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ORIGINAL ARTICLE

Impact of levator trauma on pelvic floor muscle function

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Abstract

Introduction and hypothesis Levator trauma is common after vaginal delivery, either as macrotrauma, i.e., levator avulsion, or microtrauma, i.e., irreversible overdistension of the levator hiatus. The effect of microtrauma on muscle function is unknown. We tested the hypothesis that levator trauma is associated with reduced contractile function of the levator ani.

Methods Pregnant nulliparous women were recruited and seen before and after childbirth. All underwent an interview, a clinical examination including pelvic floor muscle (PFM) assessment using the Modified Oxford scale (MOS) [as an optional component] and translabial ultrasound. Sonographic and clinical parameters of PFM function were assessed before and after childbirth.

Results Out of 560 women, 446 returned at a median of 5 months after childbirth and 433 were suitable for analysis. There was a significant reduction in all measures of PFM function except for MOS. Change in MOS was associated with delivery mode [analysis of variance (ANOVA) $P = 0.006$). Forty-seven (15 %) vaginally parous women were diagnosed with levator avulsion, which was associated with a reduction in PFM contractility on sonographic parameters and MOS. However, only clinical assessment reached statistical significance. Sixty-five of 312 (21 %) women were diagnosed with microtrauma. We found no evidence of impairment in PFM contractility on ultrasound, but there was a statistically significant reduction in MOS.

Conclusions Both levator avulsion (macrotrauma) and irreversible overdistension (microtrauma) are associated with reduced contractile function. This effect is more easily detected by palpation than by sonographic indices of levator function.

Keywords Childbirth · Translabial ultrasound · 3D/4D ultrasound · Birth trauma · Pelvic floor function · Levator ani

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Introduction

Pelvic floor muscle (PFM) integrity—specifically, integrity of the levator ani—plays a major role in the support of the pelvic organs [1] and maintenance of continence [2]. Damage to the levator ani muscle is common after vaginal delivery. It may take the form of macrotrauma, i.e., levator avulsion [3, 4], or microtrauma, i.e., irreversible overdistension of the levator hiatus [5, 6]. The latter may be more common than avulsion, affecting up to 30 % of women after vaginal delivery [7]. The pathophysiology of irreversible delivery-related overdistension is unclear. It may be due to physical alterations in connective tissue or muscular structures [8], to permanent changes in resting tone or baseline cortical activation, or to changes in neuromuscular pathways [9].

One of the most interesting questions is whether irreversible overdistension is the result of neuropathy, either as the result of alteration of the neuromuscular unit, nerve trauma, or due to some centrally mediated effect. If this is the case, then one would expect an association between irreversible overdistension and contractile function. Deterioration of muscle contractility (strength) would indicate damage to the neuromuscular unit. The same would be expected if overdistension had a direct effect on muscle ultrastructure. Damage to the sarcomeres themselves may be expected if muscle fibers are stretched to ≥130–160 % of their original length [10], which routinely occurs in childbirth [11, 12].

PFM function can be determined by palpation [13], visual observation, electromyography, perineometry, magnetic resonance imaging (MRI) [14], and translabial ultrasound (US) [15–17]. However, to date, no single method has been shown to be optimal [18]. This may be due to the fact that PFM strength has three dimensions that could be assessed in a different fashion by these means: duration, pressure, and displacement [19]. Several arguments favor the use of US as a tool for assessing PFM function. It is noninvasive and relatively inexpensive; provides objective, highly repeatable information; can be performed as part of a standardized urogynecological imaging protocol; allows visual biofeedback [18]; and has been shown to correlate strongly with vaginal palpation of muscle strength and perineometry [20].

The aim of this study was to test the hypothesis that irreversible overdistension of the levator hiatus is associated with a reduction in contractile function of the levator ani muscle.

Materials and methods

This was a retrospective analysis of US volume data sets of 560 nulliparous pregnant women recruited as part of a previously reported [7] and another ongoing prospective study [21]. Inclusion criteria were singleton pregnancy between 35 and 37 weeks of gestation, maternal age ≥18 years, no previous pregnancies >20 weeks of gestation, and uncomplicated pregnancy to date, with the woman aiming for normal vaginal delivery. Participants were recruited between January 2007 and December 2010, were seen between 35 and 37 weeks' gestation, and were invited for a follow-up assessment 3–4 months postpartum. The operator undertaking the follow-up assessment was blinded against antenatal findings and delivery data. All patients had completed a Kings Health Questionnaire (KHQ), the Edinburgh Depression Scale, and a locally validated [22] Sexual Dysfunction Questionnaire. They underwent an optional clinical examination, including Modified Oxford Score grading MOS (*see* Table 1,) [13, 23] and the International Continence Society Pelvic Organ Prolapse Quantification scale (ICS POP-Q) [24] and a translabial 4D US examination using Voluson 730 expert systems with RAB 8–4 MHz transducers (GE Kretz Ultrasound, Zipf, Austria), as previously described [25]. MOS assessment was undertaken by operators with >3 months' experience in digital pelvic floor assessment, who provided tactile biofeedback training, verifying correct contraction technique. Translabial US was performed with the patient in the supine and after voiding. Images were obtained in the midsagittal plane with the angle of acquisition set at 85°. US

Table 1 Modified Oxford Score

Grading	Muscle response
0	Nil
1	Flicker
2	Weak
3	Moderate, slight lift of the exaniner's finger, no resistance
4	Good, sufficient to elevate the examiner's finger against light resistance
5	Strong, sufficient to elevate the examiner's finger against strong resistance

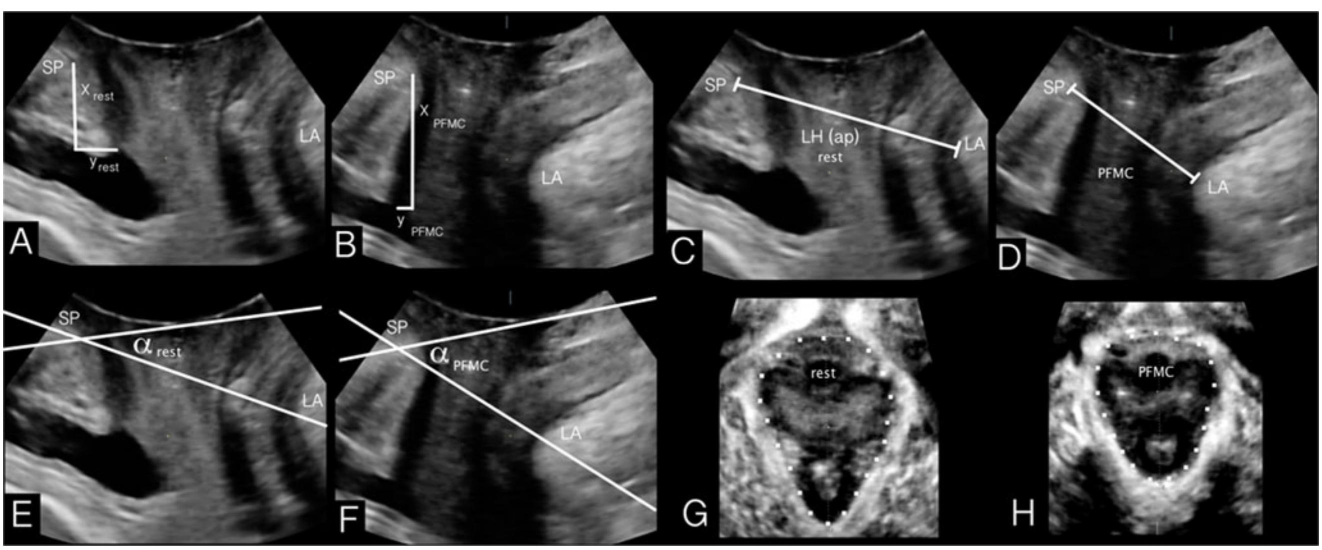

Fig. 1 Assessment of pelvic floor muscle function by translabial ultrasound. **a**, **b** Determination of bladder-neck lift in the midsagittal plane. **c**, **d** Shortening of midsagittal hiatal diameter. **e**, **f** Change in levator plate angle. *GH* reduction in hiatal area on PFMC, *SP* symphysis pubis, *PFMC* pelvic floor muscle contraction, *LH* levator hiatus, *LA* levator ani

Table 2 Delivery data (n=433)

Variable	Results
Gestational age at first assessment (week)	36.4 (±0.9)
Gestational age at delivery (week)	39.9 (±1.2)
Delivery mode	
Vaginal delivery	320 (74 %)
Normal vaginal	232 (54 %)
Forceps	29 (7 %)
Vacuum	59 (14 %)
Caesarean section	113 (26 %)
Prelabor	22 (5 %)
First stage	67 (15.5 %)
Second stage	24 (5.5 %)
Length of first stage median, range)	420 (60–1,465)
Length of second stage (median, range)	60 (0–472)
Use of intrapartum Syntocinon	184/428 (43 %)
Intrapartum epidural	201/428(47 %)
Episiotomy	89/432 (21 %)
Any perineal tear	145/430 (34 %)
third degree	11/430 (2.6 %)
fourth degree	1/430 (0.2 %)
Vaginal tear	63/431 (15 %)
Neonatal birth weight (g)	3,470 (±460)

Data are mean ± standard deviation, number (%), or median (interquartile range)

volumes were acquired with the patient at rest, on Valsalva, and during PFM contraction (PFMC). At least three Valsalva maneuvers and two PFMC were performed, with the best results archived and later analyzed by postprocessing on a desktop personal computer using GE Kretz 4D View v 7.0 (GE Medical Ultrasound, Ryde NSW, Australia). A Valsalva maneuver was performed for a minimum of 5 s to provide for standardization [26]. The US postprocessing operator was blinded against all other data, clinical and sonographic. A test–retest series for all US parameters was conducted prior to analysis and showed good interobserver agreement. Irreversible overdistension (microtrauma) was defined as an increase of >20 % in hiatal area on maximum Valsalva when comparing antenatal and postnatal volume data sets [7]. Levator avulsion was diagnosed on tomographic US imaging (TUI), as described previously [27], with a data set rated positive for avulsion if the puborectalis insertion of all three central slices was abnormal. Partial trauma was diagnosed if there were any abnormal insertions anywhere between the plane of minimal dimensions and the slice 1.25-cm above without fulfilling criteria for a full avulsion. To assess for changes in PFM function, we measured the following US indices before and after childbirth, as previously described [28]: (a) reduction in anteroposterior hiatal diameter, i.e., distance between the inferoposterior margin of the symphysis pubis (SP) and the puborectalis muscle (PM) at the level of the anorectal angle on PFMC, (b) change in levator-plate angle, i.e., angle formed by the central symphyseal axis and a line connecting the inferoposterior margin of the SP to the anorectal angle on PFMC, (c) cranioventral displacement of the bladder neck or bladder-neck elevation relative to the inferoposterior symphyseal margin on PFMC, with the latter calculated as the hypotenuse of a right angle triangle [Disp=square root (Δx2+Δy^2)] to obtain the length of a vector describing bladder-neck displacement on PFMC, and (d) reduction in hiatal area measured in the axial plane of minimal hiatal dimensions on PFMC (*see* Fig. 1). We also compared MOS readings before and after childbirth as a measure of changes in contractile function.

Both parent studies had been approved by the Sydney West Area Health Service Human Research Ethics Committee (SWAHS HREC 07–022 and 05/004). Statistical analysis was performed with Minitab V13 (Minitab, State College, PA, USA). Intraclass correlation coefficient was used to determine interobserver agreement. Student's t test was employed to analyze continuous normally distributed data. Normality was checked using the Kolmogorov–Smirnov method. Analysis of variance (ANOVA) was used to study the association between delivery mode and PFM function; $P<0.05$ was considered statistically significant. As the study was a subanalysis of two parent projects, power calculations were not performed specific to the research question addressed in this study.

Table 3 Change in pelvic floor muscle function in women after a first delivery

Parameters	Antepartum	Postpartum	P value
Bladder-neck elevation (mm)	8.9 (SD 4.1)	6.5 (SD 3.7)	<0.001
Reduction in AP diameter (cm)	0.97 (SD 0.5)	0.83 (SD 0.5)	<0.001
Change in levator angle (°)	11.81 (SD 5.04)	10.43 (SD 4.92)	<0.001
Reduction in hiatal area (cm^2)	3.2 (SD 2.1)	2.6 (SD 1.8)	<0.001
Modified Oxford Score	2.94 (SD 0.85)	2.87 (SD 0.91)	0.172

Number=433 for all parameters except Modified Oxford score (n=332). Paired t test

AP anteroposterior, *SD* standard deviation

Table 4 Comparison between women with avulsion or no avulsion in postpartum change on pelvic floor muscle function parameters

Parameters	No avulsion $n=386$	Avulsion $n=47$	P value
BNE change (mm)	−2.31 (SD 4.39)	−3.11(SD 3.66)	0.177
AP diameter change (cm)	−0.13 (SD 0.52)	−0.19 (SD 0,55)	0.49
Levator angle change (°)	−1.19 (SD 5.86)	−2.99 (SD 6.34)	0.07
Area change (cm^2)	−0.59 (SD 2.51)	−0.98 (SD 2.38)	0.30
Modified Oxford Score change	−0.011 (SD 0.912)*	−0.56 (SD 0.928)**	0.002

BNE bladder-neck elevation, *AP* anteroposterior, *SD* standard deviation

*$n=297$ **$n=35$.;two-sample t test

Results

In a test retest series of 20 US volume data sets, the intraclass correlation coefficient (ICC) for reduction in anteroposterior (AP) diameter of the hiatus was 0.73 [95% confidence interval (CI) 0.43–0.88], change in levator plate angle 0.67 (CI 0.33–0.86), bladder-neck elevation change 0.94 (CI 0.86–0.97), and reduction in hiatal area 0.71 (CI 0.4–0.87), signifying good to excellent repeatability.

Of 560 original participants seen at an average gestation of 36.4 (range, 33.2–38.3) weeks, 446 (79 %) returned for their postpartum assessment an average of 5 months after childbirth [median, 4.4 months, interquartile range (IQR), 3.8–5.4 months]. Thirteen were excluded because of missing data ($n=5$), poor image acquisition ($n=4$), second pregnancy at the postpartum assessment ($n=3$) .and another delivery in the interim ($n=1$), leaving 433 data sets to which the following analyses apply: mean age 29.2 [standard deviation (SD) 5.4, range 18–45) years, body mass index (BMI) in late pregnancy 29.7 (SD 5.3), 86 % Caucasians. Three hundred and twenty women (74 %) had a vaginal delivery [normal vaginal delivery (NVD) 232 (54 %), vacuum 59, (14 %); forceps 29 (7 %)]; 113 (26 %) had a cesarean section (CS) [prelabor CS 22 (5 %); first-stage CS 67 (15.5 %); second-stage CS 24, (5.5 %)]. Table 2 shows delivery-related data. At the antenatal appointment, participants complained of stress urinary incontinence (SUI) ($n=148$, 34 %), urge urinary incontinence (UUI) ($n=34$, 8 %), urinary frequency ($n=259$, 60 %), nocturia ($n=271$, 63 %), and symptoms of prolapse ($n=15$, 3 %).

At the postnatal appointment, participants complained of SUI ($n=113$, 26 %), UUI ($n=37$, 8.5 %), frequency ($n=106$, 24 %), nocturia ($n=34$, 7.9 %), and symptoms of prolapse ($n=16$, 4 %). Three hundred and thirty-two women agreed to an optional vaginal examination, with an average mean MOS of 2.87 and no side difference. On comparing ante- and postpartum assessments, there was a significant reduction in all measures of PFM function except for MOS (*see* Table 3). However, only the change in MOS was associated with delivery mode (ANOVA, $P=0.006$).

Forty-seven participants (15 % of 320 vaginally parous women) were diagnosed with levator avulsion (32 unilateral and 15 bilateral). Avulsion was associated with a statistically significant reduction in PFM contractility as measured by MOS but not by sonographic criteria (*see* Table 4). Partial trauma, that is, patients with abnormal indications on TUI that did not reach minimal criteria for a full avulsion, was diagnosed in 73 women (22.8 % of vaginally parous women).

After excluding women with avulsion or partial trauma, 65/312 women were diagnosed with microtrauma (20.8 %). We found no evidence of impairment in levator muscle contractility on US parameters. In fact, some measures, such as hiatal diameter and hiatal area reduction on PFMC, seemed improved. However, there was a statistically significant reduction on clinical assessment using the MOS (Table 5).

Table 5 Comparison between women with and without microtrauma, excluding avulsion and partial trauma

Parameters	No microtrauma $n=248$	Microtrauma $n=65$	P value
BNE change (mm)	−2.38 (SD 4.37)	−1.29 (SD 4.7)	0.096
AP diameter change (cm)	−0.179 (SD 5.12)	0.1 (SD 0.53)	<0.001
Levator angle change (°)	−1.21 (SD 5.89)	0.19 (SD 5.35)	0.07
Area change (cm^2)	−0.80 (SD 2.47)	0.63 (SD 2.42)	<0.001
Modified Oxford Score change	0.102 (SD 0.89)*	−0.366 (SD 0.85)**	0.001

BNE bladder-neck elevation, *AP* anteroposterior, *SD* standard deviation

*$n=181$, **$n=56$. 2Two-ample t test

Discussion

In this retrospective analysis of a series of >400 primiparous women seen before and after a singleton delivery at term, 15 % of vaginally parous women were diagnosed with levator avulsion and 21 % with microtrauma. PFM function, as determined by US, was significantly reduced after childbirth, which agrees with a previously reported study by one of the authors [29]. Peschers et al. [16] showed similar findings in a cohort of primiparous and multiparous women 3–8 days postpartum among women who had a vaginal delivery. However, in their study, muscle strength on palpation and US was restored to antenatal values at 6–10 weeks postdelivery, and only perineometry pressures remained significantly lower in primiparous women. However, the sample size in their study was small (eight primipara and seven multipara). Our observation of a highly consistent reduction in all US measures of contractility in contrast to unchanged MOS may be explained by hormonal effects on tissue elasticity/compliance. Stiffer tissue would result in reduced displacement for a similar contractile strength.

As regards levator avulsion, this finding was significantly associated with a reduction in MOS, and there was a trend toward a reduced levator plate angle. This is not surprising, as disconnection of a muscle from its insertion is bound to result in functional impairment. Our results are consistent with data showing a greater subjective reduction of PFM function after avulsion injury postpartum [30] and with studies in symptomatic women showing an association between avulsion and reduced contractile strength [31, 32]. Microtrauma to the levator muscle, i.e.., overdistension of the levator hiatus, was associated with a highly significant reduction in MOS, which may suggest that this sonographically defined entity describes actual trauma to neuromuscular units rather than just a resetting of resting muscle tone.

Rather counterintuitively, however, US measures of PFM contractility in some instances seemed superior in women classified with microtrauma. This may be due to a basic limitation of sonographic measures of PFM function, which rely on displacement of anatomical structures. If there is an increase in distensibility of support structures, even an inferior contractile effort may result in a greater anatomical change due to a lower baseline from which the displacement occurs. This effect may also have confounded sonographic measures of PFM function in women after avulsion. In this context, it appears that MOS obtained by simple digital palpation may be a superior measure of contractile function.

A number of limitations of our study must be acknowledged. First is the retrospective analysis of data sets of two prospective studies. Thus, we did not perform power calculations to address our research question. However, to our knowledge, this is the largest series of patients reported to date addressing this topic. Another limitation is the wide variation in timing of the postpartum assessment. Differences in PFM strength may be time dependent and may be affected by posttraumatic reinnervation. However, as only 16 individuals had follow-up intervals between 2.3 and 3 months, muscle reinnervation should have been complete in the vast majority [33]. In addition, it would have been preferable to provide other objective measures of PFM function, such as perineometric measurements, and concentric needle electromyography (CNE) may have shed light on a potential neuropathic contribution to changes observed by us. However, compliance with follow-up is critical in studies of this kind, and addition of invasive techniques, particularly any intervention likely to cause pain (such as CNE) would very likely have resulted in a substantial reduction in recruitment and follow-up.

In summary, both levator avulsion (macrotrauma) and irreversible overdistension (microtrauma) of the levator hiatus seem to have a negative effect on contractile function of the levator ani muscle. This change did not reach significance for all sonographic indices of PFM contractility but was highly significant on digital palpation.

Conflicts of interest None.

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