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Comparison of bony dimensions at the level of the pelvic floor in women with and without pelvic organ prolapse

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Abstract

Objective—Compare bony pelvis dimensions at the level of pelvic support in women with and without pelvic organ prolapse (POP).

Study Design—Pelvic floor dimensions of 42 Caucasian women with POP ≥ 1 cm beyond the hymen were compared to 42 age and parity-matched women with normal support. Bony landmarks relevant to connective tissue and levator attachments were identified on MRI. Dimensions were independently measured by two examiners and averaged for each subject.

Results—Measurements (cms) for cases and controls are as follows: Interspinous Diameter, 11.2 ± 0.8 vs. 11.1 ± 0.7 , $p=0.19$; Anterior-Posterior Outlet Diameter, 11.7 ± 0.7 vs. 11.7 ± 0.8 , $p=0.71$; Pubic Symphysis to Ischial Spine - Left, 9.5 ± 0.5 vs. 9.5 ± 0.4 , $p=0.91$; -Right, 9.5 ± 0.4 vs. 9.5 ± 0.5 , $p=0.81$; Sacrococcygeal junction to Ischial Spine - Left, 7.0 ± 0.6 vs. 7.0 ± 0.5 , $p=0.54$; - Right, 7.0 ± 0.6 vs. 6.9 ± 0.4 , $p=0.32$.

Conclusion—Bony pelvis dimensions are similar at the level of the muscular pelvic floor in Caucasian women with and without POP.

Keywords

bony pelvis; prolapse; pelvic floor; pelvic dimensions

Introduction

Pelvic organ prolapse is defined as the downward descent of female pelvic organs. Epidemiologic studies are lacking on the prevalence of symptomatic prolapse; however, we do know that by 1997 statistics, 225,000 women underwent surgery for correction of prolapse (at a cost estimated at \$1 billion US dollars), and that prolapse is the leading indication for postmenopausal hysterectomy.^{1,2}

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Several hypotheses have been generated in an effort to identify risk factors associated with pelvic organ prolapse. One of these concerns the size and shape of the pelvis. These observations have concerned traditional obstetrical dimensions developed to assess pelvic capacity for vaginal delivery. They have investigated pelvic size as it relates to pelvic floor injury with the hypothesis that pelvic architecture may influence the occurrence of pelvic floor injury during vaginal birth.³ Handa's case control study utilizing pelvic magnetic resonance imaging demonstrated a wider transverse pelvic inlet and shorter obstetrical conjugate in women with pelvic floor disorders.⁴ Sze found a wider transverse inlet in CT scans of women with prolapse compared with normal controls.⁵

However, there is another way in which pelvic architecture might influence pelvic organ prolapse. The shape or dimensions formed by the attachments of the muscular floor to the bony pelvis might predispose a woman to prolapse. It is possible that different pelvic sizes or shapes pose different mechanical challenges in supporting the pelvic organs relevant to the problem of pelvic organ prolapse. In a prior report we described a series of measurements relevant to the attachment points of critical pelvic floor structures to the bony pelvis.⁶ The purpose of this study is to compare the dimensions of the bony pelvis at the level of the pelvic floor in matched cohorts of women with and without pelvic organ prolapse.

Methods

MRI scans for analysis were taken from a larger IRB approved case control study with group matching for age and parity among women with pelvic organ prolapse (cases) and women with normal pelvic organ support (controls).⁷ These women were recruited from The University of Michigan Urogynecology Clinic and advertisements sent to the surrounding community from November 2000 through October 2004. In order to remove race as a confounder, all included subjects were Caucasian. To be a case a woman had to have a portion of the vaginal wall or cervix at least one centimeter below the hymen. The control group was recruited to match for age, race, BMI, parity, and hysterectomy status. To be a control all areas of the vagina and cervix (or apex) had to be at least one centimeter above the hymen. Potential controls were excluded if they demonstrated stress urinary incontinence on a pre-study full bladder stress test.

All subjects underwent clinical examination which included assessment of prolapse status utilizing the pelvic organ prolapse quantification (POP-Q) system. In addition, they completed a full bladder stress test and pelvic floor functional studies as described in the parent study.⁷

Sample size was chosen based on a pre-study power calculation that indicated a sample size of 21 subjects in each group would be needed to achieve an alpha of 0.05 and a beta of 0.8 using the 4% difference in means and the standard deviations in transverse diameters found by Sze.⁵ We chose to double this number in case different values were found. The study set was assembled by selecting artifact-free complete scans from consecutively recruited women beginning with the most recently recruited women and working backward until the target sample was obtained.

Imaging

All subjects underwent a magnetic resonance (MR) imaging scan using our established protocol.⁸ This included axial, sagittal, and coronal two-dimensional fast spin proton density MR scans (echo time: 15 ms, repetition time: 4000 ms) obtained in the supine position with a 1.5 Tesla superconducting magnet (Signa; General Electric Medical Systems, Milwaukee, WI). The slice thickness was 4 mm with a slice gap of 1mm, yielding an image spacing of 5 mm using a 160 × 160 mm field of view and an imaging matrix of 256 × 256.

Bony Pelvis Dimensions

Bony landmarks associated with attachment sites of the muscular pelvic floor were identified on MR scans for each subject and included the following: 1) the arcuate pubic ligament (APL) that forms the inferior margin of the pubic symphysis anteriorly, 2) the left and right ischial spines laterally (IS_L, IS_R), and 3) the midline sacral-coccygeal articulation posteriorly (S5/Co1) (Figure 1). This later point was chosen rather than the inferior lateral angle of the sacrum which we used previously⁶ because the thin bone in this area is not consistently visible in MR images and because the immediately adjacent sacral foramina can confound consistent bony point identification. The inferior extent of the arcuate pubic ligament was identified on axial MR scans as the midline point of the most caudal section in which the arcuate pubic ligament spanned both sides of midline. The sacral-coccygeal articulation was identified on sagittal MR scans as the junction between the fifth sacral and first coccygeal vertebrae. Left and right ischial spines were identified at their most medial projection on axial MR scans (Figure 2).

Distances between points that did not lie in the same scan plane were calculated using the Pythagorean Theorem ($a^2 + b^2 = c^2$) and the fact that the slice interval was 5 mm. The distance between points would then be comparable to the hypotenuse, and the height or y-axis, the measurement of the slice interval (i.e. 10 mm if separated by two slices). This technique was chosen over 3-D model reconstruction because it avoids artifacts that occur in model construction as the software constructs an object and allows the evaluator to precisely establish the measurement point on the original scan. All bony pelvis dimensions were plotted and measured independently by two examiners blinded to prolapse status. The reported value is the average of these two measurements.

Statistical analyses were performed using SPSS. The null hypothesis—that there is no difference in bony dimensions between cases and controls— was tested against each pelvic dimension by using the independent samples t test with a value of $p < 0.05$ indicating significance. The relationship between prolapse status and pelvic floor dimensions was tested through a Pearson Correlation.

Results

42 cases and 42 controls met criteria and were included in the study. The demographics of the cohorts are shown in Table 1 confirming successful matching for age, race, parity, number of vaginal births, and BMI. As mentioned above, all subjects were Caucasian. Within the prolapse group 23 subjects had cystoceles, 10 had rectoceles, and 9 had enteroceles.

Table 2 illustrates the bony pelvis dimension measurements in women with pelvic organ prolapse and women with normal pelvic support. The mean distances between all bony landmarks are identical to the nearest millimeter in the two groups of women except for the distance between the right ischial spine and the sacral/coccygeal junction and the distance between the two spines. In both of these cases, however, the mean difference is minimal (1 millimeter or less) and is not statistically different in the two groups.

In addition to comparing bony pelvis dimensions between the two groups, we also tested the association between each dimension (e.g., IS_R to APL, IS_R to IS_L) and prolapse status. Pearson correlations for each of these measures indicated no relationship between prolapse and any pelvic dimension associated with the muscular pelvic floor.

Inter-examiner reliability for each measurement was assessed via independent samples t test and showed no difference between the measurements of the two examiners (Table 3). Test/re-test reliability of one examiner was assessed on all measured distances of three randomly

selected control subjects. Measured dimensions were identical in all but four measures. In these measures, the difference was 1mm or less.

Comment

Our study indicates that pelvic dimensions at the level of the pelvic floor support in matched cohorts of women with and without pelvic organ prolapse are similar. These measurements (see Table 2) taken at levator ani muscle attachment sites along the bony pelvis in women who were well-matched for age, race, and parity are a strong indication that these dimensions are similar in Caucasian women with and without prolapse. These findings do not support our hypothesis that women with prolapse would have different pelvic dimensions than those without. We had fully expected to find differences between these groups based on the presumption that a larger pelvis may subject the pelvic floor structures to greater forces resulting in a higher rate of prolapse.

Current theories as to how pelvic dimensions may impact prolapse development can be grouped into two main categories: 1) by influencing birth mechanism in a way that might increase damage at delivery, or 2) by contributing to geometric factors that would predispose to structural failure later in life. Vaginal birth is a well-recognized risk factor for the development of pelvic floor dysfunction. There are several theories as to how different bony pelvis dimensions predispose laboring women to increased rates of neuromuscular injury, and thus subsequently the development of pelvic floor dysfunction. Based upon her research findings, Handa theorizes that certain pelvic shapes such as the platypelloid pelvis with its narrow anterior-posterior diameter might be more likely to result in a prolonged second stage of labor and increased rates of nerve injury. She also suggests that in a pelvis with a shorter obstetrical conjugate, the trauma may be focused anteriorly and cause more injury to the origins of the levator ani, uterosacral ligaments, and hypogastric nerve along the anterior portions of the bony pelvis.⁴ In a different manner, after publishing her study, Sze suggests that a smaller pelvis may be protective and that it may in fact be increased pelvic dimensions which permit larger infants to pass through the birth canal resulting in increased rates of neuromuscular injury.⁵

Another theory supporting that a larger pelvis has a predisposition to pelvic floor dysfunction is postulated by Baragi. Utilizing basic physical principles, he argues that the downward force generated by intra-abdominal pressure is equal to this pressure multiplied by the cross-sectional area of the pelvic floor; therefore, if this cross-sectional area is larger, it is subject to more force.⁶ Conversely, if we consider the maximum downward force generated by people to be a constant, then a larger pelvic floor gives a larger cross-sectional area across which this force can disperse, and results in an overall decreased intra-abdominal pressure. Although all of these theories individually make sense, it is evident that our understanding of these potential mechanisms is limited, and that the biomechanics and interaction of different forces and support structures is poorly understood and would benefit from further investigation.

There have been other efforts quantifying differences in pelvic dimensions among populations with prolapse when compared with controls, however these studies used classical obstetric measurements to describe the bony pelvic architecture, not the level of pelvic floor support. Handa and Sze have found differences in obstetrical parameters with wider transverse diameters of the pelvic inlet in women with pelvic floor disorders.^{4,5} Handa also identified a shorter obstetrical conjugate in those with pelvic floor disorders. This particular study had several limitations.⁴ The study examined women with a wide variety of pelvic floor disorders with only 80% of the study population having pelvic organ prolapse. In addition, there were significantly different racial compositions in the cases and controls: the case group had 8.5% African Americans while the control group had 36%. This is a potentially important confounder because these 2 racial groups are known to have different pelvic architecture,⁶ although this

was controlled for statistically in the analysis. In addition, racial differences have been described at the level of the pelvic floor and must be accounted for in studies of pelvic morphology. Hoyte identified these crucial differences in a study of African-American and Caucasian women with normal support: African-American women had increased muscle bulk and closer puborectalis attachment than their Caucasian counterparts.⁹

Although the inlet of the pelvis may indeed differ in women with prolapse compared to women without, the results of our study show that among Caucasian women the bony dimensions do not differ at the level of the muscular pelvic floor. This infers that among the Caucasian study population, there is no specific dimension of the bony pelvis, with regard to its functional role as an anchoring site for the muscular pelvic floor, which predisposes women to an increased risk for pelvic organ prolapse. There are certain limitations to our study design regarding the measurement technique. MRI visibility necessitated the use of a simplified version of the pelvic bony landmarks in order to maintain consistent measurements across subjects and among examiners. True pelvic floor geometry is hexagonal in shape, comprised of the left and right medial pubic bones, ischial spines and lateral portions of the sacrum.⁶ In contrast, the dimensions in this study formed a diamond-shaped pelvic floor as the lateral margins of the sacrum were difficult to locate in either axial or sagittal MRI scans. Instead, measures were taken from the midline sacral-coccygeal junction as the attachment site for the posterior (or dorsal) portion of the pelvic floor. However, the exact similarity in the two groups makes it unlikely that other dimensions at the level of the pelvic floor will be of a major magnitude. Additionally, our study was limited to the Caucasian population and therefore, cannot be generalized to other racial populations.

The scientific study of the pelvic floor has been greatly enhanced by the advent of modern imaging. The ability to see the structural geometry and integrity of specific pelvic floor elements now allows measurements of properly matched cohorts by investigators blinded to subject status. This will allow us to make progress in evaluating structure-function hypotheses and identifying structures which underlie mechanisms of disease. Further studies of pelvic functional morphology might consider the interaction between soft tissue and bone in relation to prolapse development by taking into account measurements of the pelvic floor muscle strength, thickness, fiber length and visible defects, making sure to account for racial disparities.

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Figure 1. Landmarks for the bony pelvis dimension at the level of the pelvic floor

Bony landmarks used in analysis. The pubic symphysis was identified at the level of the arcuate pubic ligament (APL) and the sacral-coccygeal junction, was identified as the junction between the fifth sacral and first coccygeal vertebrae (S5/Co1) to define the anterior-posterior diameter (AP). The ischial spines were identified at their most protuberant location (IS_L & IS_R) to define the inter-spinous diameter.

Figure 2. Axial and Sagittal Measurements

A. Axial proton density image at the level of the ischial spines showing the interspinous diameter. B. Midline sagittal image showing the AP diameter, between the inferior pubic point and *sacral-coccygeal junction* junction.

Table 1
Subject Demographics

	*Prolapse Cases (n=42)	Normal Controls (n=42)	P value
Age (y)	52.8 ± 13.6	52.6 ± 13.2	0.9548
Race (% white)	100 %	100 %	
Parity	2.6 ± 1.2	2.7 ± 1.4	0.7439
Vaginal Deliveries	2.1 ± 0.8	2.0 ± 1.0	0.40397
BMI (kg/m ²)	26.2 ± 5.3	25.9 ± 5.2	0.7658

* Prolapse group comprised of cystoceles (n=23); rectoceles (n=10) and enteroceles (n=9).

Table 2
Bony pelvis dimensions of prolapse cases vs. normal controls

Pelvic Dimension	Prolapse Cases (n=42)	Normal Controls (n=42)	P Value *
	Mean $\pm$ SD (cm)	Mean $\pm$ SD (cm)	
Interspinous Diameter (IS _R - IS _L)	11.2 $\pm$ 0.8	11.1 $\pm$ 0.7	0.19
Anterior Posterior Outlet (APL-S5/Co1)	11.7 $\pm$ 0.7	11.7 $\pm$ 0.8	0.71
Pubic Symphysis to Ischial Spine (IS-APL)			
Left	9.5 $\pm$ 0.5	9.5 $\pm$ 0.4	0.91
Right	9.5 $\pm$ 0.4	9.5 $\pm$ 0.5	0.81
Sacrococcygeal junction to Ischial Spine (S5/Co1-IS)			
Left	7.0 $\pm$ 0.6	7.0 $\pm$ 0.5	0.54
Right	7.0 $\pm$ 0.6	6.9 $\pm$ 0.4	0.32

* Independent samples t-Test: left and right ischial spine, IS_L & IS_R; APL: arcuate pubic ligament; sacral-coccygeal junction S5/Co1.

Table 3
Inter-Examiner Reliability

Bony Dimension	Inter-Examiner Mean Difference (cm) n=84	P-value *
APL-IS _L	0.0476	0.20
APL-IS _R	0.0250	0.52
RIS-S5/Co1	0.0405	0.29
LIS-S5/Co1	0.0191	0.63
IS _L -IS _R	0.0012	0.98
Axial APL-S5/Co1	0.1107	0.06
Sag APL-S5/Co1	0.0357	0.29

* Independent samples t-Test APL: arcuate pubic ligament; LIS: left ischial spine; RIS: right ischial spine; S5/Co1: sacral-coccygeal junction.