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Are bony pelvis dimensions associated with levator ani defects? A case–control study

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Abstract

Introduction and hypothesis—Bony pelvis dimensions have been shown to differ in women with and without pelvic floor dysfunction. The goal of this study was to determine whether bony pelvis dimensions are different when comparing women with severe bilateral levator ani defects (LAD) with those with normal muscles.

Methods—This is a secondary analysis of a case–control study comparing women with and those without pelvic organ prolapse. Subjects underwent pelvic organ prolapse quantification (POP-Q) examination and were classified as either having prolapse or being normal. All underwent pelvic magnetic resonance imaging (MRI). Levator defects were assessed based on the muscles' appearance on imaging and subjects were stratified into two groups—women with normal muscles (n=99) and women with severe bilateral LAD (n=50). Bony pelvis dimensions were measured via MRI pelvimetry. The subpubic angle, interspinous and intertuberous diameters, and the sacrococcygeal joint-to-infrapubic point (SCIPP) lengths were compared.

Results—Both groups had similar demographics. The SCIPP length was 2.5 % (3 mm) shorter in women with severe LAD than in those without defects (P=0.02). The SCIPP measured 4 % (5 mm) less in women with prolapse and severe LAD than in subjects with prolapse but normal muscles (P=0.01). Logistic regression identified SCIPP length and history of forceps delivery as being independent predictors of severe bilateral LAD.

Conclusions—Severe bilateral LAD are associated with shorter SCIPP length and forceps-assisted vaginal delivery.

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Keywords

Bony pelvis; Levator ani defects; Magnetic resonance imaging; Pelvic floor disorders; Pelvic organ prolapse

Introduction

Levator ani defects (LAD) have been associated with pelvic floor dysfunction, including pelvic organ prolapse and fecal incontinence [1, 2]. Vaginal delivery is a well-characterized risk factor for levator ani avulsion injuries; however, relatively few demographic and obstetric characteristics have been identified as being associated with LAD, including older maternal age, use of epidural anesthesia, and forceps assistance [3, 4].

One possible set of maternal characteristics that may be associated with the development of LAD is the size of the bony pelvis. The bony pelvis has historically been assessed by obstetric providers because of its effects on birth mechanics [5]. It has previously been demonstrated that there are differences in bony pelvis dimensions when comparing women with and without pelvic floor dysfunction [6–8]. It is therefore plausible that variations in bony pelvic dimensions may pose as risk factors for delivery-induced levator ani trauma, and hence, pelvic floor dysfunction. Our understanding of these possible effects is limited by the fact that previous studies often involved comparisons of non-demographically matched groups. The differences in pelvic dimensions may therefore reflect differences in race/ethnicity, rather than true associations with pelvic floor dysfunction [9]. It is not known whether bony pelvis dimensions are related to the presence or absence of LAD that might partially mediate the increased occurrence of pelvic floor disorders. The goal of this study was to investigate whether levator ani injuries are associated with bony pelvis dimensions at the level of pelvic floor attachments.

Materials and methods

This is a secondary analysis of an institutional review board-approved case–control study examining levator ani defects in women with clinically diagnosed pelvic organ prolapse and in women with normal pelvic support (University of Michigan Institutional Review Board IRBMED #HUM00043445). Results from the parent study have been published previously [10]. Subjects self-completed questionnaires, including questions about demographics and obstetric and gynecological history. All subjects underwent clinical examination, including pelvic organ prolapse quantification (POP-Q) examination in a semi-recumbent lithotomy position [11]. In the parent study, subjects were classified as cases (with pelvic organ prolapse) if any POP-Q point was measured at least 1 cm beyond the hymen. Controls were identified as subjects with all POP-Q points at least 1 cm above the hymen and who had no demonstrable stress urinary incontinence. The original groups were selected to be of similar age, race, and parity by matching the controls to women already enrolled as cases. The controls were selected if they were within 5 years of the age of a case, if they were of the same race, and if they had similar parity (within one).

All subjects underwent pelvic magnetic resonance imaging (MRI). Complete details of MRI acquisition in these groups have been published previously [10], and include acquisition of 5-mm spaced fast-spin proton density images in the axial, coronal, and sagittal planes in the supine position using a 1.5-T superconducting magnet (Signa; General Electric Medical Systems, Milwaukee, WI, USA). Levator ani defects were graded on MR scans by two independent investigators blinded to the prolapse status [12]. The right and left muscles were each graded separately, with possible scores 0 (no defect), 1 (less than half of the muscle was missing), 2 (more than half of the muscle was missing), or 3 (complete loss of muscle bulk). The total levator ani defect score was the sum of the scores from each side, with totals ranging from 0 to 6. For this analysis, women were included if they had no levator ani defects (total LAD score 0) or severe bilateral muscle defects (defined as a total LAD score of 5 or 6). Women with LAD scores of 1 to 4 were excluded. All subjects included in this analysis had previously undergone vaginal delivery.

For each subject with digital MRIs available demonstrating all the relevant anatomical landmarks, the interspinous diameter (Fig. 1a), intertuberous diameter (Fig. 1b), subpubic angle (Fig. 1b), and sacrococcygeal joint-to-the-inferior pubic point (SCIPP) distance (Fig. 1c) [13] were measured. These bony dimensions were chosen to reflect boundaries and attachment sites of the pelvic floor musculature. All measurements were made independently by two authors (M.B.B. and S.K.D.) using ImageJ 1.42q software (National Institutes of Health, Bethesda, MD, USA), and the average value of each pelvic dimension was used for analyses. The SCIPP lengths were measured on bony midsagittal slices by drawing a line from the arcuate pubic ligament that forms the caudal end of the pubic symphysis to the inferior–ventral aspect of the periosteum of the sacrococcygeal joint. The length of this line was calculated using ImageJ 1.42q software.

Since an individual subject may have asymmetric anatomy, and the long axis of the subject is not always perpendicular to the axial plane of the MR images, the relevant landmarks for determination of the interspinous and intertuberous diameter lengths and the subpubic angle may not be visualized on the same axial image. We therefore identified the (x, y, z) coordinates for the infrapubic point, the ischial spines, and the ischial tuberosities on axial images, and then calculated the length or angle between them using geometric functions. The infrapubic point was identified as the midline point at the inferior edge of the arcuate pubic ligament on the first image with right-to-left continuity of the ligament while scrolling through the images in a caudad-to-cephalad direction [14]. The coordinates of the ischial spines were identified at the medial aspect of the periosteum at the level of maximal insertion of the sacrospinous ligaments into the spines. The ischial tuberosities were similarly marked at the medial aspect of the periosteum at the medial tip of the insertion site of the sacrotuberous ligaments into the tuberosities, selecting the first image in which the insertion site appears when scrolling through the images from a cephalad-to-caudad direction. Distances between points were calculated using the Pythagorean theorem, and the sub-pubic angle was calculated as the angle between the two lines generated by connecting the infrapubic point to each ischial tuberosity; the angle was calculated using the geometric law of cosines.

We used published differences in pelvic dimensions in women with and without pelvic floor disorders (PFD) as a proxy to calculate an estimate of our study's power, because data concerning the measures of interest in women with and without severe bilateral levator ani defects were not available. Handa et al., identified statistically significant differences in both the interspinous and intertuberous diameter lengths (amongst other pelvic measurements) in women with pelvic floor disorders compared with women without PFD [6]. Using the results from the Handa study and the sample sizes available in our sample set, we estimate that we have 95.0–99.3 % power with a 95 % two-sided confidence interval to detect similar magnitude differences in the interspinous and intertuberous diameters in our subjects, as measured by Handa and colleagues.

Comparisons were made using the independent Student's *t* test or Mann–Whitney *U* test for continuous variables, and the Chi-squared test for categorical variables. Inter-rater reliability was assessed using intraclass correlation coefficients. PASW version 18.0 (IBM Corporation, Armonk, NY, USA) was used for statistical analysis, and OpenEpi version

2.3.1. [15] was used for power calculations. *P* values less than 0.05 were considered statistically-significant.

Results

Of the vaginally parous women in our parent study, there were 99 subjects with no levator ani defects, and 50 subjects with severe bilateral LAD for whom MRIs were available with the relevant bony landmarks visible. Demographics of these two groups were similar (Table 1). However, as levator ani defects are so highly associated with pelvic organ prolapse [10, 16], the proportion of subjects with prolapse in the severe bilateral LAD group was more than 3-fold higher than that in the group with normal muscles (Table 1). This is further reflected by the significantly higher values of POP-Q measurements, i.e., more descent, in the anterior, apical, and posterior vaginal wall compartments in the subjects with severe bilateral LAD than in those with no defects (Table 1).

Inter-rater reliability for all bony pelvic dimension measurements was high, with intraclass correlation coefficients (ICCs) for the various pelvic measurements ranging from 0.975 to 0.995. *P* s (using average measures) for all of these ICCs were less than 0.001.

Bony pelvis measurements from the group with normal muscles and the group with severe bilateral LAD are presented in Table 2. The only pelvic dimension for which there is a statistically significant difference is the length of the SCIPP line, which is 2.5 % (3 mm) shorter in women with severe levator ani defects than in women with normal muscles.

Since LAD are so highly associated with pelvic organ prolapse, we separately analyzed bony pelvis dimensions only in the subset of subjects (both with normal muscles and with severe bilateral LAD) with clinically diagnosed prolapse (Table 3). There were 31 subjects with normal muscle morphology who had prolapse, and 49 subjects in the group with severe bilateral levator ani defects. Again, the only pelvic dimension for which there was a statistically significant difference between the two groups is the length of the SCIPP line, which is approximately 4 % (5 mm) shorter in the women with severe muscle defects, compared with those with normal levator ani appearance. A similar analysis looking at the subset of women with normal pelvic support (controls) could not be meaningfully performed as there was only one subject with normal support and severe bilateral LAD.

Logistic regression was used to identify characteristics that could plausibly play a role in the development of severe bilateral levator ani defects. We first analyzed demographics, obstetric and gynecological factors, and bony pelvic measurements in univariate analyses (Table 4). The only variables with statistically significant associations with the presence of severe bilateral LAD are a history of forceps-assisted vaginal delivery and the length of the SCIPP line. Multivariate logistic regression was then performed, with the final model shown in Table 4. This model further confirmed that the length of the SCIPP line is associated with severe muscle injuries, even after controlling for forceps delivery.

Discussion

The results of this study show that the anterior-to-posterior bony pelvis dimension, as measured by the SCIPP length, is shorter in women with severe bilateral levator ani defects than in women with normal pelvic floor muscles. This observation holds true whether analyzing all subjects or only women with pelvic organ prolapse. We are unable to detect differences in the remainder of the bony pelvis dimensions comparing women with severe bilateral LAD and those with no levator defects.

There are two conceptual models with which the association between bilateral LAD and a shorter SCIPP length might be explained: first, levator ani avulsions result in changes to the bony pelvis, and second, shorter anterior-to-posterior (A-P) dimension of the bony pelvis predisposes women to birth trauma resulting in severe bilateral LAD. As our case–control study design does not allow for causal determination, we cannot definitively prove or disprove either hypothesis. However, we favor the latter postulate, i.e., a shorter SCIPP distance increases a woman's risk of birth-related levator ani trauma. On average, a shorter pelvis would be associated with shorter muscles. For a given fetal size, the shorter the muscle length before delivery, the more it will have to stretch to allow for birth to occur. It is certainly possible that a short A-P pelvic dimension predisposes women to difficult delivery, and thereby increases the frequency with which they are delivered with forceps assistance, a known factor causing LAD. However, the results from our multivariate logistic regression suggest that a shorter SCIPP length might not lead to severe bilateral LAD solely by increasing women's risk of operative vaginal delivery. Furthermore, our prior work reveals that levator injury occurs in the portion of the muscle that undergoes the greatest degree of stretch [17]. It is therefore teleologically plausible that a shorter anterior-to-posterior pelvic dimension would result in greater stretch of the levator ani during vaginal delivery, thereby predisposing to muscle injuries. By contrast, the normal role of the levator ani musculature is to maintain constant tension to compress the pelvic organs in a caudad-to-cephalad direction [18]. If major avulsion injuries of these muscles were to result in bony pelvis changes, they would therefore likely cause lengthening of the SCIPP line, compared with the shorter distance seen in our analysis.

Despite the strong association between levator ani defects and pelvic organ prolapse [10, 16], and the findings in this study that a shorter SCIPP distance is associated with severe bilateral levator ani defects, several published studies suggest that anterior-to-posterior bony pelvis dimensions might be similar in women with pelvic organ prolapse and those with normal support [19, 20]. At this time, it is not clear why a shorter SCIPP length would predispose to severe bilateral levator ani defects, but not pelvic organ prolapse. One possibility is that we are only looking at the extremes of muscle morphology, whereas the aggregate of women with prolapse fall within a spectrum of levator ani defects [10, 21]. Furthermore, the development of pelvic organ prolapse involves a complex interplay of genetics, tissue biochemistry, and pelvic floor muscle function [22–24]. It is therefore likely that risk factors for levator ani injury may not always prove to play similar roles in the development of prolapse. However, it is becoming increasingly clear that levator ani defects may play a role in pelvic floor structure and function, irrespective of pelvic organ prolapse [25].

There are several strengths to this study, including large sample sizes, availability of high resolution images for measurement from women with known symptom status and assessment of pelvic organ support on physical examination, minimization of confounders through demographic matching, the use of objective measures of levator ani defects with high inter-rater reliability, and the use of control subjects who were all healthy, asymptomatic volunteers rather than women seeking care for other reasons. Limitations of the study include the case–control design, which prevents the ability to determine causality or temporal changes, the relative racial homogeneity of our subject pool, which may limit the generalizability of the findings, the risk of recall bias for obstetric and gynecological factors, inherent limitations of image analysis, and the small magnitude of the differences in the bony pelvic dimensions identified. Our study was not powered to detect smaller differences between measurements, but we would wonder whether such small differences would be clinically significant. Furthermore, the magnitude of the differences in pelvic dimensions we identified is similar to what has been shown in other studies, suggesting that this might be a widely reproducible finding [7, 26, 27]. We acknowledge that this study may be limited by spectrum bias as we only evaluated women at the extremes of LAD scores. Future studies evaluating associations between pelvic dimensions and the entire range of LAD scores would be helpful in better characterizing these relationships.

Conclusion

The results of this study suggest the hypothesis that a shorter anterior-to-posterior bony pelvis dimension might be associated with an elevated risk of traumatic birth injury. These findings supplement the growing body of evidence that pelvic shape and size are associated with the development of pelvic floor disorders [6–8, 19, 26–28]. Although these studies utilized a variety of imaging techniques to assess pelvic dimensions, and a wide range of pelvic floor disorders were investigated, they collectively highlight the influence that the bony pelvis may have not only on childbirth, but with lasting effects throughout a woman's lifetime.

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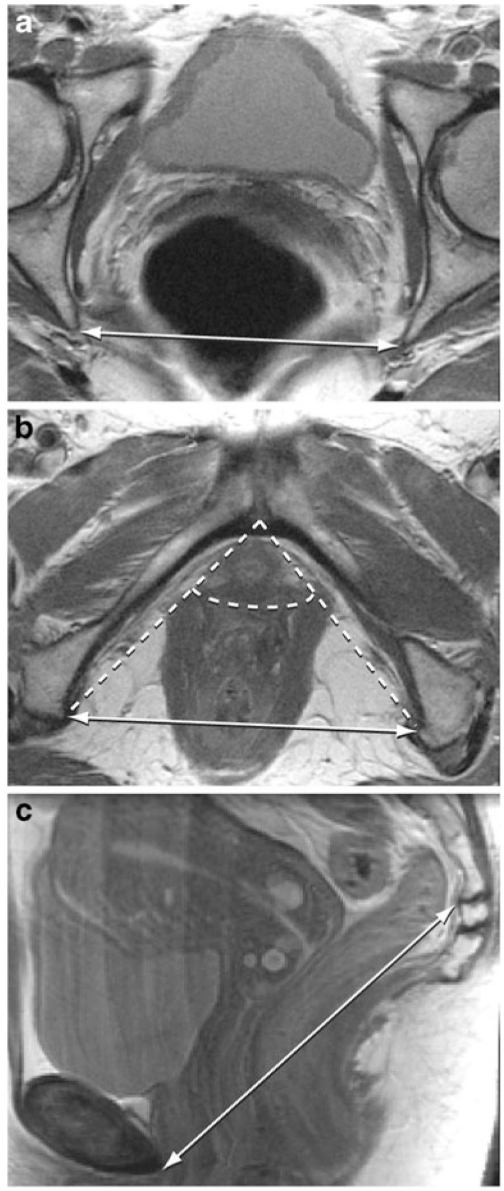

Fig. 1.

a Axial pelvic magnetic resonance imaging (MRI) slice demonstrating the interspinous diameter (*double-headed arrow*). **b** Axial pelvic MRI slice illustrating the intertuberous diameter (*solid double-headed arrow*) and subpubic angle (*dashed lines*). **c** Sagittal pelvic MRI slice demonstrating the sacrococcygeal joint-to-infrapubic point (SCIPP) line (*double-headed arrow*)

Table 1

Demographics and vaginal topography—women with normal muscles and women with severe bilateral levator ani defects

Characteristic	**Normal muscles (*n*=99)**	**Severe bilateral LAD (*n*=50)**	***P* value**
Age (years)	54.8±12.1	55.4±12.5	0.79
BMI (kg/m^2)	26.8±5.0	25.8±5.0	0.26
Height (inches)	64.2±2.6	64.4±3.3	0.66
Vaginal parity	2.0 (2.0, 3.0)	2.0 (2.0, 3.0)	0.54
Caucasian (%)	92.8 (90/97)	94 (47)	1.00
Forceps delivery (%)	25.9 (22/85)	74.4 (32/43)	<0.001
Cesarean delivery (%)	7.1 (7/98)	4.0 (2)	0.72
Weight of heaviest baby (gm)	3,585±588	3,760±396	0.06
Hysterectomy (%)	13.3 (13/98)	16.0 (8)	0.63
Postmenopausal (%)	63.2 (60/95)	66.7 (32/48)	0.72
Taking ERT (%)	18.8 (18/96)	24.5 (12/49)	0.52
Prolapse (%)	31.3 (31)	98 (49)	<0.001
POP-Q point Aa (cm)	−1.0 (−2.0, −1.0)	0 (0, 1.0)	<0.001
POP-Q point Ba (cm)	−1.0 (−2.0, −1.0)	2.0 (0, 3.0)	<0.001
POP-Q point C (cm)	−6.0 (−7.0, −5.0)	−1.0 (−4.0, 3.0)	<0.001
POP-Q point Ap (cm)	−2.0 (−2.0, −1.0)	0 (−2.0, 1.0)	0.005
POP-Q point Bp (cm)	−2.0 (−2.0, −1.0)	0 (−2.0, 1.0)	0.001

All data are presented as mean ± standard deviation, median (25th percentile, 75th percentile), or percentage (number of subjects). Denominators are presented in the number of subjects if there are missing data

Forceps delivery was defined as the percentage of women having had at least one forceps-assisted vaginal delivery

Cesarean delivery was defined as the percentage of women having had at least one Cesarean delivery

LAD levator ani defects, *BMI* body mass index, *ERT* estrogen replacement therapy, *POP-Q* Pelvic Organ Prolapse Quantification

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Table 2

Bony pelvis dimensions from all subjects, comparing women with normal muscles and women with severe bilateral levator ani defects

Bony pelvis measurement	Normal muscles (*n*=99)	Severe bilateral LAD (*n*=50)	*P*
Interspinous diameter (cm)	10.7±0.8	10.6±0.7	0.77
Intertuberous diameter (cm)	11.2±1.0	11.1±0.8	0.40
Subpubic angle (°)	89.5±7.4	88.2±7.2	0.31
SCIPP length (cm)	11.9±1.0	11.6±0.7	0.02

All data are presented as mean ± standard deviation

LAD levator ani defects, *SCIPP* sacrococcygeal joint-to-the-inferior pubic point

Table 3

Bony pelvis dimensions from subjects with prolapse, comparing women with normal muscles and women severe bilateral levator ani defects

Bony pelvis measurement	Normal muscles (*n*=31)	Severe bilateral LAD (*n*=49)	*P*
Interspinous diameter (cm)	10.7±0.9	10.6±0.7	0.44
Intertuberous diameter (cm)	11.5±1.1	11.1±0.8	0.09
Subpubic angle (degrees)	90.6±8.2	88.2±7.3	0.19
SCIPP length (cm)	12.1±0.9	11.6±0.7	0.01

All data are presented as mean ± standard deviation

LAD levator ani defects, *SCIPP* sacrococcygeal joint-to-the-inferior pubic point

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Table 4

Logistic regression models predicting severe bilateral levator ani defects

Independent variable	Odds ratio	95 % CI	Regression coefficient	Standard error	*P*
Univariate analyses					
Age (years)	1.00	0.98–1.03	0.004	0.01	0.78
Vaginal parity	0.92	0.73–1.16	−0.08	0.12	0.49
Height (inches)	1.03	0.91–1.16	0.03	0.06	0.66
BMI (kg/m^2)	0.96	0.89–1.03	−0.04	0.04	0.26
Forceps delivery	8.33	3.60–19.29	2.12	0.43	<0.001
Cesarean delivery	0.54	0.11–2.71	−0.61	0.82	0.46
Weight of heaviest baby (gm)	1.00	1.00–1.00	0.001	<0.001	0.06
Hysterectomy	1.25	0.48–3.24	0.22	0.49	0.65
Postmenopausal	1.17	0.56–2.42	0.15	0.37	0.68
Taking ERT	1.41	0.61–3.22	0.34	0.42	0.42
Interspinous diameter (cm)	0.99	0.95–1.04	−0.007	0.02	0.78
Intertuberous diameter (cm)	0.99	0.95–1.02	−0.01	0.02	0.43
Subpubic angle (degrees)	0.98	0.93–1.02	−0.02	0.02	0.31
SCIPP length (cm)	0.96	0.92–1.00	−0.05	0.02	0.03
Multivariate analysis					
Intercept	–	–	5.98	2.99	0.05
Forceps delivery	10.70	4.27–26.81	2.37	0.47	<0.001
SCIPP length (cm)	0.94	0.89–0.99	−0.07	0.03	0.01

Forceps delivery is coded as 1 if the subject had at least one forceps-assisted vaginal delivery, 0 if she never had a forceps delivery

Cesarean delivery is coded as 1 if the subject had at least one Cesarean delivery, 0 if she never had a Cesarean section

C.I. confidence interval, *BMI* body mass index, *POP-Q* Pelvic Organ Prolapse Quantification, *ERT* estrogen replacement therapy, *SCIPP* sacrococcygeal joint-to-the-inferior pubic point