Analysis of Minimal Levator Ani Hiatus Area Based on MRI in Women without Pelvic Floor Dysfunction at Different Age Groups

Xiaoyi He
Qilu Hospital of Shandong University  https://orcid.org/0000-0002-4453-4368
Qian Du
Lingyu Chang
Yan Jiang
Weiqiang Dou
Dexin Yu
Qing Wang
Yiting Guo
Fang Wang (✉️ 329571483@qq.com )

Research Article

Keywords: female pelvic floor, levator ani hiatus, magnetic resonance (MR)

Posted Date: July 5th, 2023

DOI: https://doi.org/10.21203/rs.3.rs-3095113/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License. Read Full License

Version of Record: A version of this preprint was published at Archives of Gynecology and Obstetrics on November 6th, 2023. See the published version at https://doi.org/10.1007/s00404-023-07253-9.
Abstract

**Purpose:** To investigate the association of minimal levator ani hiatus area with age in women without pelvic floor dysfunction.

**Methods:** 552 female subjects aged one year ~90 years without pelvic floor dysfunction, divided into four groups (Group A, ≤29 years old; Group B, 30~39 years old; Group C, 40~49 years old; Group D, ≥50 years old) based on age, underwent traditional pelvic two dimension (2D) T2-weighted imaging (T2WI) axial to the body (AxB) for measuring the minimal levator ani hiatus area. 39 female volunteers were re-recruited to undergo both traditional pelvic 2D T2WI AxB and three dimension (3D) T2WI. An axial plane parallel to the direction of the puborectalis muscle (AxPRM) was acquired based on 3D T2WI. The difference of levator ani hiatus area measured on AxB and AxPRM images in 39 female volunteers was compared by one-sample t-test, to verify if minimal levator ani hiatus area can be acquired on traditional pelvic 2D T2WI AxB images. Spearman analysis evaluated the association of minimal levator ani hiatus area with age and the rank-sum test analyzed the area differences among four age groups.

**Results:** Female age was positively correlated with minimal levator ani hiatus area ($r = 0.29; p < 0.001$). The minimal levator ani hiatus areas of 552 subjects were: 13.74±3.48 cm$^2$ in Group A, 15.52±2.21 cm$^2$ in Group B, 16.03±2.16 cm$^2$ in Group C and 16.40±2.10 cm$^2$ in Group D. ANOVA showed significant statistical differences among four age groups (F=23.99, $p 0.0001$). Significant differences in minimal levator ani hiatus areas were found between Group A and Group B ($p = 0.0012$), Group A and Group C ($p < 0.0001$), Group A and Group D ($p < 0.0001$), and Group B and Group D ($p < 0.0001$). There was no statistical difference in minimal levator ani hiatus areas measured on AxB and AxPRM images in 39 female volunteers ($p = 0.1000$).

**Conclusions:** Based on a large sample, this study summarized the minimum levator ani hiatus area of women without pelvic floor dysfunction in different age groups. We found significant differences among different age groups. In addition, a positive correlation was found between age and the minimum levator ani hiatus area. These findings can provide reference criteria for diagnosing pelvic organ prolapse in women of different age groups.

**What does this study adds to the clinical work?**

- Based on a large sample, in different age groups of women without pelvic floor dysfunction, the minimal levator ani hiatus area increases with age.
- The minimal levator ani hiatus areas of women without pelvic floor dysfunction in different age groups were measured, and significant differences were found among the four age groups. The effect of age on the minimal levator ani hiatus area should be considered in the diagnosis of pelvic floor dysfunction.
- The minimal levator ani hiatus area in Han women was statistically larger than that in Caucasian women.
Introduction

Female pelvic organ prolapse (FPOP) is a common disease that seriously troubles patients' lives (1–4). Levator ani hiatus is the largest potential hernial portal in the human body, and FPOP can be described as a herniation of pelvic organs through it. Prolapse quantification system of the International continence society (5, 6) pointed out that FPOP can be determined clinically by measuring the length and area of the minimal levator ani hiatus (7–9), which is the space between the inferior pubic rami and the puborectalis component of the levator ani muscle (10). Previous studies (11–14) have shown that age and minimal levator ani hiatus area are strongly correlated with symptoms of FPOP. However, the current clinical challenge is the lack of the reference range of minimal levator ani hiatus area in women without pelvic floor dysfunction at different age groups.

Translabial ultrasound is widely used in the clinic for minimal levator ani hiatus area measurement in diagnosing FPOP (11, 12). However, this method primarily depends on the operator's experience and is less reproducible (15, 16), limiting further clinical application. As an alternative, high-resolution anatomic magnetic resonance imaging (MRI) can provide reliable images with excellent tissue contrast. With high-resolution T2-weighted imaging (T2WI), the outline of pelvic organs, peritoneal fat, and levator ani anus muscle has been clearly delineated, presenting a possibility for reliable quantitative measurement of minimal levator ani hiatus area.

Therefore, this study's main goal was to obtain potential references of minimal levator ani hiatus areas for women without pelvic floor dysfunction at different ages with high-resolution T2WI in a large cohort. Moreover, the association of minimal levator ani hiatus area with age was also aimed to be evaluated.

Methods

Subjects

This was a retrospective study. The research protocol has been approved by the Ethics Committee of Qilu Hospital of Shandong University and informed consent was waved. This study strictly followed the principles of the Declaration of Helsinki. We finally collected 552 female subjects aged one year to 90 years who were admitted to Qilu Hospital of Shandong University from March 2018 to January 2022. The exclusion criteria were the presence of pelvic floor dysfunction (including uterine, rectal prolapse, and cystocele) or previous pelvic floor surgery, and contraindications to MRI. The subjects were divided into four age groups (every 10 years)(15): Group A (youth group, ≤ 29 years old) with 77 subjects; Group B (young and middle-aged group, 30 ~ 39 years old) with 149 subjects; Group C (middle-aged group, 40 ~ 49 years old) with 139 subjects and Group D (middle-aged and elderly group, ≥ 50 years old) with 187 subjects. The procedure of case collection and age grouping is shown in Fig. 1.

Theoretically, the minimal levator ani hiatus area should be measured on an axial plane parallel to the direction of the puborectalis muscle (AxPRM) based on three dimension (3D) reformatted images. However, the MR images of retrospective cases were almost two dimension (2D) images (axial to the
body, AxB), so it is necessary to verify whether there is a statistical difference between the minimal levator ani hiatus area measured on AxB and AxPRM T2WI images. We thus re-recruited 39 female volunteers aged 23 to 49 years (32 ± 7.72 years) to undergo both pelvic floor MRI with both AxB and AxPRM T2WI.

In addition, to compare with the literature findings (all subjects as healthy nulliparous women), 27 matched nulliparous subjects from 19 to 39 years old (32 ± 2.32 years old) were randomly selected from above mentioned 552 female subjects. These 27 subjects were named as nulliparous group in terms of delivery history.

**Magnetic Resonance Imaging Acquisition**

All subjects were performed at GE HDX TWINSP 3T MR in a supine position using an 8-channel external phased array body coil placed in the center of the pelvis. No special preparation was required. All 552 subjects underwent 2D high-resolution T2WI, and 39 volunteers received additional 3D high-resolution T2WI. For axial 2D T2WI, the scan parameters were of TR = 8390ms, TE = 112ms, matrix = 512×512, FOV = 200mm×200mm, slice thickness = 3 ~ 5mm, spacing = 0.8mm. The total scan time was 3 minutes. For axial 3D T2WI, the following scan parameters were applied, including repetition time (TR) = 1700ms, echo time (TE) = 95ms, matrix = 512×512, field of view (FOV) = 260mm×260mm, slice thickness = 0.9mm, interval = 0.9mm. The total scan time was 6 minutes.

**Image analysis**

For 39 volunteers, AxB slices were obtained (Fig. 2, A and B). Then, using a mid-sagittal image as a guide (16), and the multiplanar view associated with the TWINSP HDx interface, the acquisition angle was tilted (Fig. 2, C and D) to be parallel to the puborectalis muscle (AxPRM). This was accomplished by aligning the acquisition field of view rectangle so as to parallel a line originating at a point on the pubic bone 10 to 15 mm from its inferior-most point to the visible anorectal angle (16).

All 2D and 3D T2WI images of female subjects were imported into IMPAX Volume Viewing 3D Viewing for analysis. Two well-trained radiologists (AA, 4 years of experience; BB, 16 years of experience) independently delineated and calculated the minimal levator ani hiatus area. In the AxB and AxPRM T2WI images, a closed curve was manually drawn along the medial border of the pubis and the medial border of the levator ani muscle. The corresponding area measured was the minimal levator ani hiatus area (Fig. 3).

**Statistical Analysis**

GraphPad Prism 8.0.2 software was used for all statistical analyses. The measurement data of this study were expressed as \( x \pm s \). The intra-class correlation coefficient (ICC) was used to evaluate the inter-observer agreement of the data measured by two radiologists. ICC > 0.75 means high consistency, 0.4 ≤ ICC ≤ 0.75 indicates medium consistency, and ICC < 0.4 indicates poor consistency. All subjects were tested for normality (Kolmogorov-Smirnov test and Shapiro-Wilk test) and homogeneity of variances for age and minimal levator ani hiatus area. Pearson correlation analysis was used to analyze the correlation
between age and minimal levator ani hiatus area with normal distribution and homogeneous variance. Otherwise, Spearman correlation analysis was used. One-way analysis of variance (ANOVA) followed by post-hoc analysis was used to assess the differences of minimal levator ani hiatus area with normal distribution and homogenous variance in all subjects among four age groups. Otherwise, the Kruskal-Wallis test (rank-sum test) was applied. The measured results were compared with the reference values in the literature using a two-sided one-sample t-test. \( P < 0.05 \) was considered statistical significance.

**Results**

**Interobserver Agreement Analysis**

Excellent interobserver agreement over two radiologists was confirmed by obtaining high ICC values. The ICC value of minimal levator ani hiatus area in female subjects was 0.979. Meanwhile, similar ICC values of 0.973 and 0.997 were also revealed for AxPRM and AxB images in 39 female volunteers.

**Correlation Analysis between Age and Minimal Levator Ani Hiatus Area in 552 Female Subjects**

The age of all subjects conformed to a normal distribution with homogeneous variance, and the minimal levator ani hiatus area did not conform to a normal distribution. So, Spearman analysis was applied and showed that age was positively correlated with the minimal levator ani hiatus area (\( r = 0.29; p < 0.001 \), Figure 3).

**Intergroup Comparison of Minimal Levator Ani Hiatus Area among Four Age Groups**

The minimal levator ani hiatus area of female subjects at different ages were: 13.74±3.48 cm\(^2\) in Group A; 15.52±2.21 cm\(^2\) in Group B; 16.03±2.16 cm\(^2\) in Group C, and 16.40±2.10 cm\(^2\) in Group D. ANOVA showed that there were significant statistical differences among four age groups (\( F = 23.99, p = 0.0001 \)). With the rank-sum test, statistically significant difference in minimal levator ani hiatus area was found between Group A and Group B (\( p = 0.0012 \)), Group A and Group C (\( p < 0.0001 \)), Group A and Group D (\( p < 0.0001 \)) and Group B and Group D (\( p < 0.0001 \)), as shown in Table 1 and Figure 4.

**Comparison of the Minimal Levator Ani Hiatus Area in 39 Female Volunteers on AxB and AxPRM T2WI Images**

All data conformed to a normal distribution with homogeneous variance. The minimal levator ani hiatus area through AxPRM and AxB planes were 12.06±1.94cm\(^2\) and 12.80±1.98cm\(^2\), respectively. There was no statistical difference between the two measurements (\( p = 0.1000 \)).

**Comparison of the Minimal Levator Ani Hiatus Area between the Nulliparous Group and the Literatures**

Findings

The minimal levator ani hiatus area of nulliparous women in this study was comparatively larger than that in the literature (Table 2).
Discussion

FPOP is a common form of hernia where pelvic organs herniate out through levator hiatus. It has been confirmed that FPOP can be determined clinically by measuring the length and area of the levator ani hiatus, and both age and minimal levator ani hiatus area were strongly associated with symptoms of FPOP (11–14). However, the minimal levator ani hiatus area of normal women at different ages has not been uniformly determined. This study investigated whether the minimal levator ani hiatus area has changed for women of different ages in a large cohort. Our findings showed that subject age was positively correlated with minimal levator ani hiatus area. Moreover, statistically significant differences in minimal levator ani hiatus area were found among four age groups. Understanding normal reference and changes in age-related minimal levator ani hiatus area is helpful for the diagnosis of FPOP.

In this study, there was high agreement between the two radiologists' measurements of the minimal levator ani hiatus area for all subjects. The statistical results showed that the age of women without pelvic floor dysfunction was positively correlated with the minimal levator ani hiatus area (Fig. 3). It can be considered that with the increase of female age, the minimal levator ani hiatus area increased accordingly. It has been reported in the literature (17) that aging affects muscle mass and strength, innervation function, and connective tissue throughout the body. After women's menopause, the mass of pelvic floor muscles begins to decline dramatically (18, 19). Previous studies (20, 21) showed that the muscle strength of obturator internus and levator ani in women was significantly negatively correlated with age. In this work, with the increase of age, the minimal levator ani hiatus area had an increasing trend, and the minimal levator ani hiatus area of Group D (≥ 50 years old) was larger than that of the other groups. It also suggested that aging did affect the female levator ani muscle. With increasing age, the mass and innervation function of pelvic floor muscles were further reduced, the collagen content of the pelvic floor muscles increased, fibrosis occurred, and the levator ani hiatus area increased (22, 23).

In order to further investigate the changes in age-related minimal levator ani hiatus area, the female subjects were divided into four age groups, referring to the standard commonly used, i.e., grouping at every 10 years (15). The proportion of female subjects under 18 years old and over 60 years old were small (3.6% and 12.7%, respectively). The large difference in sample size among groups would cause an error in the statistical analysis, so we designated subjects at one year ~ 29 years as youth group (Group A), and those over 50 years as middle-elderly group (Group D).

The results of the inter-group analysis showed that there was no statistical difference in the area of hiatus between Group B and Group C, and between Group C and Group D. It can be considered that in women, the changes in the hiatus area were relatively small in the youth-middle (30 ~ 39 years old) to the middle (40 ~ 49 years old), and middle (40 ~ 49 years old) to middle-elderly (≥ 50 years old) stages (24), while the hiatus areas in the youth (≤ 29 years old) to youth-middle (30 ~ 39 years old) and youth-middle (30 ~ 39 years old) to middle-elderly (≥ 50 years old) stages had larger changes. The reason for the former may be that young women are in the stage of rapid body development, and the development of
pelvic floor muscles and pelvic organs and the increase in body weight enlarge the levator ani hiatus area (25). The latter can be interpreted as the decrease of hormone levels in postmenopausal women and the atrophy of pelvic floor muscles, resulting in decreased pelvic floor muscle function and increased levator ani hiatus area (26).

It has been pointed out in the literature (16) that the measurement of minimal levator ani hiatus area in AxPRM images is the most accurate. In this study, the results in 39 volunteers showed no significant difference in minimal levator ani hiatus area measured on AxB and AxPRM images. In addition, the AxB images can be acquired in a shorter scanning time than the AxPRM images. Therefore, we consider that the minimal levator ani hiatus area can be measured on AxB images and replace that on AxPRM images.

We compared measurements of minimal levator ani hiatus area between the nulliparous group in this study and the previous MRI studies with similar subjects. The result in this study was larger than those in literatures, but was roughly within the range of value measured by Alt et al (27–29). The reasons for this may be listed as following: (1) The subjects included in this study are all Chinese and the interethnic difference between Chinese and other races should be taken into account. It has been reported in the literatures(30, 31) that Chinese women have stronger pelvic support structures; (2) The composition of female pelvic floor muscles is complex, but the measurement is only based on bone and soft tissue markers. There may be differences in measurement and calculation methods among different studies.

This study has limitations. First, the normal reference value range and change trend of minimal levator ani hiatus area only applied to the Han nationality. It could be insufficient in the evaluation of individuals from different ethnic origins. Second, our measurement results of the minimal levator ani hiatus area were based on AxB MR images.

**Conclusion**

In conclusion, based on a large sample, we measured the minimal levator ani hiatus area of women without pelvic floor dysfunction in different age groups. Significant differences were found among the four age groups. Age and the minimal levator ani hiatus area were positively correlated. These findings can provide reference criteria for diagnosing pelvic organ prolapse in women of different age groups.

**Declarations**

The authors declare that they have no competing interest.

**Fang Wang** Conceptualization, Methodology, Writing-Reviewing and Editing. **Xiaoyi He** Data curation, Writing-Original draft preparation, Visualization, Methodology, Formal analysis. **Qian Du**: Data curation, Validation. **Lingyu Chang**: Polish. **Yan Jiang**: Data curation, Investigation. **Weiqiang Dou**: Methodology, Writing- Reviewing and Editing, Supervision, Polish. **Dexin Yu, Qing Wang**, and **Yiting Guo**: Technical and resource support.
References


Tables

Table 1 Comparison of minimal levator ani hiatus areas among four age groups (rank-sum test).

<table>
<thead>
<tr>
<th>Dunn's multiple comparison test</th>
<th>A vs. B</th>
<th>A vs. C</th>
<th>A vs. D</th>
<th>B vs. C</th>
<th>B vs. D</th>
<th>C vs. D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean rank difference</td>
<td>-83.33</td>
<td>-118.7</td>
<td>-162.5</td>
<td>-35.38</td>
<td>-79.15</td>
<td>-43.77</td>
</tr>
<tr>
<td>Adjusted p value</td>
<td>0.0012</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>0.3598</td>
<td>&lt;0.0001</td>
<td>0.0856</td>
</tr>
</tbody>
</table>

Note: A, youth group; B, young-middle group; C, middle group; D, middle-elderly group.

Table 2 Comparison of the measurement results of the minimal levator ani hiatus areas in the nulliparous group in this study and the reference value in the literatures (̅x±s).
<table>
<thead>
<tr>
<th>Literatures</th>
<th>Mean ± Standard deviation</th>
<th>This study Mean ± Standard deviation</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dietz et al (52 nulliparous volunteers)</td>
<td>11.25±2.7</td>
<td>15.53±1.72</td>
<td>0.0001</td>
</tr>
<tr>
<td>Weinstein et al (23 nulliparous women)</td>
<td>13.4±1.8</td>
<td>13.22±3.05</td>
<td>0.0013</td>
</tr>
</tbody>
</table>

**Figures**

![Figure 1](image.png)

Figure 1
The flow chart of case inclusion and age grouping.

Figure 2

AxB and AxPRM measurement of the minimal levator ani hiatus areas in the women

**Note:** The axial image (A) is generated from the midsagittal plane shown in (B), the typical axial to body (AxB) plane through the pubic bone 10-15mm from its inferior-most point. The axial image (C) is generated from the midsagittal plane shown in (D), a plane that tracks the fiber directions of the puborectalis muscle (AxPRM), from a point on the pubic bone 10-15mm from its inferior-most point to the visible anorectal angle (16).
Figure 3

Sketch map of minimal levator ani hiatus area.

Note: In the axial T2WI image with the minimal levator ani hiatus, a closed curve is drawn along the medial border of the pubis and the medial border of the levator ani muscle. The area enclosed by the curve (white area) is the minimal levator ani hiatus area. S: pubic symphysis; U: urethra; V: vagina; R: rectum.
Figure 4

Correlation analysis between age and minimal levator ani hiatus area in women without pelvic floor dysfunction (scatter plot).

$r = 0.29$

$p < 0.001$
Figure 5

Comparison of minimal levator ani hiatus areas among four age groups (violin diagram).

**Note**: The width of each violin plot represents the concentration of the sample distribution on the vertical axis, the two endpoints of each violin plot represent the maximum and minimum values, the thick dashed line represents the median, and the thin dashed line represents the quartile.

A, youth group; B, young-middle group; C, middle group; D, middle-elderly group. **: $P < 0.001$. 