboviscеral muscle diameter (axial) (cm) | 0.73 | 0.16 |
| Puboviscеral muscle area (axial) ($cm^2$) | 7.59 | 1.72 |
| Levator hiatus at rest (AP) (cm) | 4.52 | 0.67 |
| Levator hiatus at rest (LR) (cm) | 3.75 | 0.50 |
| Hiatal area at rest ($cm^2$) | 11.25 | 2.70 |
| Hiatal area on Valsalva maneuver ($cm^2$) | 14.05 | 5.87 |
| Puboviscеral muscle diameter (coronal) (cm) | 1.33 | 0.55 |
| Puboviscеral muscle area (coronal) ($cm^2$) | 1.33 | 0.59 |
| Distance from perineal surface (cm) | 2.42 | 0.44 |

AP, sagittal (anteroposterior); LR, coronal (left to right).

**Table 3** Correlations between hiatal area at rest and on Valsalva maneuver and pelvic organ descent as ascertained by translabial ultrasound in the mid-sagittal plane

| *Parameter* | r | $R^2$ *adj. (%)* | P |
|---|---|---|---|
| Hiatal area at rest ($n = 49$) vs. | | | |
| Bladder descent | −0.338 | 9.5 | 0.018 |
| Uterine descent | −0.498 | 23.2 | < 0.001 |
| Rectal descent | −0.407 | 14.7 | 0.004 |
| Hiatal area on Valsalva ($n = 38$) vs. | | | |
| Bladder descent | −0.628 | 37.8 | < 0.001 |
| Uterine descent | −0.656 | 41.4 | < 0.001 |
| Rectal descent | −0.600 | 34.3 | < 0.001 |

$R^2$ adj., Nagelkerke's $R^2$ adjusted on best-fit linear regression.

## DISCUSSION

3D volume transducers currently in use for transabdominal 3D ultrasound are generally well suited for pelvic floor imaging, provided they allow an acquisition angle of at least 70°[9]. Incomplete imaging of the levator hiatus on Valsalva maneuver in this study was at times due to acquisition angle limitations, which may have artificially reduced means for measurements on Valsalva. Fortunately, the newest generation of 3D volume transducers now allow angles of up to 85°, which should reduce the likelihood of incomplete imaging of the levator in women with marked distension ('ballooning') of the hiatus on Valsalva. Another reason for missing data was our lack of experience with volume data acquisition at the time, resulting in asymmetrical or technically inferior volumes on Valsalva maneuver.

This study has established 3D translabial ultrasound as a method for assessing biometric indices of the puboviscеral muscle, both for the muscle itself and the levator hiatus. Measurements of the levator hiatus, such as diameters in the sagittal (ICC 0.82) and coronal planes (ICC 0.70) as well as the hiatal area (ICC 0.74), seem the most reliable, which is most likely due to a high reproducibility of the plane for minimal hiatal dimensions used in this study. Measurements of muscle diameter and area, both in the axial and the coronal plane, were less repeatable, with ICC values ranging from 0.44 to 0.54.

A wide range of biometric measurements was obtained in this group of young nulliparous women, with the area of the levator hiatus varying from approximately 6.34 to 18.06 (mean 11.25) $cm^2$ at rest, and from 6 to 36 (mean 14.05) $cm^2$ on Valsalva maneuver (Table 2). Tunn *et al.* have documented a hiatal area of approximately 15 $cm^2$ at rest in parous women[7]. Data for hiatal width can be compared with MRI data obtained in 10 healthy volunteers, and measurements seem comparable (3.75 cm on 3D ultrasound vs. 4.17 on MRI)[13]. Levator thickness in the axial plane has also been evaluated on MRI, and again measurements are comparable (5.2 to 7.6 mm mean thickness on MRI depending on location, 7.3 mm mean thickness in the present series)[6]. Contrary to what has been described on MRI[13], we found no significant side difference, neither for thickness nor for muscle area.

Significant correlations were documented between levator hiatus area and pelvic organ descent, and this relationship was observed for all three compartments (Table 3). This is not surprising for measurements taken on Valsalva maneuver – the increase in levator hiatus area may be either the cause or effect of pelvic organ descent. It is more remarkable, however, that levator area at rest seemed to predict descent on Valsalva. This confirms work showing a correlation between the clinical dimensions of the urogenital hiatus and prolapse[14]. The wider the hiatus was at rest, the more descent of pelvic organs occurred on Valsalva, and this was true for all three compartments.

In contrast with the hiatal area on Valsalva, measurements taken at rest and in the supine position should be independent of fascial biomechanics. Therefore, our data provide support for the hypothesis that levator ani anatomy plays an independent role in determining pelvic organ support[1]. This role seems to be more important for the central and posterior compartments than for bladder support. Further work will have to focus on levator anatomy in symptomatic women as there is little information to date on whether levator functional anatomy is of relevance for clinical conditions such as urodynamic stress incontinence and pelvic organ prolapse. Another area for future research would be the relevance of levator biometric indices for intrapartum events. The area of the fetal head at term can be estimated at 60–90 $cm^2$ (equivalent to a head circumference of 300–350 mm). It has recently been shown that, based on 3D modeling of an MRI volume obtained at rest, the most inferomedial aspects of the levator have to stretch by a factor of 3.5 to allow vaginal delivery[15].

The data presented here would suggest that there may well be marked variation in the degree of deformation and potential trauma necessary to allow passage of the fetal head, due to variations in both anatomy and biomechanics of the pubovisceral muscle. Some of the young women who underwent imaging in this study, achieved elongation of pubovisceral muscle fibers by a factor of two with a simple Valsalva maneuver (see Figure 4 for an example). Others barely showed any elongation of fibers at maximal Valsalva, which is expected to achieve pressures of well over 100 cm $H_2O$ in young women. It appears likely that both anatomy and biomechanics of the pubovisceral muscle would have an impact on progress in labor as well as on the likelihood of significant intrapartum soft tissue trauma.

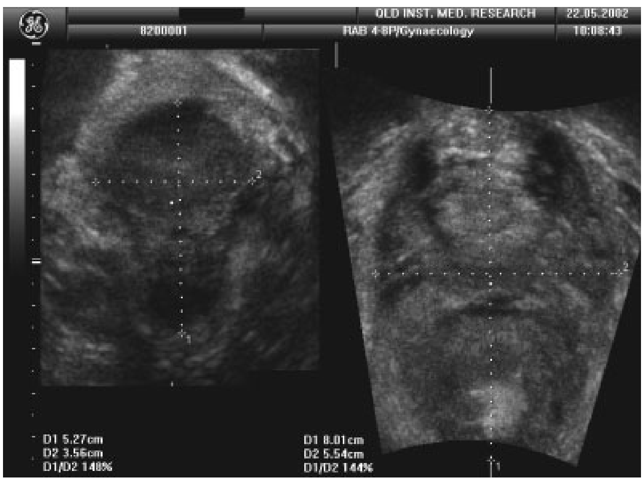


**Figure 4** Marked distension of the levator hiatus on Valsalva maneuver (right) in an asymptomatic 22-year-old nulligravid Caucasian woman. The left image shows measurements at rest.

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