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Effect of pelvic position on ultrasonic measurement parameters of pelvic floor in postpartum women

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Abstract

Objective To analyse the effect of pelvic position on ultrasonic measurement parameters of pelvic floor in postpartum women.

Methods This study included 132 postpartum participants who visited Fujian Maternity and Child Health Hospital from May 2020 to May 2024. All participants were assessed by medical professionals for general information and pelvic floor four dimensional ultrasound. Ultrasonic measurements were performed in three different positions of the pelvis (anterior pelvic tilt, posterior pelvic tilt, and neutral pelvic tilt) based on lithotomy position.

Results Our results indicated that the differences in the diagnosis of cystocele, uterine prolapse, perineal overactivity, and hiatal ballooning among the neutral position, anterior pelvic tilt, and posterior pelvic tilt were statistically significant (P<.001, P<.001, P<.001, and P<.001 respectively). The differences among neutral pelvic tilt, anterior pelvic tilt, and posterior pelvic tilt in hiatal area (during contraction), hiatal area (during rest), hiatal area (during valsalva), bladder neck descent, urethral rotation angle, cervical descent, rectal ampulla descent, hiatal area increase, and hiatal area decrease were statistically significant (P <.001, P <.001, P <.001, P <.001, P <.001, P <.001, P <.001, P <.001, and P <.001 respectively), with almost all the values of those parameters in posterior pelvic tilt the highest among three groups. The differences in cervical position (at rest), rectal ampulla position (at rest), and bladder neck position (during valsalva), cervical position (during valsalva), and rectal ampulla position (during valsalva) among neutral pelvic tilt, anterior pelvic tilt, and posterior pelvic tilt were statistically significant (P <.001, P =.035, P <.001, P <.001, and P <.001 respectively), with almost all the values of those parameters in posterior pelvic tilt the lowest among three groups.

Conclusion During the pelvic floor muscle contraction, the posterior pelvic tilt showed the most reduction of hiatal area compared to that in other positions. During Valsalva, not only the most increase of the hiatal area, but also the greatest bladder neck descent, cervical neck descent, and rectal ampulla descent were observed in the posterior pelvic tilt position.

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Keywords Postpartum, Pelvic floor, Pelvic position, Ultrasound

Introduction

Pelvic organ prolapse (POP) is defined as the descent of the uterus and/or the different vaginal compartments and their neighbouring organs, such as the bladder, rectum or bowel [1]. Age, vaginal delivery, parity, birthweight, age, and body mass index are common risk factors for POP [2]. A systematic review of papers published from 2009 to 2021 has revealed that the total prevalence of POP is 30.9%, with 25.0% reported via questionnaire estimation and 41.8% reported via physical examination [3]. POP is closely related to difficulty defecating, lower abdominal pain, and difficulty voiding, resulting in functional limitations in daily life [4, 5]. The cost of POP to individuals and to society is considerable in terms of productivity [6]. A detailed and accurate examination is necessary and important to determine whether there is prolapse and the severity of the prolapse before treatment.

In recent years, ultrasound has become increasingly popular in the diagnosis of POP because of its high reliability and economic acceptability [7–9]. Pelvic floor muscle (PFM) contraction and the Valsalva manoeuvre are important in the evaluation of POP. On the basis of the definition of the reference point (inferoposterior margin of the symphysis pubis), POP is diagnosed through observing the descent of the urethra, bladder, cervix, and rectum during the Valsalva manoeuvre [10]. The ability of the subject to perform the Valsalva manoeuvre well during the test could lead to different diagnoses. Pelvic floor prolapse may be misdiagnosed or missed due to poorer or better performance in the Valsalva manoeuvre, and PFM contraction may be affected by the pelvic position. Few women have reduced pelvic floor perception and are unable to complete PFM contraction or cannot relax their PFM voluntarily [11, 12]. Studies have reported that measurements of organ descent are greater in the standing position than in the lithotomy position [13, 14]. This result is not surprising, as the pelvic floor receives greater pressure in the standing position. Other studies have reported that PFM activity changes in different pelvic positions [15, 16]. However, no studies on the effects of the pelvic position on PFM contraction and the Valsalva manoeuvre have been reported thus far. Our hypothesis is that the ultrasonic parameters of the pelvic floor is affected by the position of the pelvis. To better observe the changes that the pelvic position may make, women in the postpartum period were selected as participants in the present study because these women would have a relaxed pelvic floor compared with those who are nulliparous. Therefore, the aim of the present study was to evaluate the effects of the pelvic position on the ultrasonic measurement parameters of the pelvic floor in postpartum women via pelvic floor 4-dimensional (4D) ultrasound.

Materials and methods

Participants

The present study included 132 participants who visited Fujian Maternity and Child Health Hospital from May 2020 to May 2024. General information, including age, height, weight, BMI (body mass index), gestational weight gain, neonatal weight, gestation, parturition, education, and delivery mode, was collected by medical professionals for all participants who signed the consent form. The inclusion criteria were as follows: participants who had a vaginal birth and who were 2 years within the postpartum period and could tolerate a gynaecological examination. The exclusion criteria were participants with gynaecologic bleeding, those suspected of being pregnant, those who could not perform the Valsalva manoeuvre, and those who had a history of pelvic floor surgery that may affect the results of the assessment. This study has been approved by the Ethics Committee of Fujian Maternity and Child Health Hospital (No. 2020KY145), and has been registered in the Chinese Clinical Trial Registry (ChiCTR2300073809) on 21 Jul 2023.

Assessment of pelvic floor 4D ultrasound

Pelvic floor 4D ultrasound has been widely recommended for several years to assess pelvic floor morphology because of its noninvasiveness and objectivity [17]. All ultrasound assessments were performed by an experienced sonographer (Y.W.) at the Fujian Maternity and Child Health Hospital. The figures used for the assessments were stored on a computer and then checked by another sonographer (Y.Z.) to ensure the accuracy of the measurement results. Ultrasonic measurements were performed in three different positions of the pelvis (anterior pelvic tilt, posterior pelvic tilt, and neutral pelvic tilt) in the supine lithotomy position. The primary supine lithotomy position was considered a neutral pelvic tilt. During the positions of the anterior pelvic tilt and posterior pelvic tilt, a 5 cm pillow was placed under the third lumbar spine to tilt the pelvis anteriorly and under the tailbone to tilt the pelvis posteriorly. The participants were asked to lie down on pillows as relaxed as possible to eliminate the interference of synergistic muscle contraction (Figs. 1, 2 and 3). There was a 1-min rest among the three measurements, and the position was chosen randomly during the test in case of fatigue and practice effects.

Fig. 1 Neutral pelvic tilt (provided by Y.W.)

Transperineal ultrasound with a Mindray Reson8s 4D ultrasound system (Mindray Reson8s [11], Shenzhen, Guangdong, China) was used to evaluate the pelvic floor morphometry of the participants. The participants who underwent the test were placed in the supine lithotomy position, and a transducer (D8-2U Resona 8, Shenzhen, Guangdong, China) was placed on the perineum in a mid-sagittal plane, with a sweep angle of 85 degrees obtained at rest, during the Valsalva manoeuvres and PFM contraction. The participants were asked to perform the Valsalva manoeuvres and PFM contractions until they mastered the test correctly, and the following guiding words were used during the practice: “Please hold in as if you are experiencing an urge to urinate and have a bowel movement at the same time” and “Please inhale deeply and hold your breath, then tense your chest and abdominal muscles and push down as if you are defecating or giving birth”. At most, three Valsalva manoeuvres and PFM contractions were needed, with the most effective contraction being used for evaluation. The hiatal area was measured under three pelvic conditions, while the bladder neck position, cervical position, and rectal ampulla position were only measured at rest and during the Valsalva manoeuvre, in which the lower margin of the symphysis pubis was used as the reference line. Figure 4a-e show the measurement of the parameters used in the present study. Negative numbers indicated that the pelvic organs were below the lower margin of the pubic symphysis. POP on transperineal ultrasound was defined on the basis of previously published cutoffs of descent at ≥ 0 mm, ≥ 0 mm, ≥ 15 mm, and ≥ 0 mm below the symphysis pubis for cystocele, uterine prolapse, perineal overactivity, and rectocele, respectively, and hiatal ballooning was defined as a hiatal area ≥ 20 cm^2 [18]. The following equations were utilizes: urethral rotation angle = urethral tilt angle (at rest) - urethral tilt angle (during the Valsalva manoeuvre); cervical descent = cervical position (at rest) - cervical position (during the Valsalva manoeuvre); bladder neck descent = bladder neck position (at rest) - bladder neck position (during the Valsalva manoeuvre); hiatal area increase = hiatal area

Fig. 2 Anterior pelvic tilt (provided by Y.W.)

(during the Valsalva manoeuvre) - hiatal area (at rest); and hiatal area decrease = hiatal area (at rest) - hiatal area (during contraction).

Sample size calculation

A preliminary experiment with 41 participants was conducted. Among the ultrasonic parameters, bladder neck descent, cervical descent, rectal ampulla descent, hiatal area increase, and hiatal area decrease were the best indicators of changes in the pelvic floor in different pelvic positions. Thus, these parameters were chosen as references for the sample size calculation. G*Power 3.1 was used to calculate the required sample size for the present study. Sample sizes of 24, 52, 87, 73, and 49 participants were required to detect 95% power and a significance level of $p = .05$ according to the values of bladder neck descent (2.69 ± 0.78, 2.21 ± 0.88, and 3.23 ± 0.88, respectively), cervical descent (2.05 ± 1.16, 2.05 ± 1.16, and 2.90 ± 1.02, respectively), rectal ampulla descent (2.74 ± 0.76, 2.49 ± 0.84, and 3.02 ± 0.88, respectively), hiatal area increase (6.39 ± 3.72, 5.32 ± 3.30, and 7.86 ± 3.88, respectively), and hiatal area decrease (2.88 ± 1.58, 2.33 ± 0.99, and 3.63 ± 1.61, respectively) in the three pelvic positions.

Statistical analysis

All the statistical analyses were performed via SPSS software version 26.0. Counting data are expressed as n%, and measurement data are expressed as $\bar{x} \pm s$ and quartiles according to the results of the normality test. The chi-square test was used to compare the differences in counting data. Moreover, one-way ANOVA and the Kruskal‒Wallis test were also used to assess the differences among the anterior pelvic tilt group, posterior pelvic tilt group, and neutral pelvic tilt group. For all tests, a two-tailed P value < 0.05 was considered statistically significant.

Results

A total of 189 subjects who met the inclusion and exclusion criteria were invited to participate in the present study, but 28 subjects did not meet the inclusion criteria,

Fig. 3 Posterior pelvic tilt (provided by Y.W.)

and 29 subjects were rejected (Fig. 5). Finally, 132 participants were included in this analysis. The baseline demographic features are summarized in Table 1.

The differences in the diagnoses of cystocele, uterine prolapse, perineal overactivity, and hiatal ballooning among the neutral pelvic tilt, anterior pelvic tilt, and posterior pelvic tilt groups were statistically significant ($P<.001$, $P<.001$, $P<.001$, $P<.001$, and $P<.001$, respectively) (Table 2).

The differences among neutral pelvic tilt, anterior pelvic tilt, and posterior pelvic tilt in hiatal area during contraction, hiatal area at rest, hiatal area during the Valsalva manoeuvre, bladder neck descent, urethral rotation angle, cervical descent, rectal ampulla descent, hiatal area increase, and hiatal area decrease were statistically significant ($P<.001$, $P<.001$, $P<.001$, $P<.001$, $P<.001$, $P<.001$, $P<.001$, $P<.001$, and $P<.001$, respectively). The values of hiatal area at rest, hiatal area during the Valsalva manoeuvre, bladder neck descent, urethral rotation angle, cervical descent, rectal ampulla descent in neutral pelvic tilt were higher than that of anterior pelvic tilt ($P=.019$, $P=.010$, $P<.001$, $P=.008$, $P=.001$, and $P=.024$, respectively). In addition, the values of hiatal area during contraction, hiatal area at rest, hiatal area during the Valsalva manoeuvre, bladder neck descent, cervical descent, rectal ampulla descent, hiatal area increase, hiatal area decrease in neutral pelvic tilt were lower than that of posterior pelvic tilt ($P<.001$, $P<.001$, $P<.001$, $P<.001$, $P<.001$, $P<.001$, $P<.001$, and $P<.001$, respectively). Moreover, the values of hiatal area during contraction, hiatal area at rest, hiatal area during the Valsalva manoeuvre, bladder neck descent, urethral rotation angle, cervical descent, rectal ampulla descent, hiatal area increase, hiatal area decrease in anterior pelvic tilt were lower than that of posterior pelvic tilt ($P<.001$, $P<.001$, $P<.001$, $P<.001$, $P<.001$, $P<.001$, $P<.001$, $P<.001$, and $P<.001$, respectively). The differences in cervical position at rest, rectal ampulla position at rest, and bladder neck position during the Valsalva manoeuvre, cervical position during the Valsalva manoeuvre, and rectal ampulla position during the Valsalva manoeuvre among neutral pelvic tilt, anterior pelvic tilt, and posterior pelvic tilt were statistically

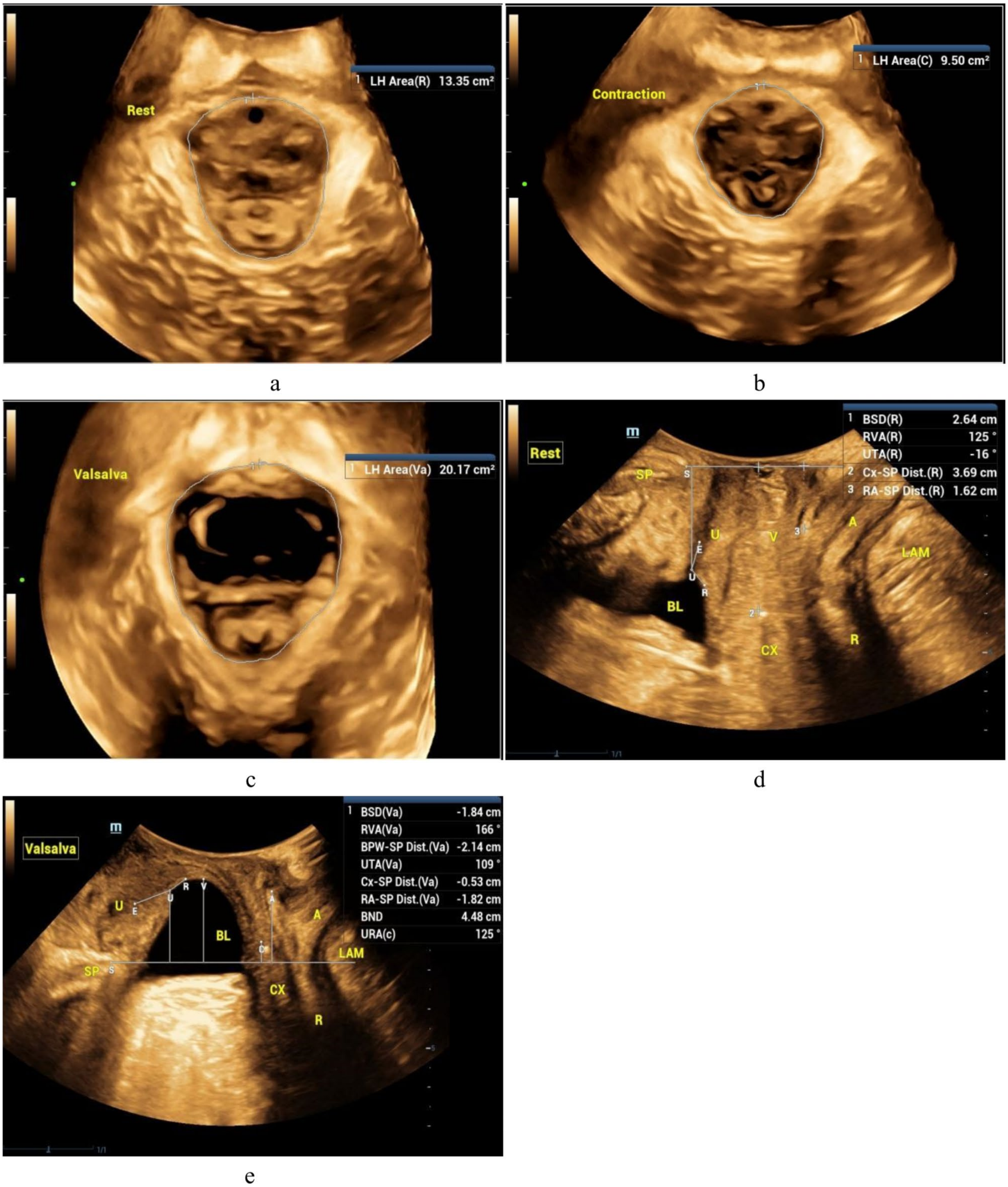

Fig. 4 **a** Hiatal area at rest; **b** Hiatal area at contraction; **c** Hiatal area during Valsalva manoeuvre; **d** Parameters measured at rest. The main structures (yellow letters) identified on this plane are, from left to right, symphysis (SP), bladder (BL), urethra (U), cervix uteri (CX), vagina (V), anal canal (A), rectum (R), levator ani muscles (LAM). The gray letters are S (the reference line of symphysis), EU (the line of proximal urethra), UR (the line of posterior wall of bladder), V (the distance from reference line to the lowest point of bladder), C (the lowest point of cervix uteri), A (the lowest point of rectum). The measurements in the top right (white letters) are bladder neck-symphysis distance (BSD), retrovesical angle (RVA), urethral tilt angle (UTA), cervix uteri-symphysis (Cx-SP), ampullae recti-symphysis (RA-SP); **e** The parameters (white letters) measured during Valsalva manoeuvre are bladder neck-symphysis distance (BSD), retrovesical angle (RVA), bladder posterior wall-symphysis (BPW-SP), urethral tilt angle (UTA), cervix uteri-symphysis (Cx-SP), ampullae recti-symphysis (RA-SP), bladder neck descent (BND), urethral rotation angle (URA)

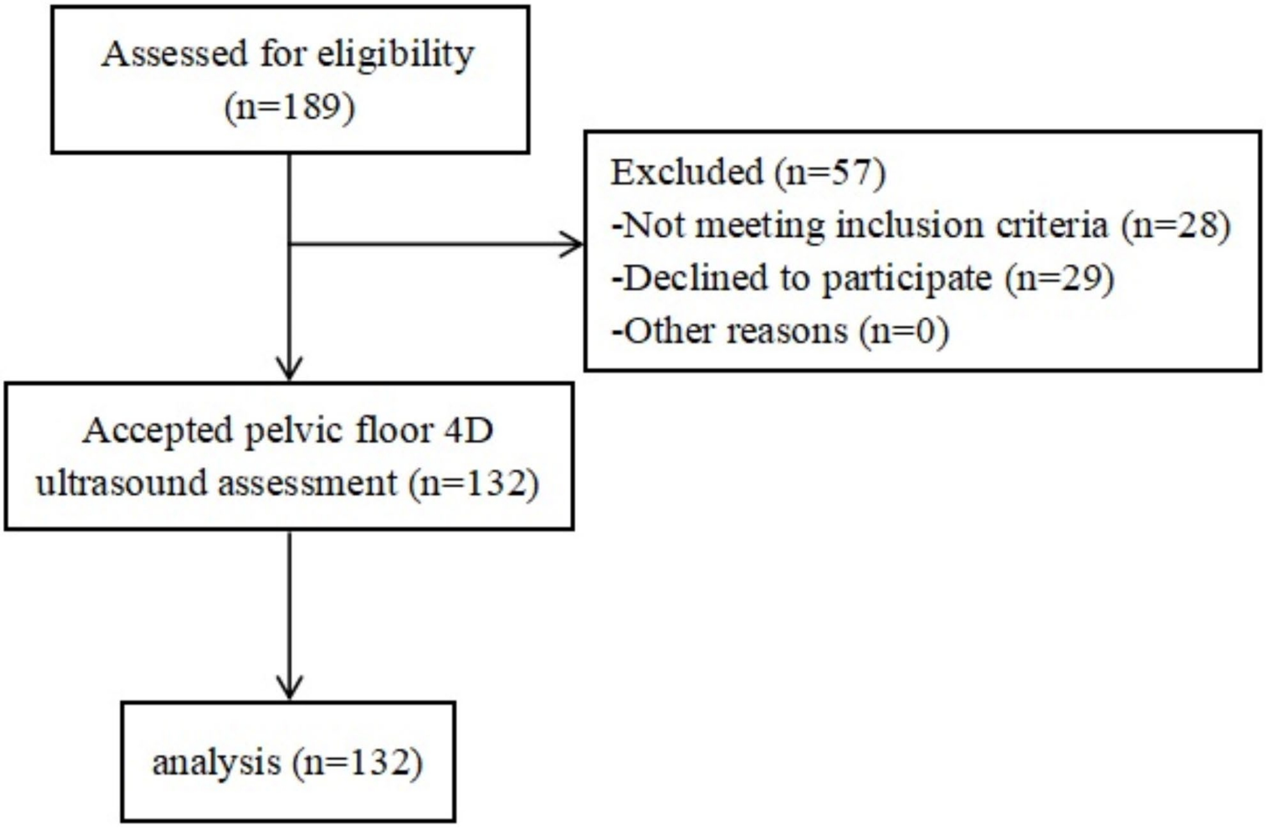

Fig. 5 Flow chart

Table 1 The participants' individual and obstetric characteristics

Variables		Mean ± SD (min, max)/ Number (%)
Age (y)		32.67 ± 5.44 (19, 58)
Height (cm)		160.04 ± 5.38 (145, 174)
Weight (kg)		59.84 ± 8.00 (43.00, 84.00)
BMI (kg/cm2)		23.35 ± 2.81 (17.69, 33.78)
Gestational weight gain (kg)		12.92 ± 4.62 (2.5, 25.0)
Neonatal weight (kg)		3.25 ± 0.38 (2.25, 4.35)
Gestation		1.98 ± 1.24 (1, 8)
Parturition		1.48 ± 0.66 (1, 4)
Education, year	<12	25 (18.94%)
	≥ 12	107 (81.06%)

Table 2 Diagnosis of pelvic organ prolapse in different pelvic position

Variables		neutral pelvic tilt	anterior pelvic tilt	posterior pelvic tilt	*P**
Cystocele	Yes	81 (61.4%)	51 (38.6%)	111 (84.1%)	**<0.001**
	No	51 (38.6%)	81 (61.4%)	21 (15.9%)	
Uterine prolapse	Yes	14 (10.6%)	7 (5.3%)	46 (34.8%)	**<0.001**
	No	118 (89.4%)	125 (94.7%)	86 (65.2%)	
Perineal overactivity	Yes	43 (32.6%)	7 (5.3%)	45 (34.1%)	**<0.001**
	No	89 (67.4%)	125 (94.7%)	87 (65.9%)	
Hiatal ballooning	Yes	60 (45.5%)	37 (28%)	101 (76.5%)	**<0.001**
	No	72 (54.5%)	95 (72%)	31 (23.5%)	

* Chi square test

significant ($P<.001$, $P=.035$, $P<.001$, $P<.001$, and $P<.001$, respectively). The values of bladder neck position during the Valsalva manoeuvre, cervical position during the Valsalva manoeuvre, and rectal ampulla position during the Valsalva manoeuvre in neutral pelvic tilt were lower than that of anterior pelvic tilt ($P=.001$, $P<.001$, and $P<.001$, respectively). Moreover, the values of cervical position at rest, bladder neck position during the Valsalva manoeuvre, cervical position during the Valsalva manoeuvre, and rectal ampulla position during the Valsalva manoeuvre in neutral pelvic tilt were higher than that of posterior pelvic tilt ($P=.003$, $P<.001$, $P<.001$ and $P<.001$, respectively). The values of cervical position at rest, rectal ampulla position at rest, and bladder neck position during the Valsalva manoeuvre, cervical position during the Valsalva manoeuvre, and rectal ampulla position during the Valsalva manoeuvre in anterior pelvic tilt were higher than that of posterior pelvic tilt ($P<.001$, $P=.041$, $P<.001$, $P<.001$, and $P<.001$, respectively) (Table 3).

Discussion

Overall, the present results revealed that the pelvic positions do have effects on the performing of PFM contraction and the Valsalva manoeuvre. Compared with the

Table 3 Differences of pelvic ultrasonic parameters in three pelvic positions

Variables	neutral pelvic tilt	anterior pelvic tilt	posterior pelvic tilt	F/Z	*P*
Hiatal area (C)	$10.18 \pm 1.51_a$	$9.83 \pm 1.42_a$	$11.43 \pm 1.95_c$	34.852	**<0.001***
Bladder neck position (R)	2.69 ± 0.27	2.66 ± 0.26	2.70 ± 0.25	0.552	0.576
Cervical position (R)	$4.05 \pm 1.01_a$	$4.19 \pm .96_a$	$3.69 \pm 1.01_b$	8.761	**<0.001***
Rectal ampulla position (R)	1.9 (1.7, 2.1)	$1.9\ (1.7, 2.2)_a$	$1.8\ (1.7, 2.1)_b$	6.704	**0.035**#
Hiatal area (R)	$12.93 \pm 1.78_a$	$12.33 \pm 1.97_b$	$15.11 \pm 2.43_c$	65.649	**<0.001***
Bladder neck position (V)	$-0.1\ (-0.5, 0.5)_b$	$-0.4\ (-0.1, 1.0)_c$	$-0.6\ (-1.1, -0.13)_a$	89.255	**<0.001**#
Cervical position (V)	$1.61 \pm 1.17_b$	$2.12 \pm 1.27_b$	$0.82 \pm 1.22_a$	38.024	**<0.001***
Rectal ampulla position (V)	$-0.8\ (-1.2, -0.51)_b$	$-0.6\ (-0.9, -0.3)_b$	$-1.2\ (-1.58, -0.9)_a$	85.610	**<0.001**#
Hiatal area (V)	$19.38 \pm 4.62_a$	$17.89 \pm 4.28_b$	$23.33 \pm 5.13_c$	47.376	**<0.001***
Bladder neck descent	$2.66 \pm .75_a$	$2.20 \pm .84_b$	$3.23 \pm .80_c$	54.879	**<0.001***
Urethral rotation angle	$73.36 \pm 24.80_a$	$65.11 \pm 25.63_b$	$78.60 \pm 25.13_a$	9.613	**<0.001***
Cervical descent	$2.45 \pm .92_a$	$2.07 \pm .93_b$	$2.87 \pm .96_c$	24.585	**<0.001***
Rectal ampulla descent	$2.70 \pm .65_a$	$2.51 \pm .66_b$	$3.06 \pm .67_c$	23.634	**<0.001***
Hiatal area increase	$6.45 \pm 4.25_a$	$5.57 \pm 3.74_a$	$8.22 \pm 4.70_c$	13.332	**<0.001***
Hiatal area decrease	$2.75 \pm 1.40_a$	$2.50 \pm 1.54_a$	$3.68 \pm 1.82_c$	19.985	**<0.001***

* one-way ANOVA test; # Kruskal Wallis test; C at contraction, R at rest, V valsalva; post hoc: a > b, a < c, b < c

other positions, the posterior pelvic tilt shows greater reduction in the hiatal area after PFM contraction. During the Valsalva manoeuvre, the posterior pelvic tilt is a position that not only shows the greatest increase in the hiatal area but also the bladder neck, cervical neck, and rectal ampulla are pushed to the lowest position.

As a POP staging system, pelvic organ prolapse quantization (POP-Q) is the most commonly used method in clinical assessments despite the disadvantages of subjectivity and inadequate diagnosis of muscle defects [19]. To complement clinical assessment, X-ray, computed tomography (CT), ultrasound, and magnetic resonance imaging (MRI) are common auxiliary examinations developed in recent years [20–22]. Although MRI is able to rapidly and clearly image the entire pelvic floor, ultrasound is more acceptable because it does not require radiation and it is cost-effective [23, 24]. The present results revealed that PFM strength is greater in the posterior pelvic tilt position tha*n* in the other positions. Although the greatest hiatal area is in the posterior pelvic tilt at PFM contraction, the decrease in the hiatal area in the posterior pelvic tilt is greater than that in any other position. Ptaszkowski et al. reported that the posterior pelvic tilt position results in increased resting and functional bioelectric activity of the PFM [25]. Bø, K et al. reported that hip adduction, gluteal muscle contraction, and abdominal muscle contraction result in synergistic contraction of the PFM [26]. Similarly, Soljanik, Irina et al. revealed that 97.2% of subjects exhibit synchronous movements of the PFM and gluteal muscle [27]. Ptaszkowski et al. reported greater rectus abdominis, gluteus maximus, and adductor magnus bioelectrical activity in posterior pelvic tilt; however, they indicated that there is no relationship between the activity of those synergist muscles and PFM, suggesting that synergist muscles are unlikely to be the cause of greater PFM contraction ability [15]. In the present study, participants were positioned such that their pelvis was anteriorly or posteriorly tilted so that their muscles relaxed as much as possible, making the synergist muscles less likely to participate in PFM contraction. Although the potential mechanism is still unclear, posterior pelvic tilt should be implemented in pelvic floor rehabilitation to improve the effect on the pelvic floor.

The present results revealed that at rest, a greater position of the pelvic organ is in the anterior pelvic tilt. Mattox et al. and Zacharin reported that a normative lumbosacral curve may protect the pelvic floor from direct intra-abdominal forces [28, 29]. The pressure from intra-abdominal forces is greater in the hypo-lordotic posture and pelvic posterior tilt, and the present finding that the hiatal area (at rest) is the smallest in the anterior pelvic tilt also suggests that the pelvic floor bears less pressure in that position [30, 31]. In contrast to the neutral pelvic tilt and posterior pelvic tilt, the reference line—the lower margin of the pubic symphysis—moves downwards in the anterior pelvic tilt, and the pelvic floor organs are positioned relatively upwards. In addition, Ruth R et al. reported that the anterior pelvic tilt results in greater PFM resting activity and thus maintains the area of the levator hiatus [16]. These findings may support the present results, demonstrated that the hiatal area is smallest in the anterior pelvic tilt group.

During the Valsalva manoeuvre, all the pelvic organs are pushed to the lowest position and have the greatest descent in the posterior pelvic tilt. Moreover, the hiatal area expands more in the posterior pelvic tilt position than in the other positions because of greater pressure from intra-abdominal forces. In obstetrics, the squatting position has been shown to shorten the labour time

Fig. 6 The tilt of the pelvic inlet

because it is similar to the position of defecation [32, 33]. The pelvis is forced to tilt posteriorly in that position, and both labour and defecation resemble the Valsalva manoeuvre. In addition, the physiological characteristic of the pelvic inlet determines that it has a forward and downward angle in the neutral pelvic tilt direction (Fig. 6). The pelvic inlet is oriented more vertically in the posterior pelvic tilt position than in other positions, which leads to direct intra-abdominal forces to the pelvic floor. Similar to the present study, JOHN K. et al. reported greater prolapse in the posterior pelvic tilt [34]. In the present study, the participants performed PFM contraction and the Valsalva manoeuvre well in the neutral position and posterior position. Owing to the universality of anterior pelvic tilt in the postpartum period, it is important to induce subjects to relax their waist during physical examination to make the lumbosacral joints as close to the bed as possible to obtain more accurate results [35].

The present study had several limitations. The present study included only postpartum vaginal participants, indicating that the results cannot be generalized to all age groups. In addition, the present study did not assess POP-related symptoms, which are important references for ultrasonic measurement results. Although studies on reproducibility and repeatability in the neutral position have been reported, no study has investigated the position of the anterior pelvic tilt and posterior pelvic tilt, which may undermine the credibility of the present study. Finally, the present study did not assess PFM displacement, PFM muscle thickness, or POP parameters during PFM contraction, which are important in the evaluation of POP.

Conclusion

During PFM contraction, the posterior pelvic tilt results in the greatest reduction in the hiatal area compared with other positions The greatest increases in the hiatal area, bladder neck descent, cervical neck descent, and rectal ampulla descent were observed in the posterior pelvic tilt position during the Valsalva manoeuvre. Further studies are recommended to explore the mechanism underlying the better performance of PFM contraction and the Valsalva manoeuvre in the posterior pelvic tilt.

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Author contributions
Y.W. M.L. and Y.Z. collected the data and prepared all the figures; Y.W. wrote the main manuscript text and analysed the data; J.F. edited the manuscript; Z.W. design the study and supervised it. All authors reviewed the manuscript.

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Data availability
The datasets analysed during the current study are not publicly available but are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The study was approved by the Ethics Committee of Fujian Maternity and Child Health Hospital (No. 2020KY145) and was conducted in accordance with Chinese law and the Guidelines of the National Human Biomedical Research Policies. All participants were asked to sign an consent form before they were included in this study was obtained from the patients.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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