Ultrasound in Pelvic Floor Physiotherapy

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Learning Objectives

1. To describe two-dimensional (2D) sonographic utilities in physiotherapy (PT) evaluation and three-dimensional (3D) sonographic utilities for research
2. To describe the use of 2D ultrasound in the PT evaluation of the pelvic floor, connective tissue, the bladder neck, and the anorectal angle (ARA) that is related to the grade of contraction of puborectalis muscle
3. To describe the use of 2D ultrasound in the PT evaluation of the abdominal muscles
4. To show an overview of the literature on the use of ultrasound in different pelvic floor disorders in therapy and research
5. To learn common pathology and biomechanics of the pelvic floor muscle (PFM)
6. To gain palpation and ultrasound examination techniques and tips

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Introduction

If an individual has difficulty with her vision, we simply look into her eyes with an ophthalmoscope to detect any abnormalities. This seemingly simple task was not possible until 1851. After its introduction, the practical value of an ophthalmoscope went unnoticed for years. Using the historical example of the ophthalmoscope, we are still in infancy with ultrasound in its ability to scan the pelvic floor. Similarly, our understanding of pelvic floor disorders, which include pelvic organ prolapse and urinary and fecal incontinence, is in its early stages of development.

Pelvic floor disorders are dynamic, multifaceted, and potentially chronic health conditions resulting from a combination of anatomical, physiological, genetic, lifestyle, and reproductive factors. Anatomically, the levator ani muscles (LAM) and the endopelvic fascia are partners in providing pelvic support. A healthy LAM with normal tone prevents transmission of pressure to the connective tissue. Once the muscles are damaged, the ligaments are burdened to carry an increasing share of the load, which may result in connective tissue failure over time [1]. But there are also connective tissue defects, such as damage of the endopelvic fascia, that may cause POP and an inability for PFM to compensate all.

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Over the past 20 years pelvic floor imaging technologies have improved exponentially. Magnetic resonance imaging (MRI) discovery of LAM defects after childbirth and the documentation of their association with pelvic floor dysfunction have increased our understanding of the disease process. Women with pelvic organ prolapse have an odds ratio of 7.3 for having major levator ani defects seen on MRI, as compared to women without prolapse. Women with new stress incontinence after their first vaginal delivery are twice as likely to have birth-associated levator defects. There is an odds ratio of 8.3 for pelvic floor disorders development when both levator defect and tissue failure are present. Levator ani defects appear to be a necessary condition for architectural distortion to occur. Given the wealth of accumulating evidence, the question is not whether we should scan the pelvic floor [2, 3], rather, what is the best way to scan the pelvic floor?

Although the number of positive studies on the use of pelvic floor ultrasound in PT has increased, there is still poor adoption of ultrasound as a core competency in PT. The challenge of this chapter is to convey the value of ultrasound for physiotherapists worldwide, not only for research, but also for clinical investigation. Given the high acceptance of ultrasound in medicine in general, its reliability in research, its ease of use, and its capacity for patient education, ultrasound is a core competency that most physiotherapists do not possess. But for physiotherapist who have already implemented this technology in their clinical practice, they can't think of daily work without thinking of dynamic rehabilitative ultrasound for evaluation, patient education (explanation of the biomechanics) and treatment.

The Physical Therapist's Role

A physiotherapist analyzes the functional deficits associated with symptoms such as loss of bladder neck stabilization for example during a cough, which can be assessed and treated during PT. Physical therapy is no longer only a clinical treatment method but also an analytic one that includes analysis-guided therapy. From this point of view, urogynecology and PT have the same background; thus for both professions ultrasound is an important tool in diagnosing not only structural defects but also changes of normal mechanisms. Many symptoms can be treated with PT. Typically, the therapy prescribed is similar to sports strengthening and endurance exercises of the PFM treated for other conditions. An overwhelming body of research shows that it is important to investigate the connective tissue (endopelvic fascia) of the PFM, and their interaction with each other. It is also important to determine the best rehabilitation program for the muscles and and to ascertain if connective tissue can be treated by PT. It has been shown in motor control studies, that a PFM contraction is physiologically co-activated with contraction of the transverse abdominal muscle during a voluntary contraction [4–6]. This contraction is preserved in healthy women and lost in patients with urinary incontinence [7].

According to the 2014 consensus statement from the International Continence Society's "state-of-the-science" seminar on improving PFM training adherence: Physiotherapists/clinicians should: (1) judiciously offer sufficient accurate information to grow patient "knowledge," (2) teach the "physical skills" of a correct PFM contraction, then enhance performance and develop patient confidence and (3) enable constructive "cognitive analysis, planning and attention" to increase patient adherence [8]. In all these points, "dynamic rehabilitative ultrasound (DRUS)" provides a perfect instrument to fulfill all of these recommendations.

The Role of Ultrasound in Physiotherapy

Ultrasound help us understand why PT may fail. For example, if a PFM contraction cannot in any way be performed or recalled because the women is not able to contract the muscle because there is a inhibition or a coordination problem or there is a severely atrophy, no effect from muscle training can be expected. Other treatment options, such as electrical stimulation, will appear logical for patients with neurogenic or atrophied muscles and may be utilized instead. Prolapse surgery can be considered when a symptomatic grade 2 or above prolapse is not correctable with a pelvic floor contraction and not reduced permanently with PFM training [9].

Although ultrasound has been used therapeutically in the field of incontinence, there are only studies that have been performed for a better understanding of the mechanistic characteristics of pelvic floor disorders (pathomechanisms) [10–20]. There are only two studies, where ultrasound is added as an instrument in therapy [21, 22]. Incontinence is not only a problem of the pelvic floor. Often urine leakage occurs during single actions in daily life, such as lifting, coughing, laughing, and sneezing and during more complex activities, such as running, playing tennis, and performing gymnastic exercises. It has also been shown that an overactive bladder (OAB) is more common in women who regularly perform abdominal curls and other intense exercise. High impact sports regularly increase intraabdominal pressure (IAP) and therefore lead to a change in PFM function/reaction (loss of relaxation) and to a strain to depress the organs. For PT it is also essential to detect the motor control deficiencies of the pelvic floor and to correlate it with the patient's symptoms. Pelvic floor disorders can be dynamic problems and dysfunctions with or without anatomical defects. Knowing if an underlying muscle defect or atrophy exists is central to the treatment of dynamic pelvic floor problems. Unfortunately, most urogynecologists and physiotherapists have not been trained to use ultrasound to their advantage. Therefore, dynamic ultrasound in pelvic floor rehabilitation is a progressive, exciting, and should be considered an essential technique that is now included in an increasing number of PT courses around the world.

A study to evaluate pathomechanisms and to teach a correct PFM contraction [4, 22], and a study of healthy women by Crotty et al. [21] found cues to instruct women to contract the PFM. In patients with pelvic floor dysfunction, after thorough history taking, the physiotherapist will assess the function of the pelvic floor by visual observation, vaginal palpation, and/or measurement of muscle activity (measurement of vaginal or urethral squeeze pressure, electromyography, and ultrasound) [22].

The PFM examination is an important skill for clinicians who practice in the field of pelvic floor dysfunction. Teaching physiotherapists to perform an accurate examination of the pelvic floor musculature poses a challenge for many institutions [23]. Ultrasound in this setting provides a positive feedback to the trainee and the instructor if the PFMs are responsive. Although one study found manual palpation to be a more valid measure of PFM function than perineal pelvic floor ultrasonographically determined bladder neck displacement or reduction of hiatal AP diameter observed on PFM contraction [24], others have shown good correlation between the two [25].

Older Women

Older women with urinary incontinence demonstrate different problems with their pelvic organ support structures, depending on the type of urinary incontinence. These new findings should be taken into consideration for future research into developing new treatment strategies for urinary incontinence in older women [26]. Pelvic floor exercises should follow functional and structural findings [6]. The bladder neck position and stability during increased IAP have shown to be very important to maintenance of continence and are easily assessed by perineal pelvic floor ultrasound (pPFUS), not only in the supine but also in the standing position.

Abdominal Ultrasound: 2D and 3D Abdominal Ultrasound of the Abdominal Muscles

Since there are studies that have shown a co-activity of the deepest abdominal muscle, the transverse abdominal muscle, it is important to evaluate not only the PFM by palpation and ultrasound, but also the abdominals [4, 5, 7]. This is best done with a linear probe in women with less adiposity, subcutaneous tissue, or with an abdominal/convex probe in women with more adipose tissue, requiring more penetration by the ultrasound (Table 16.1).

Table 16.1 Characteristics of transducers used for transperineal, introital, and abdominal muscle ultrasound for physiotherapy inquiries (SonoSite, Fujifilm SonoSite, Bothell, WA, USA)

Model	Footprint	Frequency	Penetration	Use in physiotherapy
 C60nReal time 2D-convex transducer	60 mm	5–2 MHz	30 cm	Perineal ultrasound Abdominal muscles Supra-pubic ultrasound for residual volume and bladder movement
 ICTxIntra-cavity 2D-transducer		8–5 MHz	13 cm	Perineal/introital ultrasound
 L38xiReal time 2D-linear transducer	38 mm	10–5 MHz	9 cm	Abdominal muscles ultrasound in women with less subcutaneous tissue

To evaluate abdominal muscles, the ultrasound probe should be placed medial to the anterior superior spine to allow a transverse view of the three abdominal muscles (transverse abdominal, internal and external oblique abdominal muscles). For this technique the same convex probe as for pPFUS can be used. For better image quality, a higher frequency linear probe can be used, but only on women with lower body mass index (BMI) or with less abdominal adipose tissue. It has been shown in recent studies that with a correct PFM contraction, a co-contraction of only the transverse abdominal muscle is physiological. Therefore the co-contraction of the superficial muscles should be eliminated. This can be assessed by ultrasound, corrected by terminal ultrasound biofeedback, and reassessed by further ultrasound biofeedback [4].

In the early 2000s, physiotherapists performed ultrasound suprapubically to assess the movement of the bladder. Bladder scans were developed for evaluating the residual volume of the bladder non-invasively (without catheterization). This method was used by physiotherapists to assess bladder movement can be performed by a bladder scan, suprapubically with all curved/abdominal ultrasound probes (2D/3D/4D). This method gives an insight into bladder movement as well. The disadvantage of this ultlrasound technique is due to its limited validation and the influence of the IAP on probe stability during functional tasks such as straining and coughing. Furthermore there is no posiblity to scan when the bladder is empty. The advantage of this method, for example, for back pain patients, (and a collaborating diagnosis of pelvic floor disorders) and for children is that with this method patients are not required to undress fully.

Abdominal ultrasound to visualize the bladder by a supra-pubic or supra-symphysal approach has been performed by Sherburn et al. [27]. This technique was first described by Avery et al. at the International Federation of Orthopaedic Manipulative Therapistst conference in Perth, Australia [28]. Sherburn et al. established the interrater and intrarater reliability of assessment of voluntary pelvic floor contractions (validity study, $n = 10$ women and reliability study, $n = 20$

women). The method of supra-pubic or supra-symphysal ultrasound was later used for functional investigations and daily life activities. One big issue was the increase in IAP during these functional tasks and a lack of validation for these activities. Currently, there are only subjective observations; there is no validation of these tasks by the ultrasound methods. A 2005 study was designed (1) to assess the reliability of transabdominal (TA) and pPFUS during a PFM contraction and Valsalva maneuver and (2) to compare TA ultrasound with TP ultrasound for predicting the direction and magnitude of bladder neck movement in a mixed subject population. A qualified sonographer assessed 120 women using both TA and pPFUS. Ten women were tested on two occasions for reliability. The reliability during PFM was excellent for both methods. pPFUS was more reliable than TA ultrasound during Valsalva. The percentage agreement between TA and pPFUS for assessing the direction of movement was 85% during PFM contraction, 100% during Valsalva. There were significant correlations between the magnitude of the measurements taken using TA and pPFUS and significant correlations with PFM strength assessed by digital palpation [29].

For the scanning of abdominal muscles, all machines and 3D/4D curved/abdominal ultrasound probes can be used. The 3D/4D convex transducers are normally used in obstetrics for intra-uterine/pre-natal diagnosis and often available in greater or specialized clinics/practices (e.g., in multidisciplinary teams). These probes can be used and are equal to 2D transducers, but this technology is higher and therefore more expensive and absolutely not necessary for abdominal PT.

Pelvic Floor Ultrasound Techniques

Machines and probes that are widely available and used in gynecology, urogynecology, urology, coloproctology, or general medicine can also be used by physiotherapists (for example in an interdisciplinary clinical setting). At the minimum a 2D ultrasound probe is essential for clinical use, for assessing the dynamics of the pelvic floor, for patient education, and for visual biofeedback. For assessment, pPFUS (with a curved abdominal probe) or a vaginal probe/transducer (intracavity probe) can be used. It is easier and can be used also for the abdominal muscles for the physiotherapist to use the curved probe and, it can be used while either standing or sitting (Fig. 16.1). The image obtained may have variable clarity depending on probe technology and the footprint (Fig. 16.2).

Fig. 16.1 A physiotherapist evaluating a patient with perineal pelvic floor ultrasound in standing position

3D and 4D ultrasound pPFUS methods are important when measuring muscle thickness and when genital hiatus is of interest. To answer Questions related to patho-mechanisms, which are often dynamic questions, there is no need for a 3D and 4D ultrasound probe. Further more because movements are often too quick and contractions have to be maintained too long to obtain a good ultrasound image 3D and 4D technology is not posible. For example, we found [max submax paper - see in references] that a maximal pelvic floor contraction can be held for 10 s in healthy and incontinent women, but approximately 30 s is necessary to receive a good

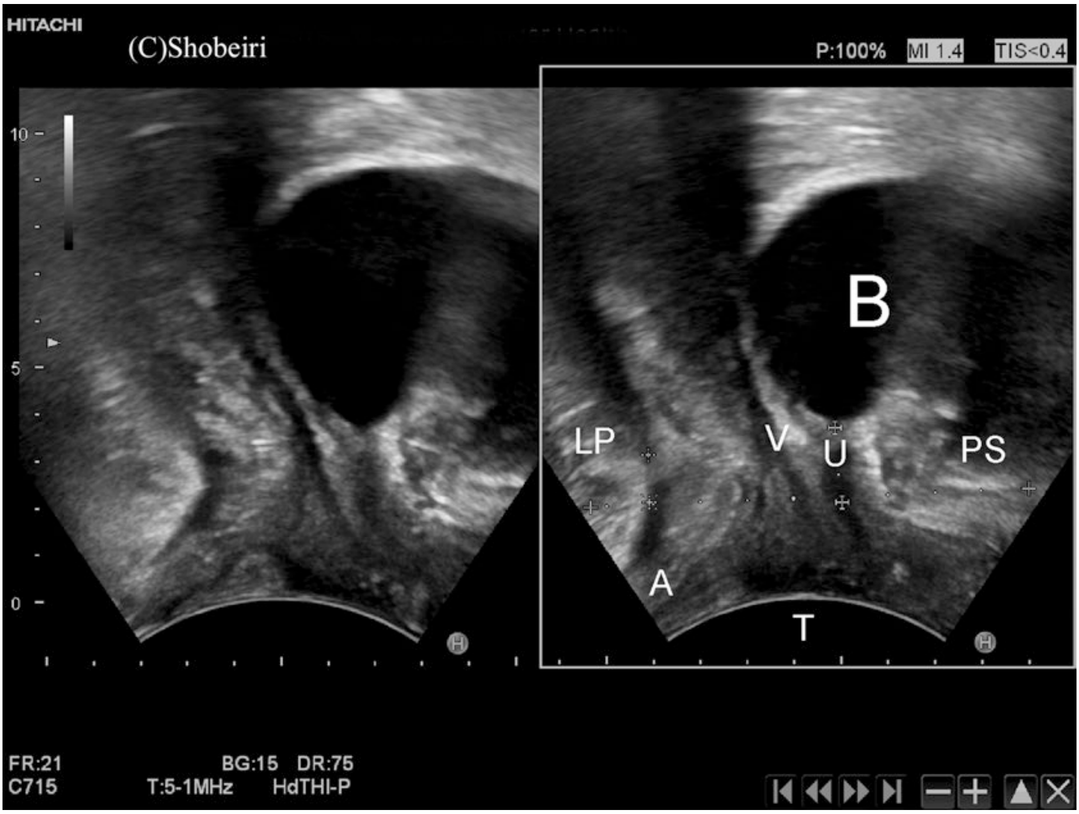

Fig. 16.2 Perineal pelvic floor ultrasound. The image on the right is labeled for easy identification. Bladder (B), pubic symphysis (PS), urethra (U), vagina (V), anus (A), levator plate (LP). © Shobeiri

3D ultrasound volume regardless of the technique used.

When performing a 3D endovaginal ultrasound, an intravaginal BK 8838 probe (BK Ultrasound, Analogic, Peabody, MA, USA) obtains images every 0.5° to create a 3D volume from about 800 scans in 30 s. One can decrease the time by scanning every 2°, but the quality suffers. It is, however, important to emphasize that, although visualizing LAM defects is possible with GE, Phillips, or similar transperineal 3D pPFUS requiring squeeze or Valsalva, endovaginal 3D BK ultrasound can visualize the LAM defects in resting position without any dynamic manuvers because of its high resolution and proximity to the LAM tissue. A 2D transperineal ultrasound images the levator plate in relationship to the pubic bone. This is akin to looking at the shadow of a wall (the levator ani muscle) (Fig. 16.3) [30]. In reality pelvic floor musculature is a dynamic 3D structure and needs to be evaluated in totality (Fig. 16.4) [31]. A 3D pPFUS is like looking at the wall at its ends (Fig. 16.5). Employing Valsalva through 4D brings the face of the wall to the sonographer to see any ballooning or warping. A 3D endovaginal probe obviates the need for 4D viewing as it is placed against the belly of the levator ani muscle visualizing the iliococcygeal and the pubococcygeal portions that are normally obscured by the puborectal fibers during pPFUS (Fig. 16.6) not topic of this chapter?

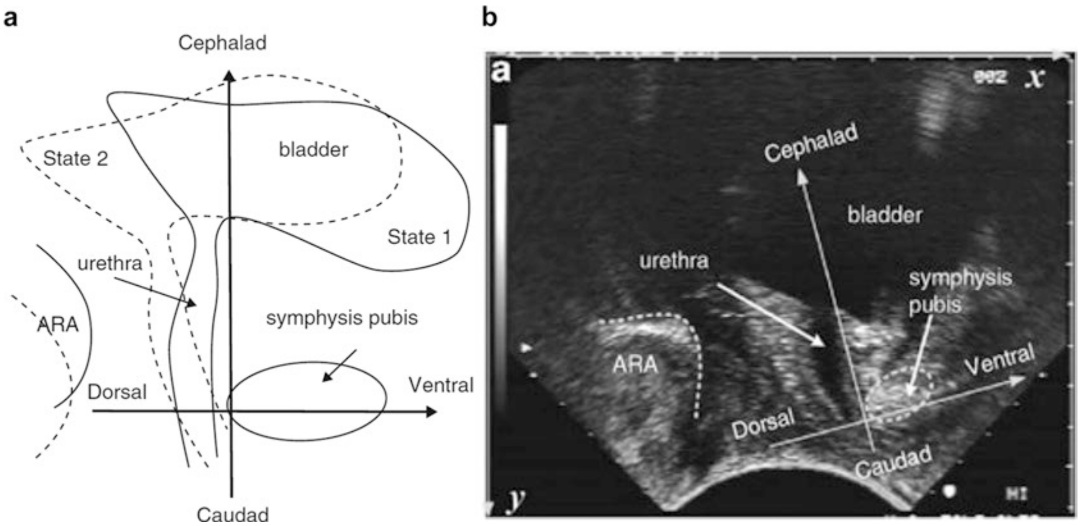

Fig. 16.3 (**a**) The orthogonal coordinate system fixed on the symphysis pubis. The two orthogonal components (ventral-dorsal and cephalad-caudad components) of the tissues displacements reflect pelvic floor functions of squeezing the urethra and supporting the bladder, respectively. (**b**) The orthogonal coordinates shown on a 2D perineal pelvic floor ultrasound. (From Peng et al. [30] with permission)

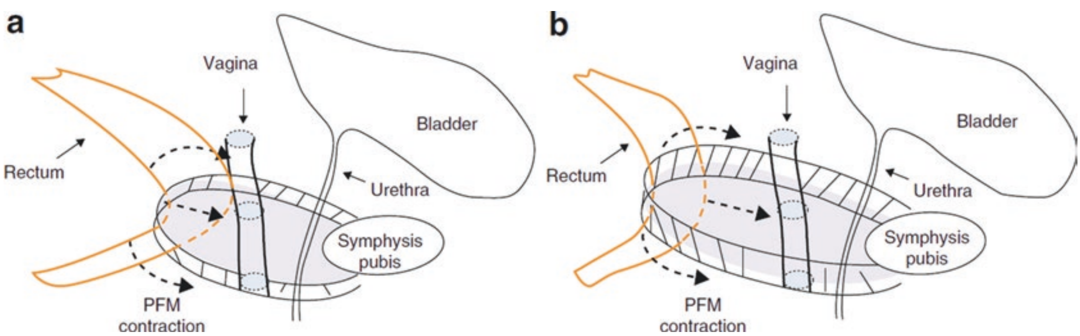

Fig. 16.4 The deformation of the rectum under different pelvic floor muscle (PFM) pressures. (**a**) The anorectal angle (ARA) is acute when the PFM is narrow and the strength of the PFM contraction is strong. (**b**) The ARA is acute when the PFM is narrow and the strength of the PFM contraction is not very strong. The deformation is also affected by the stiffness of the rectum and the content within it. (From Constantinou et al. [31], with permission)

Ultrasound Tips and Techniques

Room for Scanning

It is important to perform ultrasound in a room that can be darkened in order to obtain the best image quality. Direct solar irradiation should be avoided. Enclosed rooms that enable privacy (and because of the intimacy of the entire treatment) are preferred.

Preparation and Hygiene

For pPFUS, as with any ultrasound imaging, use of coupling gel is a critical step, as ultrasound waves do not pass through air. Whether transabdominal, transperineal, or endovaginal transducers are used, the gel should be placed between the transducer and covering. For endovaginal transducers, a disposable cover (e.g., ultrasound cover—*not a male condom*), and for curved abdominal transducers a glove or plastic wrap

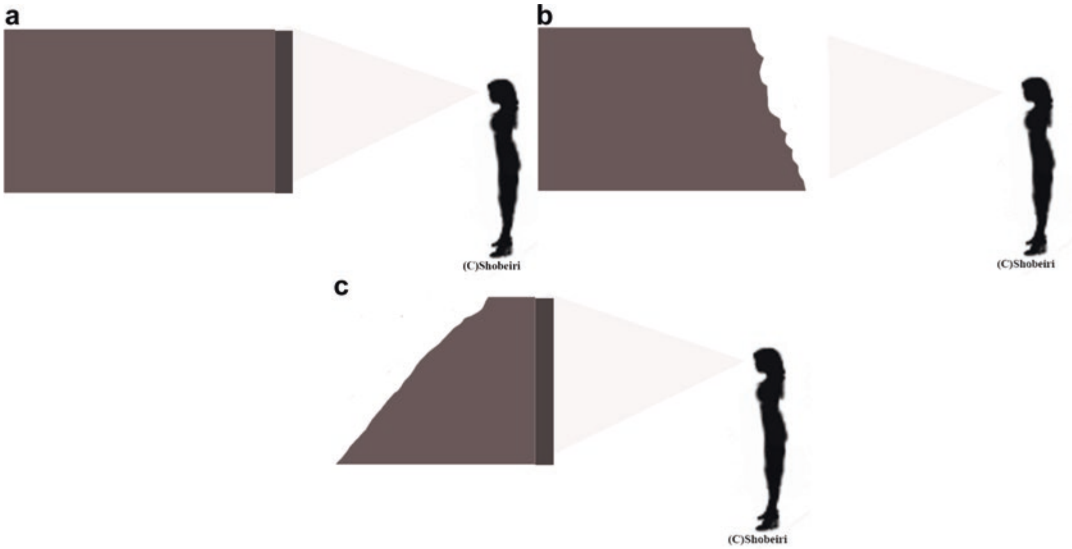

Fig. 16.5 (**a**) A transperineal probe placed at the introitus looks at the levator ani muscle (LAM) at its end. The most caudad portion of the LAM is the puborectalis muscle which is best seen by perineal pelvic floor ultrasound (pPFUS). The medial portion of the LAM attachment to the pubic bone is the pubococcygeus, and this portion may be obscured by more distal puborectalis. (**b**) In the case of avulsion where both the puborectalis and pubococcygeus are torn, an avulsion can be clearly seen by pPFUS. (**c**) In cases where the iliococcygeus or pubococcygeus are torn but the puborectalis is intact, the torn muscles may not be visible by pPFUS. © Shobeiri

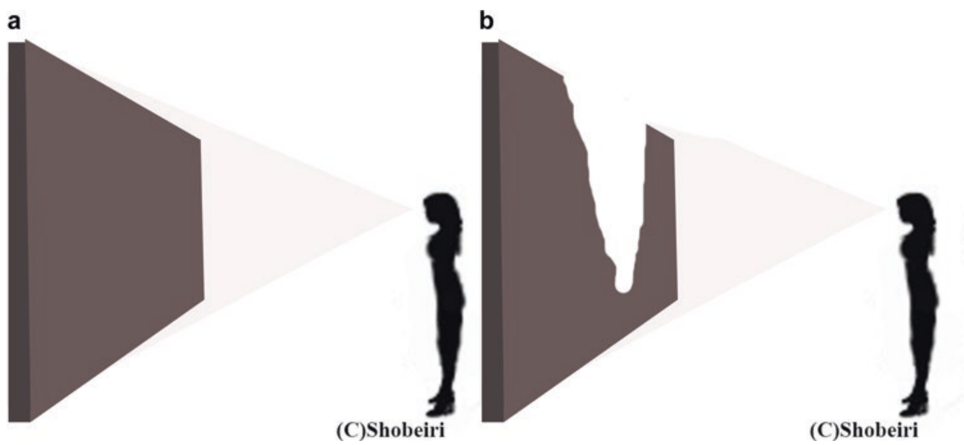

Fig. 16.6 (**a**) An endovaginal probe placed in the vagina looks at the levator ani muscle at its entirety. (**b**) As such, even minor defects in the iliococcygeus or pubococcygeus muscles are visible by endovaginal ultrasound. © Shobeiri

can be used (some ultrasound condoms are flexible enough and also fit abdominal transducers). It is not necessary to use sterile gel and sterile hygienic condoms to cover the ultrasound transducer because the region of scanning (perineum) is not sterile. Additional gel should be applied to the perineum to allow for better coupling. Warming the gel in a commercial warming device improves patient comfort. After each use, transducers should be cleaned and disinfected according to manufacturer recommendations to maximize the transducer's performance and product life. For abdominal scans, there may be no need for covering the transducer.

Orientation of the Ultrasound Picture on the Screen

For PT, there are recommended guidelines for the orientation of the ultrasound picture on the screen [32], which were described in 2005 by Tunn et al. [33]: the best image is obtained with the symphysis pubis right/bottom and the LAM left/bottom (Fig. 16.7). Because ultrasound is used not only for evaluation but also for patient education and visual biofeedback, this orientation is the most logical for patients, even when ultrasound is performed in the standing, sitting, or lithotomy positions.

Scan Technique

Perineal pelvic floor ultrasound utilizes ultrasound performed with a curvilinear transducer versus introital pelvic floor ultrasound (iPUS) utilizes ultrasound performed with a vaginal probe placed on the perineum (Fig. 16.8) [11]. The common denominator for all these techniques is placement of transducers externally on the patient's vulva rather than introduction of the transducer into the vagina or anal canal. pPFUS imaging can be performed with use of either the transabdominal curvilinear transducers or with endovaginal transducer that is typically used for endovaginal gynecologic ultrasound. The curved array transducer is typically 4–8 MHz, whereas endovaginal transducers have frequencies up to 10 MHz. It is important to keep in mind that higher frequency transducers provide superior resolution, but have less tissue penetration. This trade-off is important for achieving images of diagnostic quality. For the purposes of this chapter, ultrasound performed with curved array transducers will be referred to as pPFUS, as the transducer is placed between the labia majora to visualize the anatomic structures.

The transducer is placed midsagittal between the labia majora with the on-screen view that includes the pubic symphysis and the ARA and behind the ARA, the puboreactal muscle to have a view of all structures that are important for further therapy. The so-called footprint of the ultrasound transducer has to be large, and this is provided by nearly all convex/abdominal transducers. This is especially important when scanning patients with a large perineum, such as women directly after delivery.

Special Tools of the Ultrasound Machines and Their Use

For different clinical inquiries, specific tools of ultrasound machines can be utilized.

1. *Live scan:* This tool is used in all dynamic scanning. It can be frozen, saved as a video or

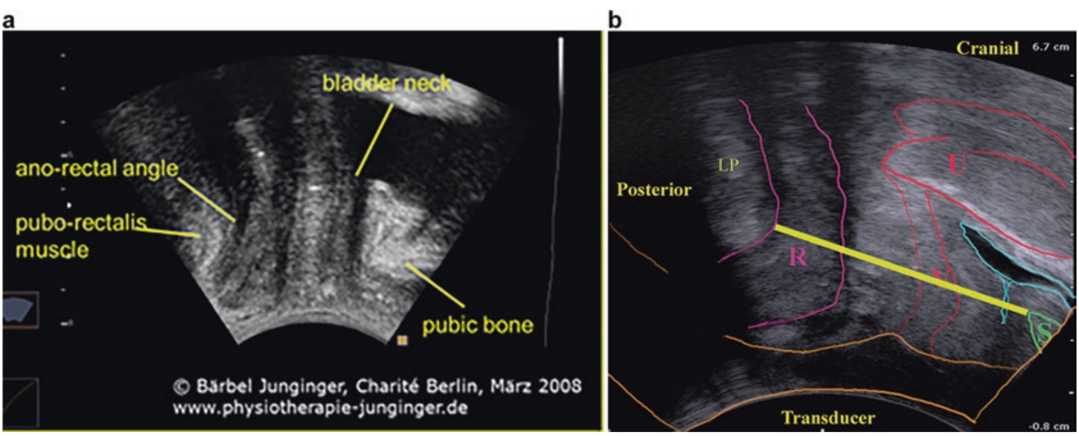

Fig. 16.7 (**a**) A typical 2D perineal pelvic floor ultrasound. (**b**) The outline of the structure and anteroposterior diameter of the minimal levator hiatus (*yellow line*) between the levator plate (LP) and symphysis (S)

Fig. 16.8 Introital pelvic floor ultrasound (iPUS) in this patient demonstrates descensus and collapse of the bladder this is a healthy woman!!!!!!. This image should be obtained at rest and maximum Valsalva. A video loop adds much value to the observation

an image, reviewed (see cine loop), and printed as images. It can be repeated and compared at a later time (the end of treatment, next appointment, etc.).

2. *Cine loop:* With this special tool, it is possible to save a movie/clip sequence of, for example, 10–15 s while the patient is performing a contraction, cough, cough with a PFM pre-contraction, etc. directly afterwards, the maneuvers can be reviewed together with the patient with the ability to select either single frames or a movie clip, playing them forward or backward with different velocities in order to explain each functionally correct or incorrect performance. Thus, explanation and so-called terminal feedback is possible.

   Typically, when utilizing this tool, the decision must be made beforehand regarding the preferred save mode and time specifications (machines have prospective and retrospective saving modalities, and in presets the timing of the sequence to be saved can be chosen).

   This tool is perfect for lay-person and patient education, for explaining symptoms, and for describing functional properties

3. *Pre−/post-therapy:* In some women, PFM contractions are performed incorrectly or even with too much abdominal muscle activity (higher IAP and descent of the organs, such as bladder neck, cervix, and other organs). It has been shown that a PFM contraction is physiologically performed with transverse abdominus (TrA) activity [4]. Other abdominal muscle activity during a PFM contraction, such as internal oblique (IO) and external oblique (EO), has furthermore shown to increase the IAP, therefore leading to no depression of the pelvic floor and the bladder neck, respectively [4]

In these cases, the performance of the PFM contraction must be corrected with specific physiotherapeutical methods, such as breathing control, relaxation of superficial abdominal muscles and more, sometimes with and sometimes without ultrasound of the abdominal muscles in different positions. For example, abdominal ultrasound may have to be performed with the patient lying on her side, sitting, and lying on her back, each maneuver customized to individual conditions. Once the performance is determined to be functionally correct, then pPFUS can be used as a post-training instrument to check the correctness of the contraction and show it to the patient.

Physical Examination and Evaluation by a Pelvic Floor Therapist

The physical examination performed by a specialist in pelvic floor PT consists of the following:

1. Patient history should be taken with a validated pelvic floor questionnaire that includes all domains of female pelvic floor symptoms, such as urinary, bowel, prolapse, and sexual problems. As an example, the Australian Pelvic Floor Questionnaire is available without charge, in both an interviewer-administered [34] and a self (patient)-administered version [35], allowing its implementation in clinic and research
2. Evaluation of the pelvic floor and especially the PFM with vaginal palpation [23]—muscle integrity (avulsion); functional properties during cough; straining; awareness of the pelvic floor (sensation, perception); voluntary PFM contraction; and voluntary pre-contraction before coughing.
3. Evaluation of the dynamics of the pelvic floor with pPFUS (automatically and voluntarily)—

for example, during coughing, squeezing, and straining

4. Evaluation of the performance of voluntary PFM contractions—coordination, strength, endurance by pPFUS and confirmation of integrity of muscles by 3D endovaginal ultrasound as necessary
5. Evaluation of posture, breathing, PFM-contraction performance (co-activation; evasive maneuver of other parts of the body—pelvic tilt, breath hold)

The goal of the physical examination by a physiotherapist should be to find the functional problems behind the individual symptoms and to create a therapy plan based on pathophysiological and dysfunctional finding. Questions related to quality-of-life bothersomeness, patient wishes for her life (social integrity, sports activities, business, etc.), and integration of training/exercises into daily life should guide individual therapy. These issues will affect the patients's willingness to train, her efficacy/self-efficacy, and her compliance and adherence.

Positioning During Examination: Influences on Therapy

As with gynecologic ultrasound most pPFUS exams are performed with the woman in either lithotomy in a standard gynecologic chair or in a modified lithotomy position on a normal therapy table. For 3D imaging the examiner may also need to prop the patient's arm or elbow, as the imaging capture time can be as long as 15–20 s and absolute stillness is critical for optimal image quality. It is certainly possible to do the pPFUS with the patient standing, which could be especially useful in patients who are not as successful with dynamic maneuver in supine position. For PT, evaluation and treatment in symptoms-related positions such as standing are essential. There are women who are able to contract their PFM in the supine position but are unable to do so in erect positions, which is important in daily life.

In many countries, examinations by a urogynecologist are performed on a special gynecological chair. Having the patient in a comfortable position, with relaxed muscles, allows for an examination without pain. Most physiotherapists do not have this kind of chair, and the examination is performed with the patient in a supine position on a normal bench or therapy table with her hips and knees slightly flexed. Placing the bench or table directly next to a wall on one side allows the therapist to stand on the other side. When the patient's legs can be supported by the wall and the therapist, to allow relaxation of the hip muscles, this scenario can assist in a comfortable and pain-free examination position. Resting tone of the muscles and the PFM structure and defects can be evaluated by palpation, and resting position of the organs and their movements during voluntary contractions can be seen on ultrasound.

On the other hand, as patients mostly report symptoms (urine or fecal loss, urge, or prolapse) in upright positions, assessment of PFM properties while standing is important to the therapist because of different findings in the same patient between a supine and standing position. An upright position has both advantages and disadvantages. For example, if a woman is not able to contract her muscles while supine, there might be a problem with her awareness of her pelvic floor, or a functional problem in that position, or even a misunderstanding on the patient's part regarding a degree of contraction that increases the IAP to the degree that it leads to a downward movement of the pelvic floor. In some women the influence of gravity is necessary to help them perceive the sensation of contracting their PFM, since they know how to contract these muscles only while standing or sitting.

Maneuvers During Evaluation

During evaluation several maneuvers are performed to obtain information. First, the therapist starts with evaluating only automatic/functional/quasi-functional tasks, which are coughing, perfoming a Valsalva maneuver, or straining. Second, the therapist follows with voluntary tasks: contraction, contraction with a cough, and a maintained pre-contraction, in order to find functional deficits.

Palpation and Ultrasound

Palpation and ultrasound are important methods to gain an overview of the patients's muscular and connective tissue structures. Additional answers can be obtained by using ultrasound as an adjunct to complete the diagnostic picture.

Palpation is used to assess the muscle structurally, (such as tears, lesions, etc.) and its functional properties (such as contractions, strength, endurance, coordination). Dynamic 2D ultrasound can give a visualization of the effects of activations of the muscles during PFM contraction: both voluntarily and involuntarily. The two methods in combination give a complete picture of the problem. Is there a spontaneous contraction at coughing? Is there descent of the bladder neck at coughing? Is it possible for the patient to contract the PFM before a cough, with an influence on the bladder neck that can be maintained during coughing?

While the 2D probe is placed on the perineum, three manuvers should be performed:

1. The woman should be instructed to cough (Fig. 16.9) [36]. The levator ani muscle/ARA is pulled anterior and cephalad in preparation for cough (see Fig. 16.9a). With cough, the bladder descends posteriorly but is counteracted by the levato rani muscle (see Fig. 16.9b).

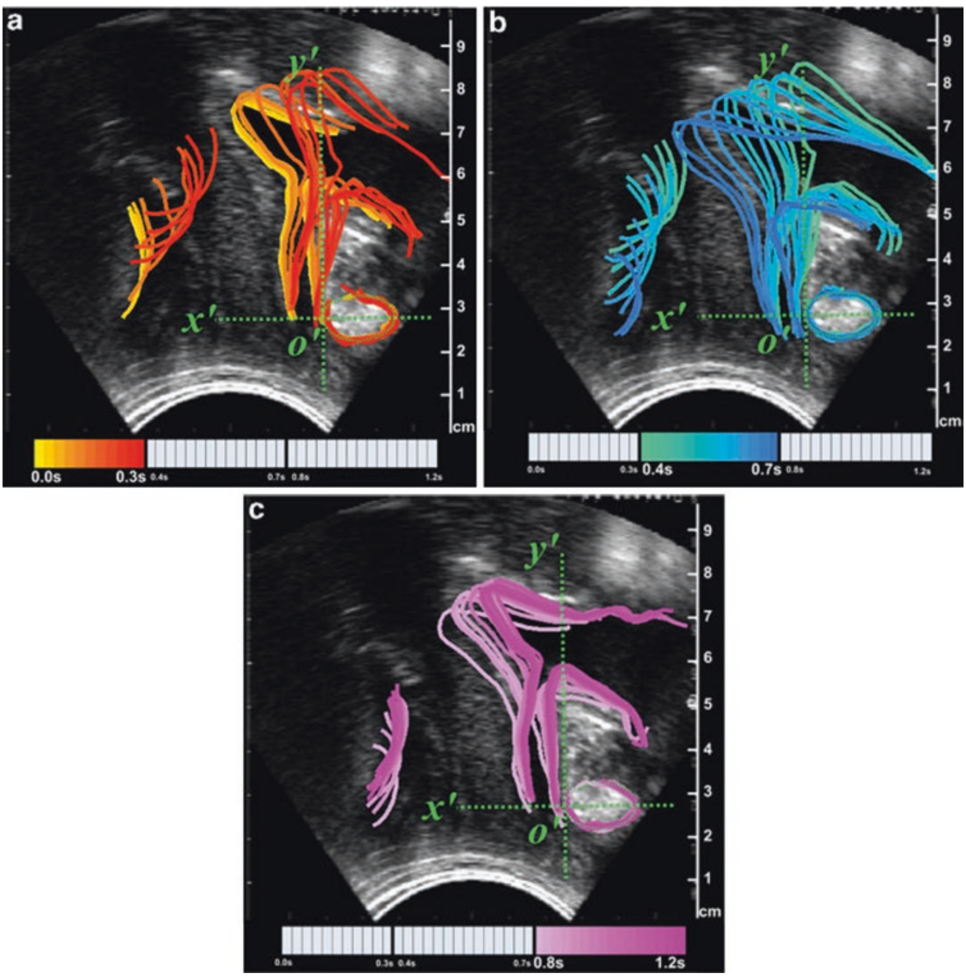

Fig. 16.9 (**a**–**c**) The timing of the movement of tissues in pelvic floor during a typical cough in a healthy volunteer. (From Peng et al. [36], with permission)

And, finally, after the cough the levator ani muscle and the bladder are returned to normal position (see Fig. 16.9c)

2. Then the woman is asked to contact the pelvic floor muscle (Fig. 16.10) [36]. The levator ani muscle is raised anterior and cephalad (see Fig. 16.10a) and then returns to normal position (see Fig. 16.10b)
3. The woman is asked to perform astraining maneuver (Fig. 16.11) [36]. The levatorani muscle/ARA flattens, the bladder neck descends (see Fig. 16.11a), and after the straining the anatomy is restored with a quick pelvic floor contraction (see Fig. 16.11b)

These three manuvers can trace levator plate and bladder neck movement differentially in relation to the pubic symphysis (Fig. 16.12) [31].

The movement of the levator ani muscle may be visualized and quantified with endovaginal ultrasound as well. Because a probe mimics a digit in some ways, the patient will have something to squeeze against. In a study comparing digital palpation with levator plate see elsewhere lift measured by endovaginal and transperineal dynamic sonography, patients were instructed to perform PFM contractions while a probe captured a video clip of levator plate movement at rest and during contraction in a 2D midsagittal posterior view. The distance between the levator plate and the probe on endovaginal sonography (EVUS) as well as the distance between the levator and the gothic arch of the pubis on pPFUS was obtained. The change in diameter (lift) and levator lift ratio (lift/rest × 100) was calculated. Pelvic floor muscle strength was assessed by digital palpation and divided into functional and nonfunctional groups according to the Modified Oxford Scale (MOS). Mean differences in levator plate upward lift were compared by MOS scores using Student t tests and analysis of variance. When measured by vaginal dynamic sonography, mean lift and lift/rest ratio values increased with increasing MOS score (analysis of variance, $P = 0.09$ and 0.04, respectively). When scores were categorized to represent nonfunctional (0–1) and functional (2–5) muscle strength groups, the mean lift (3.2 versus 4.6 mm; $P = 0.03$) and lift/rest ratio (13% versus 20%; $P = 0.01$) values were significantly higher in women with functional muscle strength. All patients with lift of 30% or greater detected by vaginal sonography had functional muscle strength. A greater levator plate lift ratio detected by dynamic endovaginal sonography was associated with higher muscle strength as determined by the MOS.

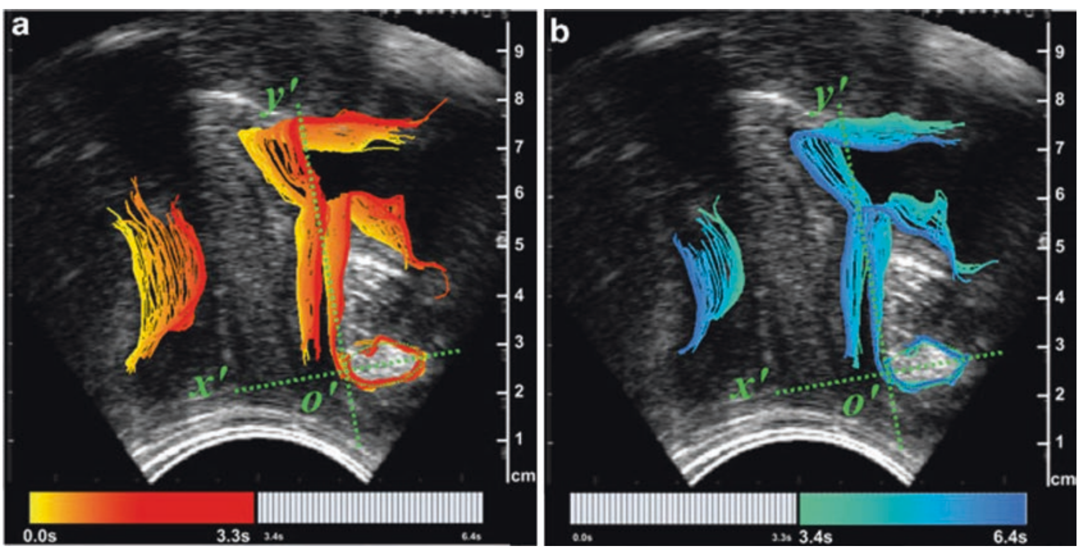

Fig. 16.10 (**a**, **b**) The timing of the movement of tissues in pelvic floor during a typical PFM contraction in a healthy volunteer. (From Peng et al. [36], with permission)

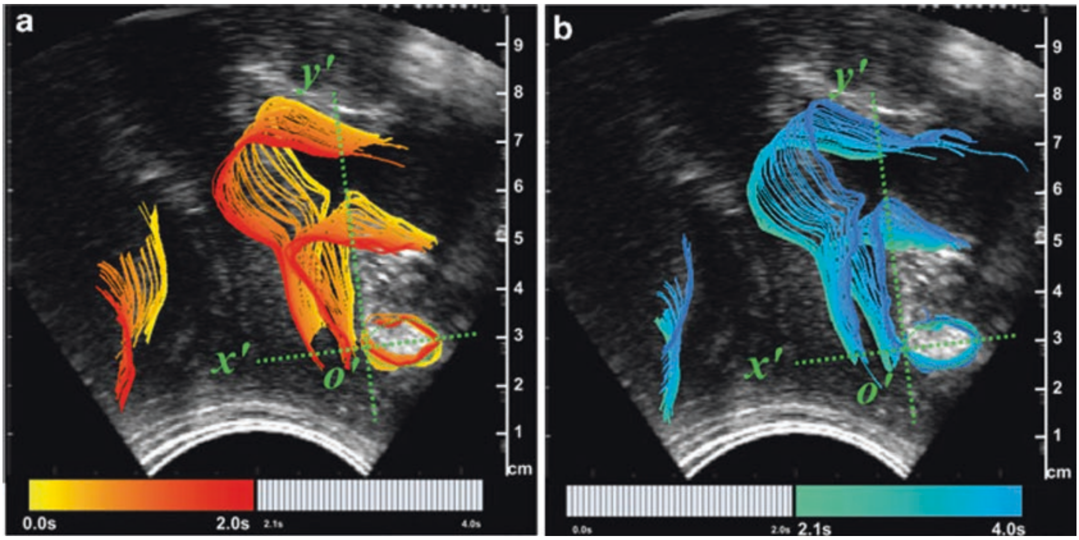

Fig. 16.11 (**a**, **b**) The timing of the movement of tissues in pelvic floor during a typical straining in a healthy volunteer. (From Peng et al. [36], with permission)

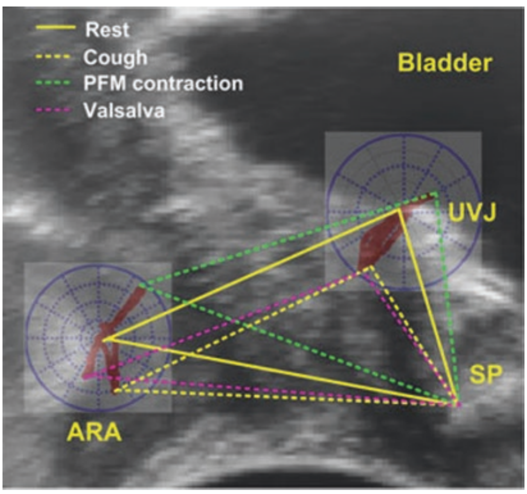

Fig. 16.12 The movement of the levator plate and the bladder neck in relationship to the pubic symphysis. (From Constantinou et al. [31], with permission)

This novel measurement can be incorporated into sonographic evaluation of levator ani function (Figs. 16.13 and 16.14) [25].

If the levatorani movement is deficient, it is because the patient lacks sensation, or she simply has no muscles to squeeze. In this situation a 3D ultrasound can provide the answer. In a study to assess the performance of levator ani muscle deficiency (LAD) evaluated by 3D EVUS to detect PFM function as assessed by digital examination, patients underwent physical examinations, including digital pelvic muscle strength assessment using the MOS. Endovaginal sonography volumes were evaluated and levator ani muscles were scored according to a validated LAD scoring system. MOS scores were categorized as nonfunctional (scores 0–1) and functional (scores 2–5). Overall, 32.5% had nonfunctional muscle strength and 44.2% were classified as having significant LAD. Levator ani muscle deficiency identified by ultrasound had a sensitivity of 60% (95% CI 41–79%) for detecting nonfunctional muscle and a specificity of 63% (95% CI 50–77%) for detecting functional muscle. Overall, LAD demonstrated fair ability to discriminate between patients with and those without poor muscle function (area under the ROC curve = 0.70 [95% CI 0.58–0.83]). Among patients with an LAD score of 16–18, representing almost total muscle loss, 70% had nonfunctional MOS scores, whereas in patients with normal/minimal LAD (scores of 0–4), 89.5% had functional MOS scores. Levator ani deficiency and MOS scales were moderately negatively correlated. Among patients with normal morphology

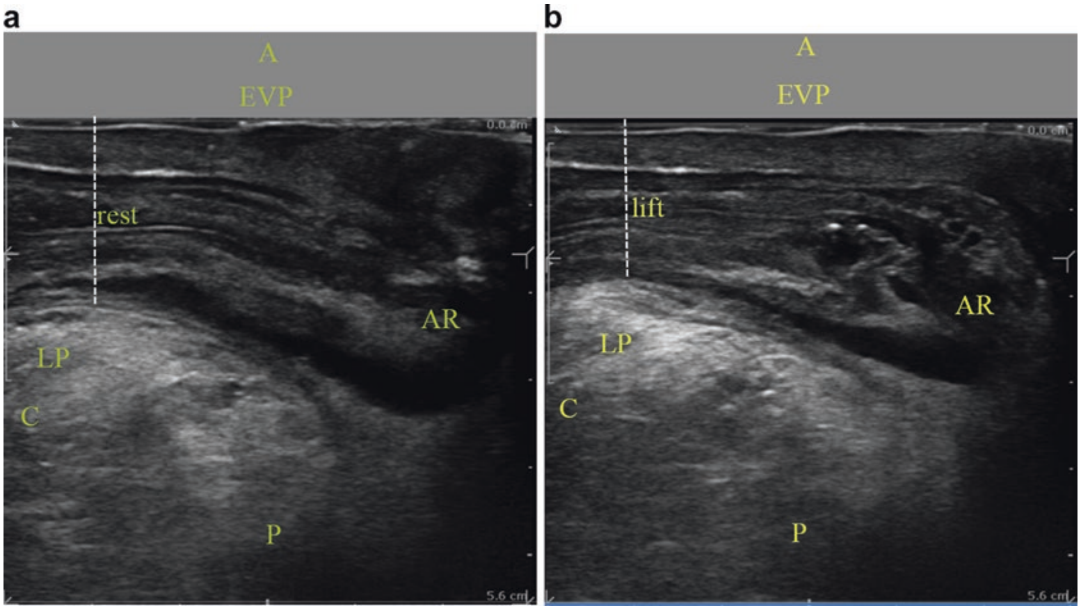

Fig. 16.13 The distance between levator and endovaginal probe in dynamic endovaginal sonography (**a**) at rest, (**b**) at Kegel maneuver. Anterior (A) endovaginal probe (EVP), levator plate (LP), anorectum (AR). (From Rostaminia et al. [25], with permission)

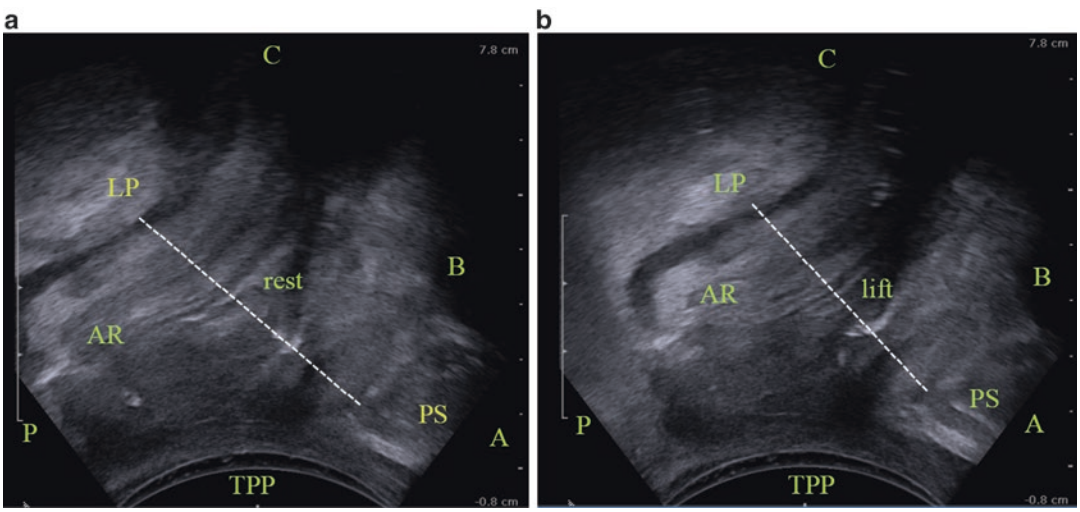

Fig. 16.14 The distance between levator plate and pubis in dynamic transperineal ultrasound (**a**) at rest, (**b**) at a PFM contraction. Cephalad (C), bladder (B) anterior (A), pubic symphysis (PS), posterior (P), transperineal probe (TPP), levator plate (LP), anorectum (AR). (From Rostaminia et al. [25], with permission)

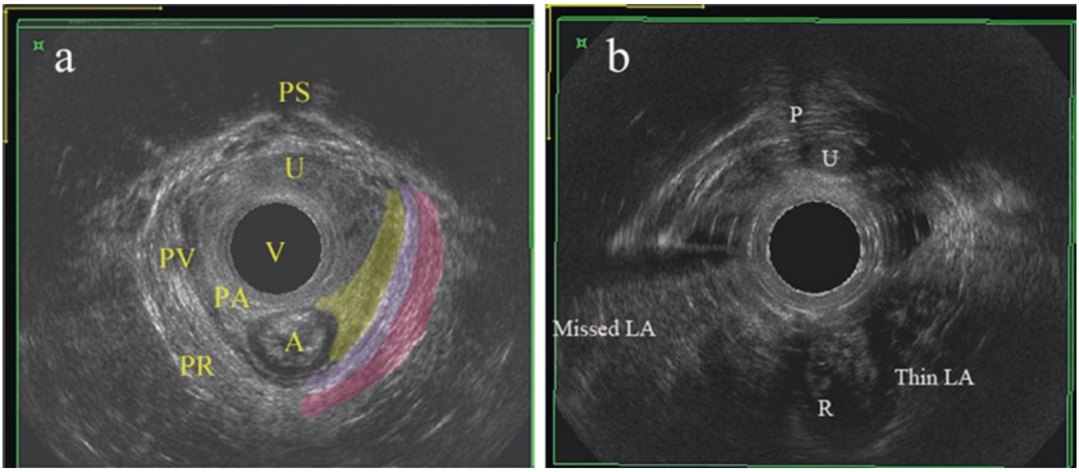

Fig. 16.15 Levator ani (LA) deficiency detected by 3D endovaginal sonography. (**a**) Normal LA muscles. (**b**) Significant levator ani deficiency with a total score of 14. Anus (A), pubic symphysis (PS), rectum (R), urethra (U), iliococcygeus/pubococcygeus (PV), puboanalis (PA), puborectalis (PR). (From Rostaminia et al. [10], with permission)

or the most severe muscle deficiency, LAD scores can identify the majority of patients with functional or nonfunctional MOS scores, respectively (Fig. 16.15) [10].

The Uses of Ultrasound to Assess Different Areas of Inquiry

The Use of Ultrasound to Quantify Levator Activity and to Teach a Pelvic Floor Muscle Contraction

Ultrasound can not only be used to quantify PFM contraction and the influence on the bladder neck and the ARA, but it can furthermore show the quality of contraction and coordination of a levator ani contraction. For teaching a *pelvic floor contraction*, a correct PFM contraction is a contraction of the LAM co-activated with a contraction of the transverse abdominis muscle. After a good explanation of the anatomy of the pelvic floor to the patient, for example, by showing an image of the pelvic floor or explaining the organs and the pelvic floor, the physiotherapist can explain the individual symptoms by hypothesizing what would be found on ultrasound; for example, if a woman experienced urinary loss at coughing, it could be expected that she will have increased movement of the bladder neck.

Assessment of Pelvic Floor Muscle Contraction in Urinary Incontinent Women

Urinary incontinence can generally mean either stress urinary incontinence (SUI) or OAB. In the first condition, an IAP increase leads to an opening of the bladder neck (a horizontal or a vertical descent) or even an increased IAP that influences the stability of the bladder neck and leads to an opening. In urinary continence two mechanisms are identified as important: urethral closure pressure and bladder neck stability [6, 37–39]. For SUI, a PFM contraction is thought to stabilize the bladder neck and compress the urethra during an increase in IAP. For OAB symptoms, PFM contractions are able to close the funneling of the bladder neck or to inhibit the detrusor overactivity/contraction and prevent leakage.

During an increase of IAP (coughing, lifting) the bladder neck has to be stabilized. A maintained Pelvic floor muscle contraction has been shown to increase the stability of the bladder neck during a cough [6]. Miller et al. showed that more than 70% of women experienced less urinary loss after 1 week, when a PFM pre-contraction, termed, “the Knack” was performed before a cough [40, 41]. When performing the Knack women demonstrate reduction of urine loss, making a PFM pre-contraction a key point in pelvic floor rehabilitation [6, 22, 40, 42].

Recent studies have observed that women with SUI demonstrate:

- No stability or cranio-ventral movement of the puborectalis sling
- Contraction of the puborectalis sling but no elevational effect on bladder neck position
- Contraction of the puborectalis sling but no hold during ongoing breathing (increase in IAP and coordination), on cough, on lifting objects

Ultrasound imaging of the pelvic floor carries diagnostically important information about the dynamic response of the PFM to potentially incontinence-producing stress, which cannot be readily captured and assimilated by the observer during the manual palpation. In an approach based on motion tracking quantitatively to analyze the dynamic parameters of PFM on the ARA, pPFUS was performed on 22 asymptomatic females and 9 SUI patients with a broad age distribution and parity. The ventral-dorsal and cephalad-caudad movements of the ARA were resolved and kinematic parameters, in terms of displacement, trajectory, velocity, and acceleration, were analyzed. The results revealed the possible mechanisms of PFM responses to prevent urine incontinence in fast and stress events such as coughs. The statistical analyses showed that the PFM responses of the healthy subjects and the SUI patients are significantly different in both the supine and standing experiments [30].

The pre-contraction activated the PFM before a cough to elevate the bladder neck of continent women to compress the urogenital structures towards the pubic symphysis, which was delated in women with SUI [6]. The maximum accelerations that acted on the PFM during a cough were generally more similar than the velocities and displacements. The urethras of women with SUI were exposed to uncontrolled transverse acceleration and were displaced more than twice as far (P = 0.0002), with almost twice the velocity (P = 0.0015) of the urethras of continent women. During a cough, normal PFM function produces timely compression of the pelvic floor and additional external support to the urethra, reducing displacement, velocity, and acceleration. In women with SUI, who have weaker urethral attachments, this shortening contraction does not occur; consequently, the urethras of women with SUI move farther and faster for a longer duration [43].

Utilization of ultrasound and motion imaging techniques was applied to illustrate the static anatomy and dynamics of PFM function of SUI women pre- and post-operatively as compared to asymptomatic subjects. Function was evaluated from the dynamics of organ displacement produced during voluntary and reflex activation. Technical innovations included the use of ultrasound analysis for movement of structures during maneuvers that are associated with external stimuli. Principal among these parameters are displacement, velocity, acceleration, and the trajectory of pelvic floor landmarks. To accomplish this objective, movement detection, including motion tracking algorithms and segmentation algorithms, was developed to derive new parameters of trajectory, displacement, velocity and acceleration, and strain of pelvic structures during different maneuvers. Results highlighted the importance of timing of the movement and deformation to fast and stressful maneuvers, which are important for understanding the neuromuscular control and function of PFM. Furthermore, observations suggested that timing of responses was a significant factor separating the continent from the incontinent subjects [44].

Slight urinary incontinence but not vaginal symptoms were common in nulliparous highly physically active women. There were no statistically significant differences in PFM function measured by strength in the continent compared with incontinent group. These results highlight the need for prevention and rehabilitation of PFMs in female athletes [45].

Voluntary PFMs can impose significant closure forces along the vaginal wall of continent women but not in women with SUI. The implication of these findings is that extrinsic urethral closure pressure is insufficiently augmented by PFM contraction in women with SUI [46].

Pelvic floor muscle training can result in anatomical changes in the levator ani and reduction of levator movement because of tighter levator ani muscles. The muscle behavior as visualized by ultrasound provides insight into the possible anatomical mechanisms through which PT enables the PFM to minimize urine leakage (Fig. 16.16) [47].

Assessment of Pelvic Floor Function in Fecally Incontinent Women and in Obstructed Defecation or Constipation (Outlet Obstruction)

For this condition, ultrasound can be used to assess the ability to contract the levator ani muscle, to move the ARA in a cranio-ventral direction to avoid/cope with an urge or to handle a loss on urge by maintaining the contraction, with the effect of bringing the stool out of the sensible urge zone by increasing/decreasing the angle until the woman is able to reach the toilet. Also for this condition, ultrasound educates the patient to understand the problem, the symptom, and the sensation by visualizing the levator plate movement.

Furthermore, ultrasound can be useful for teaching relaxation to women with problems with defecation. This symptom is often related to a hyperactive PFM. In patients with constipation there is often a paradoxical puborectalis contraction. Stool is retained and this may lead to an overflow incontinence.

Assessment of Pelvic Floor Function in Pelvic Organ Prolapse

Symptoms related to pelvic organ prolapse, urinary or fecal incontinence, obstructed defecation/micturition or pelvic pain syndrome, all may have muscular dysfunctions associated with them. These dysfunctions are often found in combination with fascial defects (endopelvic fascia) and with defects of the supporting ligaments of the pelvic floor. The question as to what degree the connective tissue or muscles are responsible if a woman is bothered by pelvic floor symptoms is facilitated by ultrasound imaging of the pelvic floor. Some of these structures can be evaluated

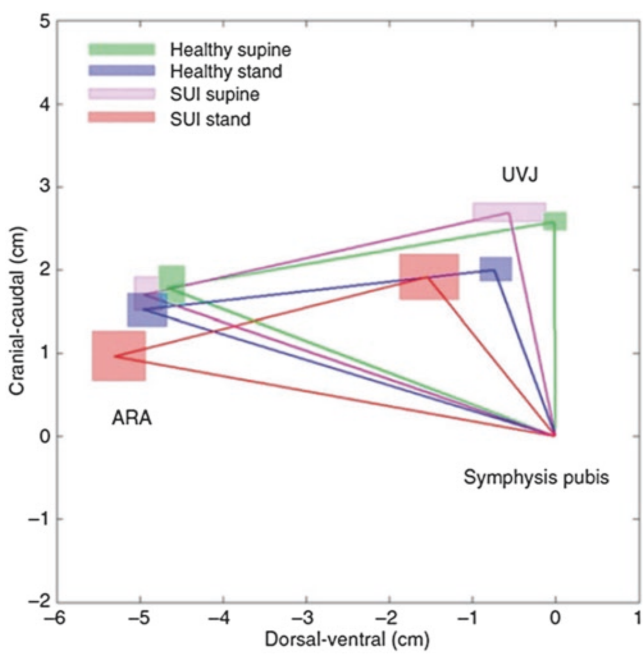

Fig. 16.16 The urethra vesical junction-pubis-anorectal angle triangles of 17 asymptomatic females and 5 stress urinary incontinent (SUI) patients. (Healthy supine: *green;* healthy stand*: blue;* SUI supine: *magenta;* SUI stand: *red.* The standard error (SE) is shown by the *transparent bars in different colors.* (From Constantinou et al. [31], with permission)

with vaginal palpation, others with diagnostic ultrasound. The importance of ultrasound has increased tremendously in the last decades in all fields of urogynecology, such as post-partum studies, in patients with prolapse, in patients with transvaginal mesh complications, and in patients who have had failed POP surgery [10–12, 14, 18–20, 25, 48–56].

In evaluating POP with ultrasound it is essential to have advanced knowledge of pelvic floor anatomy. Since the majority of patients with stage 4 POP don't have visible LAM [14], exactly how much LAM remains can have consequences to the success of PT or surgery. If the physiotherapist is interested in the evaluation of the automatic activation of the PFM, he/she can only ask women to strain. If the physiotherapist is interested in the amount of descent, he/she has to change the velocity of the straining maneuver. Differences of straining and performing a Valsalva maneuvre is important and are resulting often in differnt PFM reactions [57]. To determine which compartment is descending more, the most prominent organ descending must be identified. A physiotherapist may be able to treat this problems by assessing the ability to elevate the prolapsed organ by contracting the PFM.

Assessment of Pelvic Floor Function in Patients with Pelvic Pain Syndrome

Pelvic pain is sometimes related to an overactive or a hyperactive pelvic floor. In 2D ultrasound, this can be seen as a decreased distance between the symphysis pubis and the puborectalis, the minimal hiatal distance. Data regarding normal values have been reported [58]. It is important to know that, typically, the younger the woman, the smaller the distances, and the distance is smaller in nulliparous than in multiparous women. So in these women, a small distance may be physiological.

Because relaxation and contraction of a muscle are also the result of an individual's coordination and perception, it is essential to find out if the problem relates to her understanding of how to contract the PFM, or if it is true dsyfunction of the muscle.

A hyperactive pelvic floor may be not only the reason for pain but also a reaction to too much IAP due to different causes (high BMI, heavy lifting, lifting with breath hold, etc.) or exacerbated by frequency (heavy cough, lung desease, obtructed defaecation, etc.).

Integration of Ultrasound in Formulating a Treatment Plan

Once the patient history and the different symptoms are compiled, an individual treatment plan should be developed together with the patient. Primary as well as secondary problems should be discovered and treated. If the main problem will not be treated first (for example, urine loss during jogging), this should be explained because jogging is too complex and in the first instance, contraction during increased IAP such as during coughing should be coordinated.

The first goal when using pPFUS is to check the movement of the puborectalis slingin a cranio-ventral direction in order to assess a contraction of the muscle. The second goal is to determine the movement of the bladder neck and its effect on the bladder. Next, it is important to assess if the LAM can maintain a contraction (during ongoing breathing and during a cough). This same task should be observed in the standing position. If a cough produces too much IAP, exhalation can be used as an alternative method. Controlled breathing is also part of a coordination training program of the PFM.

For endurance training, cue the patient to increase the number of breaths and lengthen the time between breaths while holding the PFM contraction. These recommendations should be performed in both a supine and in a standing position. While the first recommendation is important for women with SUI, the second is more important for women with OAB and for women with prolapse. In women with an overactive PFM or pelvic pain symptoms, relaxation of the LAM is vital and can be visualized with pPFUS by a caudal-dorsal movement of the muscle.

Summary and Future Directions for the Use of Ultrasound in Physiotherapy

Ultrasound can be used for evaluating the individual's specific dysfunction of the PFM. Young women and all adolescents could learn via an ultrasound examination what the pelvic floor is and how to contract it. This could be performed at various schools or health centers where girls (and boys) are taught sexual education. Furthermore with this early introduction, in classes preceding childbirth, ultrasound can be used to teach women how to properly and safely strain during labor. Then, directly following childbirth, ultrasound could be used to perform a "pelvic floor check-up" to instruct a woman how to concentrate on and how to contract her pelvic floor after childbirth. In other fields of medicine, there is no pause in rehabilitation directly after the injury, the surgery, or the intervention. After childbirth, there is evidence that a pause may be bad for structural healing. Weeks after delivery, before women go to post-partum exercise classes or re-start their individual sports program, the PFM should be checked by a physiotherapist to find out if the stability of the bladder neck can be maintained during exercises of any kind [59]. With the professional skills of a physiotherapist there is a chance to act as a coach and individually adapt normal exercises to be less "dangerous" for the woman's bladder neck position and to decrease the descent of the bladder neck. Ultrasound is once again helpful in illustrating the extent of descent while performing an exercise and the reduction of the bladder neck descent during a PFM pre-contraction. It is helpful for a therapist not only to explain the problem, but also to enable the individual to see for herself the unwanted descent when performing a specific gymnastic exercise.

It could also be of interest for every woman starting with a strenous new sport to first check her pelvic floor, not only for assessment by ultrasound, but using ultrasound as a visualization tool to see the effect of any sort of strain on the pelvic floor. Just as people often go in for a cardiovascular check before starting a new sports program, the pelvic floor could be checked and individual recommendations or contraindications could be given.

Physiotherapy with ultrasound should be included in programs for weight reduction because participation in sports is one important factor for weight loss. Furthermore, because of their higher BMI, obese or overweight women are at greater risk for prolapse. A higher IAP in the overweight during exercise should be taken into account and investigated and followed by physiotherapists or physicians [60]. A documented ultrasound examination may provide better communication between the health care providers (physicians, physiotherapists, nurses, health insurers, etc.) because it quantifies any problems.

Physiotherapy is a ripe field for research. A physical therapist is expected to increase function by rehabilitating body structures. However, the use of ultrasound in pelvic floor therapy is still in its infancy, and evidence-based studies will facilitate incorporation of ultrasound imaging as a core competency into PT education.

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