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Transperineal pelvic floor ultrasound in male

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Abstract

Introduction The pelvic floor (PF) is a highly complex structure which may be affected by various stimulating factors like decreased PF support. As ultrasound can dynamically observe the position and mobility of anatomical structures, However, there are very few studies on PF ultrasound in males.

Materials and methods Twenty-one male patients with normal conditions underwent transperineal pelvic floor ultrasound (TPFU) examination. Ultrasound was performed in a supine lithotomy position. The probe was pressed on the sagittal plane of the perineum and adjusted till the anorectal angle, as well as bladder, were located and the median prostate and pubic symphysis were visible on the sagittal plane. TPFU was carried out to observe the patterns of pelvic floor movement during different phases, measure ultrasound parameters of the PF in men, and assess the potential applications and prospects of the male PF.

Results Two-dimensional male PF ultrasound can detect the bladder, prostate, male urethra, anus, rectum. Resting, Valsalva, and contraction phases of the PF are clearly shown, the pelvic organs in the Valsalva phase shift to the dorsal foot side, and shift to the cephalic ventral side when the levator ani muscle (LAM) contracts. Three-dimensional male PF ultrasound can visually show the shape and structure of the levator ani muscle hiatus.

Conclusion It is a feasible examination tool for detecting PF disorders. However, there are still many fields to explore in the future.

Keywords The pelvic floor (PF) · Transperineal pelvic floor ultrasound (TPFU) · Male

Introduction

The pelvic floor (PF) is comprised of bone, fascia, ligaments, and muscles, including the urogenital diaphragm, and is bounded by the pubis anteriorly, sacrum and coccyx posteriorly, and ischial tuberosity laterally. In males (Fig. 1), the PF consists of three layers [1, 2] the superficial perineum, urogenital diaphragm, and pelvic septum. The superficial perineum includes the bulbospongiosus muscle, ischiocavernosus muscle, superficial transverse perineal muscles, and external anal sphincter, which aid in urination and facilitate rigidity of the penis during erection and ejaculation. The urogenital diaphragm comprises the deep perineum, urethral sphincter, urethral pressure muscle, perineal membrane, and internal anal sphincter, which help to close the urethra during increased abdominal pressure. The membranous urethra and deep dorsal vein of the penis traverse through two separate openings, while the pelvic septum is mainly composed of the puborectalis and iliococcygeus muscles, which converge posteriorly to form the firm midline lambdoid suture [3]. The male PF has two functional compartments: the anterior (genitourinary) and the posterior (rectoanal), which contribute to controlling urination, bowel movements, and sexual function.

As the PF function is mainly coordinated by these structures, any slight uncompensated abnormality might lead to PF dysfunction. Although the incidence of male PF dysfunction is lower than that of females, many male patients suffer

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Fig. 1 PF anatomy in male

from several PF manifestations like urinary system diseases, fecal diseases, sexual dysfunction, and pelvic discomfort. Since many patients do not know the relation of reporting illness to PF dysfunction in the clinic, and many clinicians also focus on the symptoms of the corresponding organ disease; thus, the patient's PF symptoms are not correctly evaluated and judged.

In recent years, male PF disorders have received tremendous clinical attention; hence, accurate disease and curative effect evaluations have become extremely important. At present, the commonly used imaging methods are MRI and ultrasound. Although MRI displays high image resolution and real-time imaging of active rectal emptying, its clinical application is limited by the higher cost and complexity of the process. However, ultrasound is now widely used for visual evaluation of pelvic structure in women, and to a lesser extent in males due to its ease of operation, high resolution, and low cost. Our study aimed to investigate the characteristics of transperineal pelvic floor ultrasound (TPFU) in the assessment and diagnosis of normal male PF.

Materials and methods

Participants

Twenty-one normal male patients who underwent TPFU between January and July 2022 were enrolled; the mean age of participants was 37.43 ± 12.62 years. The inclusion criteria were: participants ≥ 18 years of age and those with no history of pelvic operation, pelvic mass, or urinary and anorectal diseases. All patients signed informed consent forms and voluntarily underwent the PF ultrasound. The study was carried out according to the principles of The Declaration of Helsinki.

Examination methods

This study used the Mindray 9 ultrasound diagnostic system with SC6–1U and D8–2U probes having a frequency range of 1–6 MHz and 2–8 MHz, respectively. All patients were asked to empty the bladder as much as possible before the examination, and an ultrasound was performed in a supine lithotomy position (supine, with knees bent). Patients were instructed to perform the correct Valsalva maneuver under real-time monitoring with ultrasound and anal retraction until their comprehension of the instructions was clarified based on the abdominal and dorsal movements of the PF organs. After covering the probe with a condom and applying the coupling agent, the probe was pressed on the sagittal plane of the perineum and adjusted till the anorectal angle (ARA), as well as bladder, were located and the median prostate and pubic symphysis were visible on the sagittal plane (Fig. 2). TPFU was performed in different clinical conditions. However, the marking line was consistent with that of the female PF ultrasound, which is a horizontal reference line passing through the inferior posterior margin of the pubic symphysis.

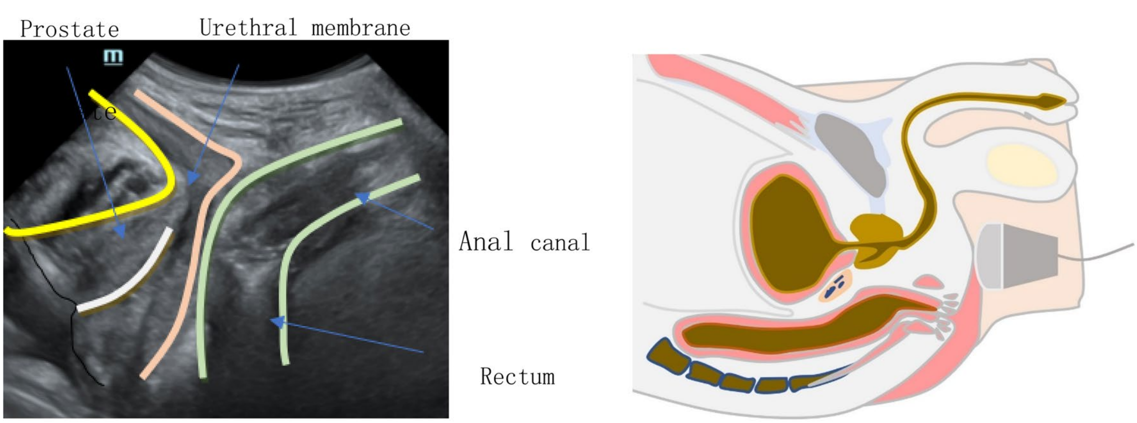

Fig. 2 Transperineal ultrasound is used to examine the PF, and a schematic diagram is often used to illustrate the examination

The subsequent ultrasound measurements were obtained

Anterior pelvic parameters

1. Bladder neck distance (BND) (Fig. 3a) and mobility (bladder neck descent distance): BND is the vertical distance between the bladder neck and the inferior posterior border of the pubic symphysis.
2. Prostatic urethral angle (PUA) (Fig. 3b): it is the acute angle between the proximal and distal prostatic urethra.
3. Pubic-prostate angle (PPA) (Fig. 3c): PPA is the angle between the pubic symphysis and ventral prostate.
4. Membranous urethral length (MUL) (Fig. 3e): MUL is the distance from the apex of the prostate to the urethral entrance at the level of the bulb of the penis.

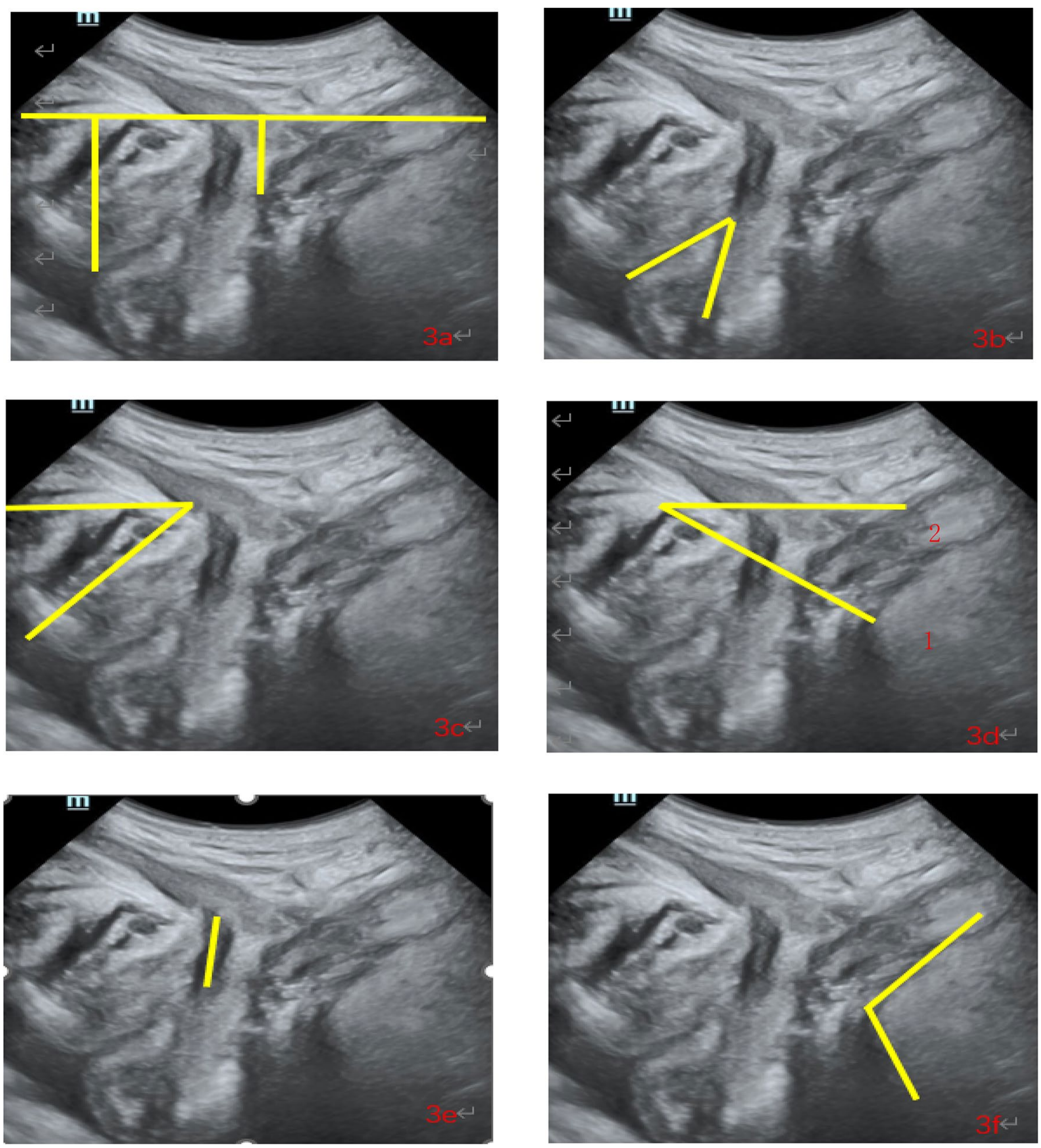

Fig. 3 **a** Bladder neck distance (BND, vertical line on the left), The distance from the anal canal junction to the anterior rectum to the horizontal line (JHD, vertical line on the right); **b** Prostatic urethral angle (PUA); **c** Pubic-prostate angle (PPA); **d** Levator plate length (LPL,1 line) and Levator plate angle (LPA,(1 line and 2 line angle); **e** Membranous urethral length (MUL);**f** Anorectal angle (ARA)

The posterior pelvic measurement parameter

1. The distance from the anal canal junction to the anterior rectum to the horizontal line (JHD) (Fig. 3a): a horizontal line is drawn parallel to the transducer's surface from the lower edge of the pubic symphysis; the distance from the resting phase to the Valsalva phase represents the descending distance of levator ani muscle (LAM) hiatus.
2. Levator plate length (LPL) (Fig. 3d): it is the distance from the apex of the posterior anorectal junction to the inferior part of the pubic symphysis.
3. Levator plate angle (LPA) (Fig. 3d): the angle between the line (made from the junction point of the posterior anorectal border to the distal pubic symphysis) and the horizontal reference line, LPA offset is calculated by subtracting the contraction phase LPA from LPA at the resting phase.
4. Anorectal angle (ARA) (Fig. 3f): it is the angle between the posterior wall of the ampulla and the anal canal. The ARA offset is the ARA of the resting phase minus that of the contraction phase.

Results

Demographic characteristics of patients are shown in Table 1

Two-dimensional male PF ultrasound findings (Figs. 2, 4)

PF ultrasound can identify the bladder, prostate, male urethra, anal canal, and rectum, as shown in Fig. 2. The resting, Valsalva, and contraction phases of the PF are clearly illustrated in Fig. 4. During the Valsalva phase, the pelvic organs move towards the dorsal foot side, while they shift towards the cephalic ventral side when LAM contracts.

Three-dimensional male PF ultrasound findings (Fig. 5)

The three-dimensional ultrasound technique can visually show the shape and structure of the LAM hiatus. The male PF hiatus has a narrow, elongated structure with an upper pubic branch, arcuate ligament, and a lower puborectalis muscle, with two internal outlet structures, urethra, and rectum, respectively.

Table 1 Demographic characteristics of patients

Patient characteristic	Mean ± SD (Range)
Age (years)	37.43 ± 12.62 (19, 59)
Height (m)	1.75 ± 0.05 (1.66,1.83)
Weight (kg)	77.62 ± 14.36 (50,100.50)
BMI (kg/m2)	25.35 ± 4.31 (16.33,31.14)

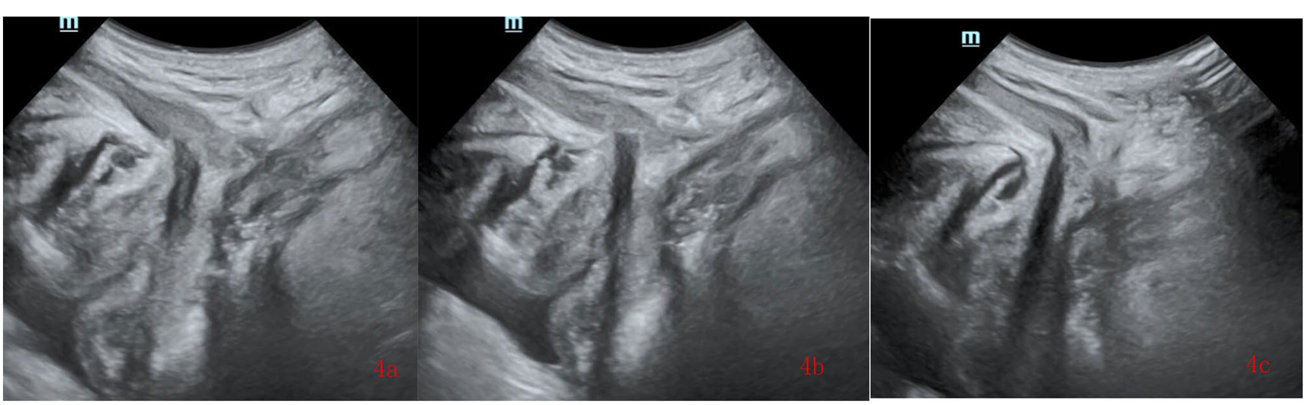

Fig. 4 Male PF ultrasound performance under different conditions. **a** resting phase; **b** Valsalva phase; **c** contraction phase

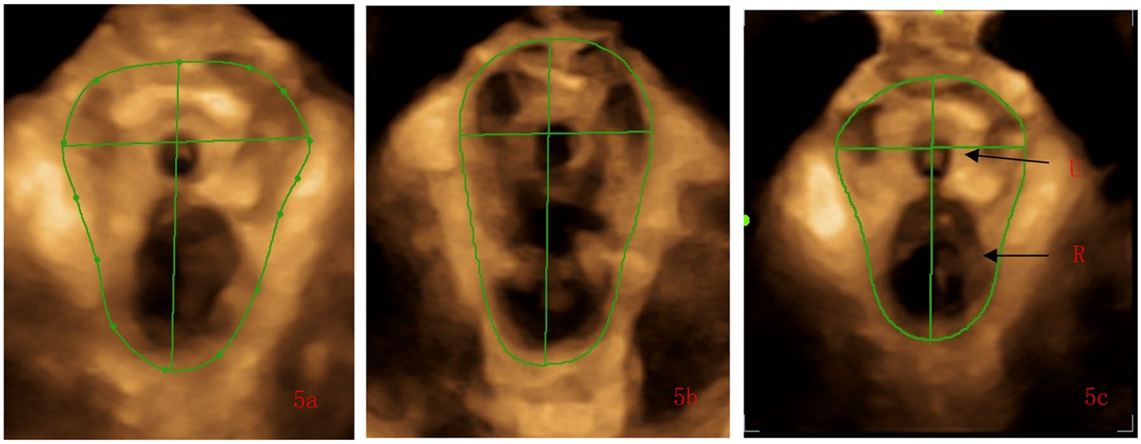

Fig. 5 Ultrasonic manifestation of LAM hiatus under different conditions. **a** resting phase, **b** Valsalva phase, and **c** contraction phase. U urethra, R rectum

The results of pelvic parameters are shown in Table 2

Discussion

PF dysfunction in males can result in urinary issues such as increased frequency and urge to urinate, fecal incontinence, pelvic pain, including prostate pain, and sexual dysfunction. A study has shown TPFU enables highly reproducible imaging of PF conditions for a thorough examination in normal men as well as in prostatectomy patients [4]. At present, TPFU in male is being used in the following fields:

Abnormal anatomical structures

TPFU is a simple, effective method for diagnosing PF structural abnormalities. It can observe the internal structures of the pelvic cavity along with disorders like perineal hernia and inflammation, bladder neck obstruction, urethral diverticulum, other urethral lesions, rectal prolapse, rectocele, and rectovaginal fistula.

Pelvic organ prolapse

The normal male urethral suspensory mechanism consists of three continuous structures: anterior, middle, and posterior pubourethral ligaments (puboprostatic ligaments). These ligaments support and stabilize the prostate's normal anatomic position and urethra for normal urination [5, 6]. Our results showed that BND reduced from 2.80 (2.41–5.44) cm in the resting phase to 2.63 (2.43–5.81) cm in the Valsalva

Table 2 The results of pelvic parameters in different phase

	Resting phase	Valsalva phase	Contraction phase
BND	2.80(2.41–5.44)	2.63(2.43–5. 81)	4.67(3. 35–6.13)
JHD	1.46(0.52–2.58)	0.93(−0.78–2.04)	1.82(1.31–2.65)
PPA	59.71(34–91)	69.19(42–98)	50.48(33–62)
LPL	4.86(3.64–6.51)	5.03(3.37–6.77)	4.18(3.02–5.13)
LPA	25.81(8–42)	19.29(4–46)	40(24–66)
MUL	1.27(0.48–1.98)		
PUA	41.52(6–73)	37.48(2–71)	36.00(5–62)
ARA	103.24(72–119)	104.95(71–123)	90.24(56–110)
LAM hiatus			
Area	11.85(7.94–25.67)	17.03(9.0–27.43)	12.10(7.3–18.9)
Front-back diameter	5.16(2.69–7.48)	5.50(3.40–7.60)	4.47(2.19–6.10)
Left and the right diameter	3.58(2.40–5.28)	3.91(2.51–6.14)	3.47(2.27–4.66)
Perimeter	15.36(11.39–19.50)	16.34(12.30–21.31)	13.51(9.99–17.75)

phase ($p > 0.05$); the resultant change was not obvious after increased abdominal pressure. Moreover, the change in JHD from resting phase 1.46 (0.52–2.58) cm to Valsalva phase 0.93 (−0.78–2.04) cm ($p < 0.05$) can be used as a reference for assessing normal location and male PF prolapse.

If only the ventral prostate is damaged during the surgery, and the remaining prostate and urethra are intact, it may still lead to urinary incontinence [7]. However, excessive weight gain can also lead to enlarged prostate and BND reduction, thus, resulting in PF disorders. Future studies can be conducted to understand the relationship between PF anatomical anatomy and clinical symptoms.

In a study involving 179 female patients with urinary incontinence, Dietz HP [8] found that there was a significant association between bladder neck position and the severity of stress urinary incontinence. After prostatectomy, the male PF loses the support of puboprostatic and surrounding ligaments. Since the PF anatomy and urodynamics are similar to that of women, observation of BND may be useful in evaluating PF dysfunction after prostatectomy.

The process of micturition

Dynamic observation of urination

TPFU can dynamically observe structural alterations in the bladder, prostate, and lower urethra during urination. Due to the inhibition of the efferent activity of the external urethral sphincter muscle and parasympathetic innervation of urethral smooth muscle during urination, nitric oxide is released, thus, causing the relaxation of the urethral and PF muscles [9]. The process of micturition includes PF relaxation, bladder neck reduction, an increased angle between the pubic symphysis and bladder neck axis, prostate contraction, and urination [10]. A study has shown a significant reduction in the head–tail length of the prostate during urination [11]. The mean head–tail length and PPA in normal conditions and at the end of micturition were 48.50 and 33.93 mm [12] as well as 37.64 and 56.8 mm, respectively. However the mean PPA and head–tail length of the ventral prostate in male patients with inability to urinate and Valsalva maneuver did not change significantly before and after micturition, as well as no change was observed in the head–tail length of the dorsal prostate in normal men, which might be related to the longitudinal urethral musculature and the prostate cross-over [13]. Consistent with the results, the prostate length was not shortened in the Valsalva phase, but the PPA in Valsava phase was increased. Moreover, the ventral prostate of a few Valsalva phase patients showed slight morphological changes and a downward displacement.

Although there is an association between PUA and international prostate symptom score, this conclusion is currently somewhat controversial [14, 15]. Our study showed that the PUA in the Valsalva and the contraction phases were 37.48 (2–71) and 36.00 (5–62). They were smaller than the resting phase angle, but no significant difference was observed among the three phases. Thus, the clinical significance of PUA was limited.

Pre-and post-prostatectomy MUL assessment

MUL has a significant impact on the overall incidence of urinary incontinence and the time taken to regain urinary control [16]. Therefore, clinicians should comprehensively assess MUL before surgery, and the urethral membrane should be preserved to its maximum extent. MUL is mostly measured by MRI with values ranging from 0.5 to 3.43 cm [16, 17] and could also be accurately measured by TPFU, with similar results as MRI [18]. The normal range of MUL in our study was about 1.27 (0.48–1.98) cm. Piotr et al. [19] reported that the measured pre-and postoperative MUL, along with the percentage of changes by TPFU, were associated with the time and rate of recovery to control postoperatively. Hence, TPFU is a reliable tool for MUL evaluation in patients with radical prostatectomy [18].

Assessment of urethral motion after prostatectomy

The position of the urethra before and after the prostatectomy changes. TPFU [4] can effectively measure anatomical landmarks, location of the pelvis, displacement of the urethra, and observe the functional status of the urethra after prostatectomy to predict the risk of postoperative urinary incontinence. Ryan E. [20] observed normal male urethral displacement at rest and maximal contraction phase while the displacement range of the ventral urethra-vesical junction (vUVJ), the dorsal urethra-vesical junction (dUVJ), the anorectal junction (ARJ), the dorsal motion of the mid-urethra (MU) and the most dorsal point of penis bulb (BP) were 4.6–20.6 mm, 3.2–27.4 mm, 4.9–21.6 mm, 4.9–21.6 mm, and 0.2–16.5 mm, respectively.

Evaluation of anorectal and perianal diseases

TPFU can diagnose anorectal and perianal diseases. The normal male ARA in the resting phase is about 101 [21], while in our study, the ARA of the resting phase was 103.24 (72–119). We observed that ARA decreased when the PF muscle contracted, especially the puborectalis muscle, which is consistent with the available literature; ARA changed significantly from the resting [103.24(72–119)] to the contraction [90.24(56–110)] phases. It can also be used for the diagnosis of PF bradycardia syndrome. The sonography showed that ARA became smaller, and the puborectalis muscle became thicker at the Valsalva phase. Since patients with partial fecal incontinence and abnormally enlarged ARA can compensate with an uninjured anal sphincter and PF muscles, the clinical significance of ARA as a marker of PF dysfunction is still unclear.

PF assessment of sexual dysfunction and chronic pelvic pain syndrome

Sexual dysfunction is closely related to PF dysfunction [22]. It is seen [23] that the mechanism of male erection and ejaculation is related to the contraction/relaxation of PF muscles. Although TPFU can visually show muscle condition, PF muscle strength can be assessed by ultrasound elastography. Additionally, PF dysfunction may be an important pathogenesis of chronic pelvic pain syndrome in men [24]. LPA offset in these patients is smaller, which [25] may be related to contractions of the pubococcygeus muscle, coccyx, and ischium coccyx muscles, indicating reduced upward movement of PF during contractions.

Assessment of the LAM hiatus area

The LAM hiatus area in female is an important index of PF examination, since females have a wider hiatus and a higher incidence of LAM injury, while males have a narrow PF and a smaller outlet, after the Valsalva motion, the area did not increase as significantly as that in the women. Male LAM hiatus does not have a high resolution as females, but it can still show the PF hiatus, urethral and anorectal structures. The clinical significance of the LAM hiatus area in males should be further explored.

Assessment of PF muscle contractility

TPFU is a reliable tool for quantifying PF muscle contractions [26]. Volloyhaug et al. [27] measured LPL at resting and contraction phases in 608 asymptomatic women and showed a significant correlation between ultrasound measurements and clinical examination. In the contraction phase, the PF and pelvic organs lift as a whole. LPA is an indicator of overall PF muscle function, changes in LPA (offset) are due to the rise and fall of PF; the greater the angle and displacement of LPA, the stronger the contraction of PF muscles. Our study showed that LPL decreased from resting phase 4.86 (3.64–6.51) cm to contraction phase 4.18 (3.02–5.13) cm. Therefore, timely detection can promote earlier recovery of PF function. Additionally, ultrasound elastography can also directly evaluate related ultrasound elastic indexes of LAM.

TPFU is non-invasive and easy to operate, it can dynamically observe the changes in PF structures and the morphology of the diaphragmatic hiatus in different states, as well as effectively measure the relevant parameters and provide comprehensive male PF data. Nevertheless, this study has limitations regarding the sample size, age range, and BMI range of the participants. Therefore, it is necessary to expand the sample size and age and BMI ranges and perform stratified analyses to obtain more precise data, which can provide a basis for diagnosing diseases and assessing their severity in the future. Furthermore, in men, the pelvic floor soft tissues are thicker, and PF structures are farther from the skin, which results in lower image resolution compared to female pelvic floor ultrasound.

Conclusion

Since TPFU can dynamically observe the morphological differences of male PF, it is a feasible examination tool for detecting PF disorders. However, there are still many fields to explore in the future.

Author contributions LW put forward the idea of the article, collected and analyzed the data, wrote the manuscript. YL supervised the progress and revised the manuscript. PX collected the data. MY supervised the progress and analyzed the data.

Funding No.

Data availability The data supporting this study's findings are available from the corresponding author upon reasonable request.

Declarations

Conflict of interest None of the authors have any conflicts of interest.

Ethical approval All procedures performed in studies were in accordance with the ethical standards of the institutional.

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