Racial differences in pelvic morphology among asymptomatic nulliparous women as seen on three-dimensional magnetic resonance images

Lennox Hoyte, MD, MSEECS, a John Thomas, MD, b Raymond T. Foster, MD, b Susan Shott, PhD, c Marianna Jakab, MSEECS, a Alison C. Weidner, MD b

Harvard Medical School, a Boston, MA; Duke University Medical Center, b Durham, NC; Rush University, c Chicago, IL

Received for publication January 6, 2005; revised May 15, 2005; accepted June 14, 2005

KEY WORDS
Magnetic resonance imaging
Levator ani
Pelvic morphology
Racial differences
Three-dimension reconstruction

Objective: Compare pelvic morphology between asymptomatic African-American and white nulliparous women.

Study design: Resting supine T2-weighted magnetic resonance (MR) images were obtained in 12 African-American (AA) and 10 white American (WA) women without pelvic floor dysfunction. Three-dimensional models were reconstructed from the MR images by a masked investigator, and predefined bony and soft tissue pelvic floor parameters were measured and compared. Nonparametric statistics were used, with significance considered at \( P < .05 \).

Results: Subjects were similar in age and body mass index. Levator ani volume was significantly greater in the AA versus the WA group (mean = 26.8 vs 19.8 cm\(^3\), \( P = .002 \)). The levator-symphysis gap was smaller in the AA (left-18.2, right-18.8 mm) versus the WA group (22.4, 22.6 mm, \( P = .003, .048 \)) on the left and right. Significant differences were seen in bladder neck position, urethral angle, and the pubic arch angle.

Conclusion: The increased muscle bulk and closer puborectalis attachment seen among the African-American nulliparous women may impact the development of pelvic floor dysfunction. These findings need further study.

Female pelvic floor dysfunction (PFD) includes urinary incontinence, pelvic organ prolapse (POP), fecal incontinence, and defecatory dysfunction. PFD is thought to stem from pelvic muscle, nerve, and connective tissue damage sustained during vaginal childbirth.1,2 Notably, approximately 75% of the 4 million annual US births are delivered vaginally.3,4

There is epidemiologic evidence of a relationship between childbirth and PFD.5 However, not all women who undergo vaginal childbirth develop PFD.6 Further, not all nulliparous women are free of PFD.7 In addition, some have observed anecdotally that urinary incontinence and POP may occur less often in women of African descent, when compared with white women.8,9 Work by Sze et al10 and Handa et al11 suggested that
bony pelvic shape, rather than race, may be a factor in the development of PFD among parous women. Therefore, we sought to determine whether there were bony and soft tissue differences in pelvic morphology between well-characterized, asymptomatic nulliparous white and African-American women. Magnetic resonance-based 3-dimensional (3D) reconstruction techniques were used as the imaging modality because of the superior tissue definition and high resolution of magnetic resonance imaging (MRI), coupled with the improved visualization of spatial relationships offered by 3D techniques.

Figure 1  A, Reconstructed dorsal lithotomy view of the bony and soft tissue pelvis. White: Pelvic bones; pink: vagina; yellow: urethra; brown: levator; gray: symphysis coccyx; dark blue: anal sphincter complex; light blue: rectum. B, Bony pelvic measures: C-F: Pubococcygeal line; B-D: intertuberous distance; A-E: interspinous distance. The angle (B-C-D) is the pubic arch angle. The arrows point to the acetabulae, which are the boundaries of the interacetabular distance.

MRI has greatly improved our ability to study the organs and tissues of the pelvis in women. Standard 2D MRI has been used to assess the anatomy of the female pelvic floor in cadavers and living women.12,13 Three-dimensional reconstruction offers additional advantage over 2D MRI because it affords better visual appreciation of key structures, and superior assessment of volumetric and plane geometry.14 Further, 3D reconstruction can minimize the artifacts possible because of variations in MR slice acquisition angle across subjects.15

Material and methods
This is an Institutional Review Board-approved, prospective observational cohort study, examining MRI data from 2 groups of nulliparous women: 12 African-American and 10 white American. All were premenopausal, and had stage 0 or 1 pelvic support as defined by the POPQ system.16 by examination in the supine straining position. To be eligible for inclusion, each subject had to deny pelvic floor symptoms of chronic
pain, urinary incontinence, prolapse, or defecatory dysfunction. Age, height, and weight were recorded.

Before MR scanning, subjects were asked to empty their bladders. Supine MRI studies were performed as follows: 3D Fast Spin Echo T2-weighted axial source images were obtained with the use of a 1.5T magnet (General Electric Medical Systems, Milwaukee, WI) and a torso phased-array coil wrapped around the pelvis. The following imaging parameters were used: repetition time = 4200 ms, time to echo = 108 ms, 128 phase encodes, 24-cm field of view, 2-mm slice thickness, no gap. Pixel dimensions were 0.625 × 0.625 mm. Total scan time was 13 minutes per subject.

The MR data were transferred to a Dell Dimension 8250 computer with 2 GB of RAM (Dell Inc., Round Rock, TX), and an ATI-RADEON 9800 graphics processor. The 3D Slicer software (www.slicer.org) was used to display the gray scale images and segmented label maps. A combination of manual and semiautomatic techniques were used to segment the axial gray scale images into anatomically significant organs, specifically bladder, urethra, levator complex, bony pelvis, symphysis, and coccyx, and the 3D reconstructions were made in a manner described in our previous work. The reconstructed models were then displayed and the parameters measured onscreen. All MR segmenting and subsequent analysis of the resulting 3D images was performed by 1 individual, L.H., who was masked to subject grouping throughout these procedures.

**Bony pelvis parameters**

The bony pelvic parameters were measured on the reconstructed 3D models. Intertuberous distance was measured from midpoint to midpoint of the iscial tuberosities. The interspinous distance was measured between the medial-most tips of the iscial spines. The interacetabular distance was measured between the medial-most aspects of the femoral sockets. The pubo-coccygeal line (PCL) distance was measured as the distance between the inferior-most aspect of the symphysis pubis and the tip of the coccyx in the midline. The pubic arch angle was

---

**Figure 3**  
A, Reconstructed side view, illustrating the pubococcygeal line (PCL, black line), the bladder neck to PCL (white line with double arrows), Bladder neck to symphysis (white line).  
B, Reconstructed side view, showing the urethral angle, formed by the symphysis and the long axis of the urethra (white lines).
measured as the angle subtended by the inferior pubic rami. The standard diagonal and obstetric conjugates were not available for measurement on the 3D reconstructions because the source axial scans did not reach the sacral promontory, disallowing reconstruction of that landmark. A dorsal lithotomy view of a reconstructed bony pelvis and soft tissues is shown in Figure 1, A. Bony measurements are illustrated in Figure 1, B.

**Soft tissue parameters**

The levator hiatus height was measured in the midline as the distance from the inferior-most aspect of the pubic symphysis to the inner aspect of the levator median raphe. The levator hiatus maximum width was measured as the maximal transverse distance of the innermost surface of the anterior levator opening. The levator-symphysis gap was measured as the distance from the middle of the inferior symphysis to the nearest aspect of the puborectalis muscle on the right and left. The levator measures are illustrated in Figure 2, A and B. The bladder neck to PCL distance (BNPCL) was measured as the perpendicular distance from the posterior aspect of the bladder neck (ie, the junction of the urethra and bladder) to the PCL. Negative values of BNPCL imply a position inferior (caudad) to PCL, positive values of

<table>
<thead>
<tr>
<th>Table I</th>
<th>Comparison of bony pelvic parameters between the groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PCL (mm)</td>
</tr>
<tr>
<td>AA</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td>Range</td>
</tr>
<tr>
<td>WA</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td>Range</td>
</tr>
<tr>
<td>P</td>
<td>NS</td>
</tr>
</tbody>
</table>

PCL is the anteroposterior distance from symphysis to tip of coccyx. It is a measure of the depth of the pelvic outlet. PUBArch is the angle of the pubic arch. InterTub is the transverse distance between the middle if the iscal tuberosities. It is a measure of the width of the pelvic outlet. InterSpi is the distance between the tips of the iscal spines. It is a marker for the width of the midpelvis. InterAcet is the distance between the medial-most aspects of the acetabular sockets. It is a marker for the width of the pelvic inlet. AA, African American; WA, White American.

<table>
<thead>
<tr>
<th>Table II</th>
<th>Comparison of levator muscle parameters between the groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LHH (mm)</td>
</tr>
<tr>
<td>AA</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td>Range</td>
</tr>
<tr>
<td>WA</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td>Range</td>
</tr>
<tr>
<td>P</td>
<td>.056</td>
</tr>
</tbody>
</table>

LHH is the distance from the inferior symphysis to the levator median raphe. LHW is the maximal transverse distance of the levator hiatus. LevVOL is the volume of the levator ani complex. LSGL is the distance between the inferior mid pubic symphysis to the nearest occurrence of the puborectalis muscle in the left (LSGL), and right (LSGR). AA, African American; WA, White American.

<table>
<thead>
<tr>
<th>Table III</th>
<th>Urethral and bladder parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BNPCL (mm)</td>
</tr>
<tr>
<td>AA</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td>Range</td>
</tr>
<tr>
<td>WA</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td>Range</td>
</tr>
<tr>
<td>P</td>
<td>.001</td>
</tr>
</tbody>
</table>

BNPCL is the perpendicular distance from bladder neck to pubococcygeal line-positive values lie superior to the PCL, negative values lie inferior to the PCL. BNSym is the distance between the bladder neck and the pubic symphysis. UreAng is the angle formed by the long axes of the pubic symphysis and the urethra. Urethra is the length of the urethra along its long axis. BVOL is bladder volume. All linear measures are in millimeters, volumes are in cubic centimeters, and angles are in degrees. AA, African American; WA, White American.
BNPCL imply positions superior (cephalad) to PCL. The bladder neck to symphysis was measured as the distance from the anterior aspect of the bladder neck to the closest point on the symphysis. The bladder neck parameters are illustrated in Figure 3, A. The urethral angle was measured as the angle subtended by the long axis of the symphysis pubis, and the long axis of the urethra, as illustrated in Figure 3, B. The urethral length was measured as the linear distance from distal to proximal tips of the urethra. Bladder volume, urethral volume, and levator volume were computed as the sums of the area on each slice multiplied by the interslice distance. Levator shape was defined as a “U” if the levator moved laterally, then superiorly from its low point at the median raphe in the midline. Levator shape was defined as a “V” if it moved superiorly then outward from its low point at the median raphe in the midline.

The SPSS statistical package was used for all statistical analysis (SPSS, Chicago, IL). Nonparametric Mann-Whitney tests were applied after review of frequency histograms that demonstrated non-normal data. Two-tailed statistical significance is considered at $P < .05$.

**Results**

Subjects did not differ by age; African-American women had a mean age $\pm$ SD of 30.13 $\pm$ 6.3 years versus white-American women at 26.4 $\pm$ 4.4 years, $P =$ NS. Similarly, although AA subjects had a slightly higher body mass index (BMI) at 26.5 (7.5) kg/m$^2$ versus WA subjects at 23.9 (3.3) kg/m$^2$, this difference was not statistically significant.

Of the bony pelvic measures, only the pubic arch angle was found to be significantly different between the groups. The pubic arch angle was larger by 13 degrees in AA women versus WA women. Bony pelvic comparisons are detailed in Table I.

Levator ani volume was significantly higher in AA women, who also had a significantly shorter levator-symphysis gap bilaterally, compared with the WA women. The bladder neck was closer to the symphysis in the AA women, and the angle of the urethra to the symphysis was also smaller in this group. These differences were statistically significant. Pelvic soft tissue comparisons are detailed in Tables II and III.

Figure 4 shows representative 3D reconstructions from an AA and WA nulliparous women, illustrating the soft tissue differences between the 2 groups.

**Comment**

Our study data shows increased levator ani muscle bulk among AA nulliparous women when compared with age-matched WA nulliparous women. In addition, the arms of the puborectalis muscle were carried closer to the superior pubic rami bilaterally, suggestive of a longer, denser attachment of the levator muscle to the arcus tendineus levator ani. The bladder neck is held higher and closer to the symphysis in the AA women than in the WA women, and the pubic arch is slightly wider among the AA women. Taken collectively, these differences suggest a levator ani complex in AA subjects that is more intimately associated with its connective tissue and bony attachments.

Previous investigators have reported striking differences in the prevalence and incidence of PFD among different races.$^5,17-22$ There is, however, no consensus in the medical literature on exactly how race impacts the development of PFD. Our data in this preliminary study suggest certain hypotheses: it is possible that the kind of musculoskeletal configuration we have observed in AA women, coupled with a favorably wide pubic arch, is protective against pelvic floor obstetric injury. For instance, perhaps a bulkier levator muscle means that an AA woman can have a more extensive denervation injury before becoming symptomatic. Alternatively,
denser and longer muscle-to-connective tissue attachments may tolerate the same length of tear injury before resulting in symptoms in AA parturients. It is interesting that we found a wider pubic arch in our AA subjects, which is inconsistent with the classic characterization of an anthropoid pelvic shape in such women. However, the clinical significance of the 13-degree difference seen in the pubic arch is unclear. We speculate that our observations are in keeping with those of Howard et al. and Baragi et al. who noted more dynamic muscular attachments and a smaller overall pelvic floor area in AA women. A smaller posterior pelvis was responsible for the latter finding. Both of these characteristics would tend to be protective against PFD by providing a stronger muscle traversing a smaller pelvic floor, which would be less vulnerable to the stresses of daily life and function in our bipedal position. It may appear counterintuitive to propose a smaller pelvic floor as being protective against PFD, because vaginal delivery is perhaps the most consistent risk factor associated with the disease, until one considers that AA neonates are consistently of smaller average birth weight than CA neonates (http://www.marchofdimes.com/peristats).

Morphologic differences in the bony pelvis between the sexes and among different races have been described and are useful in archeology and forensic science. If one assumes, based on epidemiologic evidence, that race is a predisposing factor for PFD, then bony and soft tissue pelvic morphology may be critical factors that promote PFD in one race more than another. Previous investigations have used modern imaging techniques to compare pelvic morphology in women with and without PFD. These studies suggest bony parameters that place women at risk for PFD independent of race.

Although our pilot data failed to show many significant differences in bony pelvic morphology between the African-American and white groups, the differences noted in soft tissue characteristics may help to account for some of the differences in PFD prevalence between parous African-American and white women. We are presently conducting a larger study to confirm these findings.

References