Evaluation of Female Pelvic-Floor Muscle Function and Strength

Evaluation of pelvic-floor muscle (PFM) function and strength is necessary (1) to be able to teach and give feedback regarding a woman's ability to contract the PFM and (2) to document changes in PFM function and strength throughout intervention. The aims of this article are to give an overview of methods to assess PFM function and strength and to discuss the responsiveness, reliability, and validity of data obtained with the methods available for clinical practice and research today. Palpation, visual observation, electromyography, ultrasound, and magnetic resonance imaging (MRI) measure different aspects of PFM function. Vaginal palpation is standard when assessing the ability to contract the PFM. However, ultrasound and MRI seem to be more objective measurements of the lifting aspect of the PFM. Dynamometers can measure force directly and may yield more valid measurements of PFM strength than pressure transducers. Further research is needed to establish reliability and validity scores for imaging techniques. Imaging techniques may become important clinical tools in future physical therapist practice and research to measure both pathophysiology and impairment of PFM dysfunction. [Bø K, Sherburn M. Evaluation of female pelvic-floor muscle function and strength. *Phys Ther.* 2005;85:269–282.]

Key Words: *Evaluation, Function, Measurement, Pelvic-floor muscles, Reliability, Strength, Validity.*

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Urinary incontinence is defined by the International Continence Society (ICS) as the complaint of any involuntary leakage of urine.[1] Urinary incontinence is more common in women than in men and affects women of all ages. Prevalence rates vary between 9% and 72% of women aged 17 to 79 years living in the community.[2] The most common type of urinary incontinence in women is *stress urinary incontinence* (SUI), defined as the complaint of involuntary leakage on effort or exertion, or on sneezing or coughing.[1] Urinary incontinence is a socially embarrassing condition, causing withdrawal from social situations and reduced quality of life.[3,4] Stress urinary incontinence may be an important barrier to regular physical and fitness activities in women.[5–7] This withdrawal may threaten women's general health and well-being because regular moderate physical activity is important in prevention of osteoporosis, obesity, diabetes, high blood pressure, coronary heart disease, breast and colon cancer, and depression and anxiety.[8]

Kegel[9] was the first to report training of the pelvic-floor muscles (PFM) to be effective in management of urinary incontinence in women. In uncontrolled, nonrandomized studies, he claimed an 84% cure rate in a variety of incontinence types. Since then, several randomized controlled trials (RCTs) have supported the results of his clinical series and have demonstrated that PFM training is more effective than no treatment or placebo treatment for SUI.[10–15] Cure rates, measured as ≤2 g of leakage on pad weigh tests after PFM training, vary between 44% and 67% in RCTs comparing PFM training with untreated controls or other treatment modalities.[13,14,16]

The PFM form the floor of the pelvic basin and help maintain continence by actively supporting the pelvic organs and closing the pelvic openings with their anterior and cephalad action when contracting.[17] The PFM comprise the pelvic diaphragm muscles (pubococcygeus, puborectalis, and iliococcygeus, together known as the levator ani), which can be referred to as the deep layer of the PFM; the urogenital diaphragm muscles (ischiocavernosus, bulbospongiosus, and transversus perinei superficialis, together known as the perineal muscles), which can be referred to as the superficial layer of the PFM; and the urethral and anal sphincter muscles (Figs. 1, 2). The PFM are encased in fascia, which is connected to the endopelvic (parietal) fascia surrounding the pelvic organs and which also assists in

Physical therapists need to be aware of the advantages and disadvantages of current technology to become less reliant on manual palpation alone.

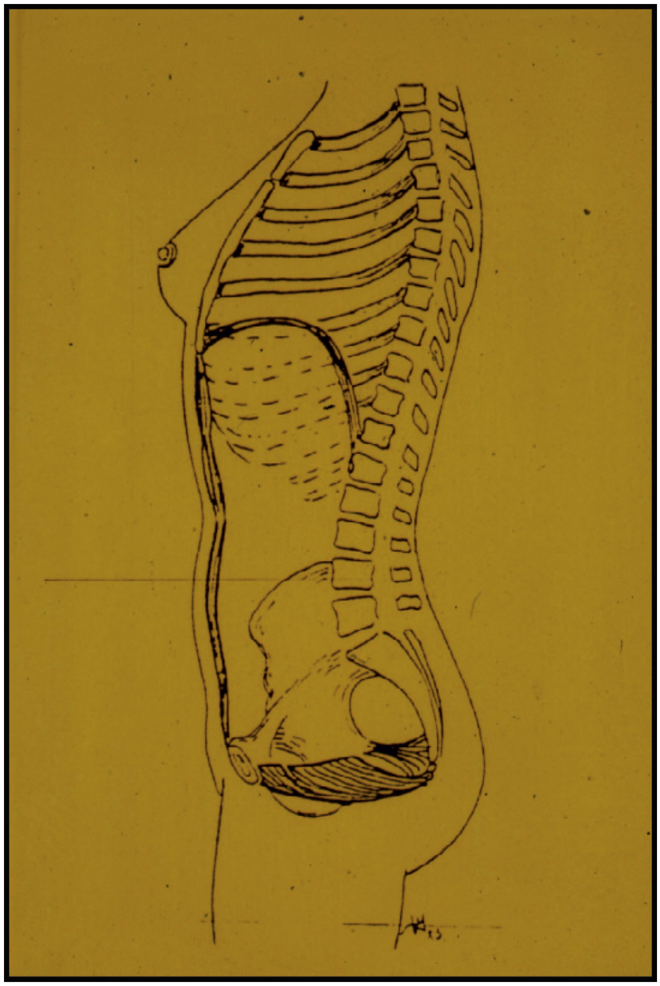

Figure 1.
The pelvic-floor muscles form the floor of the pelvis and a structural support for internal organs. Reprinted with permission from: Hahn I, Myrhage R. *Bekkenbotten: Bygnad, Funktion Och Traning*. Goteborg, Sweden; AnaKomp AB; 1999:39. Copyright 1999 AnaKomp AB.

pelvic organ support.[17–19] Although the deep and superficial layers of the PFM comprise different anatomical structures and innervation, clinically, they work as a functional unit. The PFM normally contract simultaneously as a mass contraction, but the contraction quality and contribution of the 2 layers may differ.

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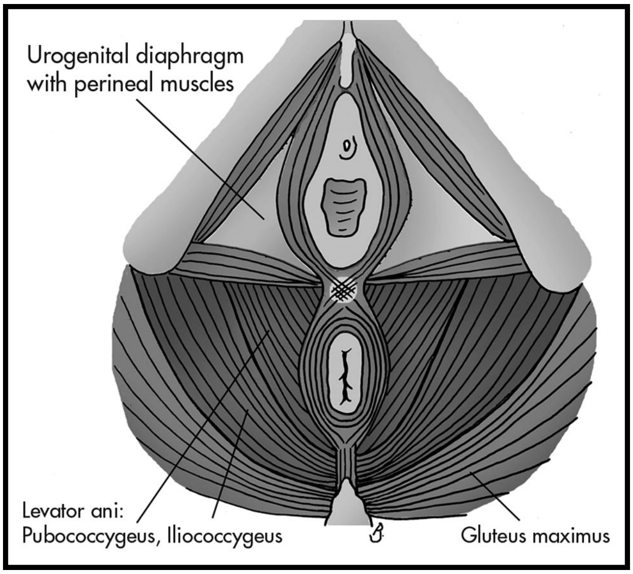

Figure 2.
Inferior view of the pelvic-floor muscles, showing the pelvic diaphragm (levator ani muscles) and urogenital diaphragm (perineal muscles). © 2005 Anatomedia Pty Ltd (www.anatomedia.com).

Correct action of the PFM has been described as a squeeze around the pelvic openings and an inward lift.[9] Measurement of the PFM muscle action becomes complicated by its diaphragmatic form and its attachments to the endopelvic fascia and pelvic organs.

In people without urinary incontinence, the PFM contract simultaneously with, or precede, the increase in abdominal pressure as an unconscious automatic co-contraction.[20,21] A voluntary contraction is a simultaneous contraction of all muscles of the pelvic floor and can be described as an inward movement and closure around the pelvic openings.[22] Magnetic resonance imaging (MRI) studies have demonstrated that, during voluntary contraction, the coccyx is moved ventrally toward the pubic symphysis. Thus, the PFM contract concentrically.[23] A true PFM contraction does not involve any visible movement of the pelvis. Submaximal PFM contractions may be performed as isolated contractions; however, a maximum PFM contraction does not seem to be possible without a co-contraction of the abdominal muscles,[24] especially the transversus abdominis and internal oblique muscles.[25] This abdominal contraction can be observed as a small inward movement of the lower abdomen.

Normal continence is maintained by the complex integration of pelvic, spinal, and supraspinal factors. The PFM are one of many factors contributing to the urethral closure mechanism for continence and are the target tissue in physical therapist management of incontinence and other pelvic-floor dysfunctions.[26] Other important pelvic factors for continence are contraction of smooth and striated muscles within the urethral wall, patent vascular plexi, and intact ligaments and fascia supporting the bladder and urethra in their optimal position during an increase in abdominal pressure.[27,28] If factors other than the function of the PFM are the cause of incontinence (eg, if urethral ligaments are totally ruptured during childbirth), PFM training may be unsuccessful. However, because the PFM are untrained in most people, training these muscles has a great potential for improvement, and well-functioning PFM may compensate for other factors unrelated to function.

Muscle strength can be defined as the maximal force that a muscle can generate and is often referred to as the weight the muscle can lift once, or the one repetition maximum (1RM).[29] When assessing muscle strength, the person being tested is asked to attempt to perform a maximum voluntary contraction of the specific muscle. This force can be measured by different instruments, each with its own qualities. Pelvic-floor muscle training may be beneficial for pelvic-floor dysfunctions other than urinary incontinence (eg, fecal incontinence, bladder outlet obstruction, pelvic organ prolapse, pain, sexual disorders). However, to date, there is evidence from RCTs and systematic reviews to support PFM training for women with stress and mixed urinary incontinence only.[30]

The *International Classification of Impairments, Disabilities, and Handicaps (ICIDH)*,[31] lately changed to *International Classification of Functioning, Disability and Health (ICF)*,[32] is a World Health Organization (WHO)–approved system for classification of health and health-related states. According to this system, the causes of a nonoptimally functioning pelvic floor (eg, muscle and nerve damage after vaginal birth) can be classified as the pathophysiological component. A nonfunctioning PFM (reduced force generation, incorrect timing or coordination) is the impairment component, and the actual leakage is a disability. How it affects the woman's quality of life and participation in fitness activities is an activity and participation component.

Pelvic-floor muscle training aims to make changes in all these components, and therefore all components should be measured in physical therapy. The theory for strength training is that, by changing PFM impairment (structural support, timing, and strength of automatic contraction), leakage will be stopped or markedly reduced. Thus, the patient can function adequately and have enhanced quality of life. DeLancey[33] suggested that cure rates after PFM training could be even higher than shown so far, if treatment could be based on a better understanding of the pathophysiology associated with incontinence symptoms in individual patients. The purposes of this article are to give an overview of evaluation methods available to measure PFM function and strength and to discuss the

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advantages and disadvantages of the different methods as they relate to clinical practice and research. For the purposes of this article, *PFM function* is defined as ability to perform a correct contraction, meaning a squeeze around pelvic openings and an inward movement (lift) of the pelvic floor, and *PFM strength* is defined as maximum voluntary contraction, meaning that a person attempts to recruit as many fibers in a muscle as possible for the purpose of developing force.

Methods

A computerized search was conducted in PubMed with the terms "pelvic floor"/"pelvic-floor muscles"/"pelvic muscles" AND "measurement"/"evaluation"/"assessment," with the limitation of English language. In addition, a hand search of the abstract books of the International Continence Society annual meetings from 1987 to 2004 and the World Confederation of Physical Therapy meetings from 1991 to 2004 was conducted.

The main reasons for physical therapists to conduct high-quality measurement of PFM function and strength are:

1. Without proper instruction, many women are unable to volitionally contract these muscles on demand because the PFM are situated at the floor of the pelvis and are seldom used consciously. Several studies[9,34–37] have shown that more than 30% of women do not contract their PFM correctly at their first consultation, even after thorough individual instruction. The most common error: contracting the gluteal, hip adductor, or abdominal muscles instead of the PFM. Some women also stop breathing or try to exaggerate inspiration instead of contracting the PFM. Some studies[36,37] have demonstrated that many women strain, causing PFM descent, instead of actively squeezing and lifting the PFM upward. For proper contraction of the PFM, it is mandatory that women receive precise training with appropriate monitoring and feedback. Hay-Smith et al[30] found that, of the 43 RCTs they reviewed, only 15 stated that a correct PFM contraction was checked before training began.

2. In intervention studies evaluating the effect of PFM training, the training is the independent variable meant to cause a change in the dependent variable, SUI.[38] Thus, measurement of PFM function and strength before and after training is important to determine whether the intervention has made changes.[13,39] Even in the presence of tissue pathology (eg, neuropathy), if there is no change in PFM function or force development after a training program commensurate with that pathology, the training program has been of insufficient dosage (intensity, frequency, or duration of the training period)[40] or the participants have had inadequate adherence. It is likely that such programs have not followed muscle training recommendations.[41]

In general, when measuring muscle strength,[42] it can be difficult to isolate the muscles to be tested, and many test subjects need adequate time and instruction in how to perform the test. In addition, the test situation may not reflect the whole function of the muscles, and the generalizability from the test situation to real-world activity (external validity) has to be established.[38] Therefore, when reporting results from muscle testing, it is important to specify the equipment used, position during testing, testing procedure, instruction and motivation given, and the parameters that are tested (eg, ability to contract, maximum force generation, duration of contraction). When testing the PFM, additional challenges are present because muscle action and location are not easily observable.

Measurement Tools to Evaluate PFM Function and Strength

Methods for evaluating PFM function and strength can be categorized as:

1. Methods to measure ability to contract (clinical observation, vaginal palpation, ultrasound, MRI, electromyography [EMG]).

2. Measures to quantify strength (manual muscle test by vaginal palpation, manometry, dynamometry, cones).

These methods measure different aspects of PFM activity, anterior and cephalad movement, squeeze pressure, and electrical activity. All of these methods have their place in physical therapist evaluation, but all have their limitations. Measurement of PFM performance is an evolving science, which is changing as new technologies become available.

Ability to Contract

Clinical observation. Observation of a correct PFM contraction can be done clinically,[9] by ultrasound,[43–45] or with dynamic MRI.[23,46] In 1948, Kegel described observation of a correct PFM contraction as squeeze around the urethral, vaginal, and anal openings and an inward lift that could be observed at the perineum.[9,22] Shull et al[47] stated that, by clinical observation, a person is generally observing superficial perineal muscles. From this observation, however, it can be assumed that the levator ani muscles are responding similarly due to their co-contraction with the superficial perineal muscles. However, to be certain, more than external observation of the skin must be undertaken.

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Figure 3.
Most physical therapists use vaginal palpation to evaluate and give feedback on ability to contract the pelvic-floor muscles.

Vaginal palpation. This is the technique currently used by most physical therapists to evaluate a correct PFM contraction and was first described by Kegel as a method to evaluate PFM function.[9,22] He placed one finger in the distal one third of the vagina and asked the woman to lift inward and squeeze around the finger. Kegel did not use this method to measure PFM strength. He used vaginal palpation to teach women how to contract their PFM and classified the contraction qualitatively as correct or not correct. For measuring PFM strength, he developed the "perineometer," a pressure manometer, which measured the ability of the PFM to develop vaginal squeeze pressure.[9]

Van Kampen et al[48] reported that since Kegel first described vaginal palpation as a method to evaluate PFM function, more than 25 different vaginal palpation methods have been developed. Some examiners use one finger, and others use 2 fingers. Worth et al[49] and Brink et al[50] have evaluated pressure, duration, muscle "ribbing," and displacement of the examiner's finger in a specific scoring system.

There has been no systematic research to determine the best method of vaginal palpation to assess the ability to contract. This may be because, in the context described here, vaginal palpation is used only to determine qualitatively whether or not there is a muscle contraction (Fig. 3).

Ultrasound and MRI. More recently, real-time diagnostic ultrasound and MRI have been used to evaluate PFM action during contraction.[23,43–49,51–55] Ultrasound can be performed either with the probe placed suprapubically or at the perineum (curved-array ultrasound probe, 3.5 and 5 MHz, and vaginal probe, 7.5 MHz) or with the probe inserted into the vagina or rectum (linear or end-firing probe, 5 and 7.5 MHz)[56–58] (Fig. 4). Magnetic resonance imaging can be conventional (2-dimensional image acquisition), ultrafast image acquisition, or 3-dimensional image acquisition.[56] Bø et al,[23] using dynamic MRI, could not confirm displacement of 2 to 4 cm of the PFM estimated by Kegel after vaginal palpation in a supine position.[22] With the subjects in a sitting position, a mean inward lift of the PFM of 10.8 mm (SD=6.0) was measured by MRI. This finding corresponds with results from a recent study using ultrasound where a mean lift of 11.2 mm (95% confidence interval=7.2–15.3) was visualized with the subjects positioned supine.[59] Further testing of responsiveness, reproducibility, and validity of data obtained with these methods needs to be done, particularly to understand the implications of subject position on the different displacement values, but there is consensus that both ultrasound and MRI should be considered an investigational imaging technique in the evaluation of female urinary incontinence and pelvic-floor dysfunction.[56] Ultrasound is increasingly being used clinically because this technology is becoming more economically available to physical therapists.

EMG. Electromyography can be used to measure the electrical activity of skeletal muscles and is a direct representation of the outflow of motoneurons in the ventral horn in the spinal cord to the muscles as a result of either voluntary or reflex PFM contraction. Electromyographic measurement can be conducted with either surface or intramuscular electrodes.[60,61] Surface electrodes are recommended to measure the activity of large, superficial muscles, whereas the use of intramuscular electrodes (needle or wire) is the method of choice to detect activity from muscles that are small or located deep within the body (eg, the PFM).[60] In clinical practice, however, surface electrodes on a vaginal probe are most commonly used due to the high sensitivity of the perineal region and skills required for using wire or needle electrodes (Fig. 5).

Several types of apparatus and different techniques of surface EMG,[62–64] wire EMG,[21,25,65] and concentric needle EMG[66–68] have been used to measure PFM activity. In general, the number of activated motor units increases with increasing force when the muscle force is low, whereas frequency of firing of motor units increases at high force levels. It is reasonable, therefore, to expect that electrical activity may represent the level of force developed by the muscle.[60] However, Turker[60] recommended that researchers be cautious about using the EMG information as the absolute measure of force because most muscles give nonlinear responses. Turker[60] also stated that comparison of single motor unit data among and within subjects on different occasions is highly unlikely, but that it is possible to compare firing and synaptic characteristics of motor units that

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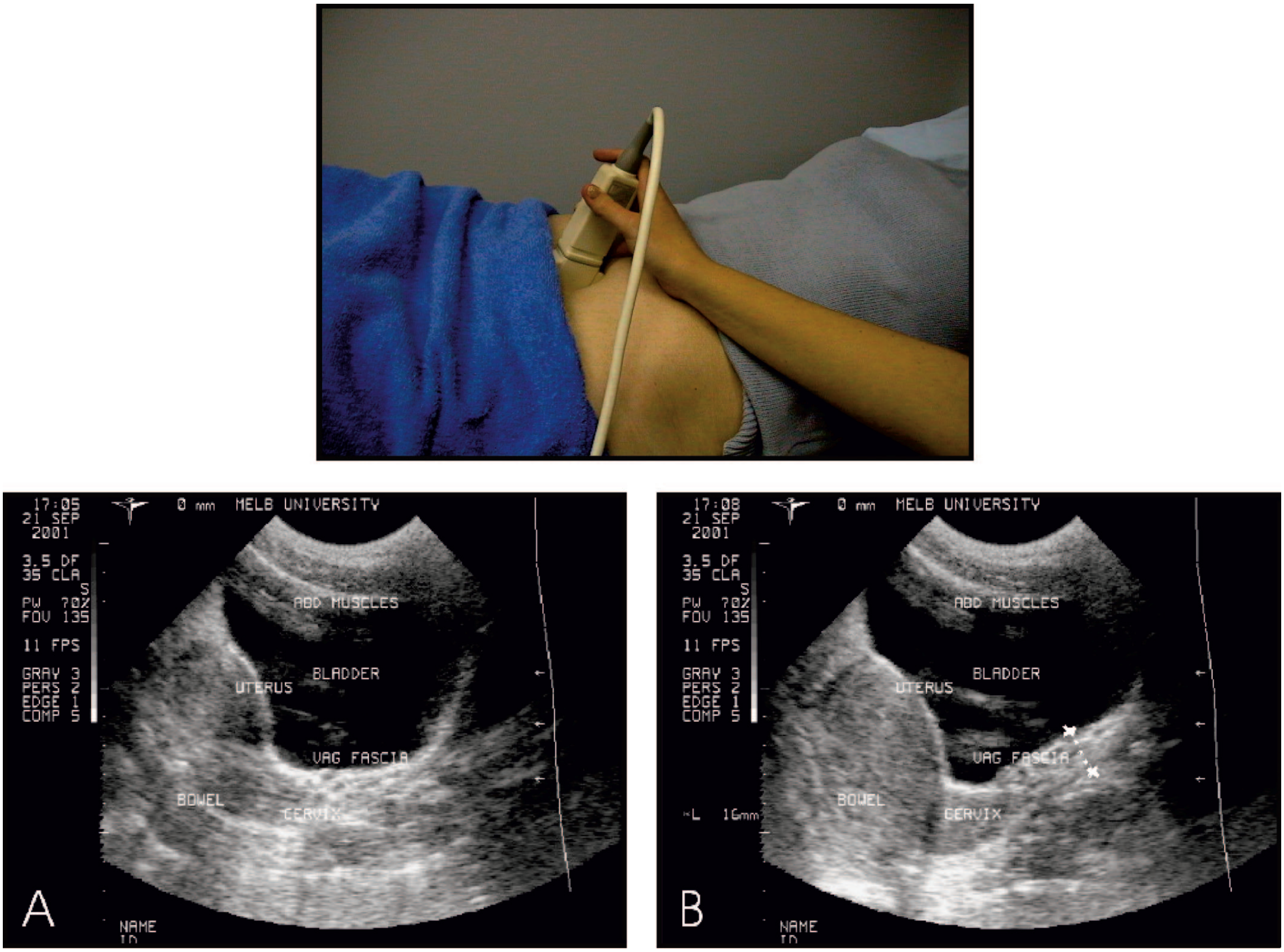

Figure 4.
Ultrasonography applied suprapubically. Sagittal midline view of pelvic floor relaxed (A) and fully contracted (B), with pelvic-floor displacement marked.

Figure 5.
Apparatus with multiple functions: measurement of pelvic-floor muscle function with surface electromyography and vaginal and rectal squeeze pressure (Enraf Nonius International, 2600 AV Delft, the Netherlands).

have similar recruitment thresholds. Podnar and Vodusek[68] recommended concentric needle EMG as the most informative test to detect PFM denervation or reinnervation.

Heitner[69] concluded that surface EMG was superior to vaginal palpation in assessment of all variables other than lift, and Gunnarsson[70] showed that PFM activity can be measured reliably with surface EMG. However, when surface EMG is used clinically, interpretation of the signals must be made with caution because the risk of cross talk from other muscles is high[60,61] and because of variability in electrode placement within the vagina. Wire EMG and concentric needle EMG, therefore, are recommended for scientific purposes.

Quantification of Muscle Strength

Measurement of squeeze pressure is the most commonly used method to measure PFM maximum strength and endurance. The patient is asked to contract the PFM as hard as possible (maximum strength), to sustain a

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contraction (endurance), or to repeat as many contractions as possible (endurance). The measurement can be done in the urethra, vagina, or rectum using manual muscle testing with vaginal palpation, pressure manometry, or dynamometry.

Manual muscle testing. Laycock[71] developed the modified Oxford Grading System[72] to measure PFM strength using vaginal palpation of the PFM. This is a 6-point scale: 0=no contraction, 1=flicker, 2=weak, 3=moderate, 4=good (with lift), and 5=strong. This measurement scale is commonly used by physical therapists because it can be incorporated with vaginal palpation in the clinical assessment, its use is considered a physical therapist's core manual skill, it is simple to use, and it does not require expensive equipment.

Bø and Finckenhagen[73] questioned the responsiveness of this scale because they did not find that the scale could differentiate among weak, moderate, good, or strong contractions when they compared the measurements with measurements of vaginal squeeze pressure using a vaginal balloon connected to a fiberoptic microtip pressure transducer (cm H_2O) in a study of 20 female physical therapist students (mean age=25 years, range=21–38), 7 with reported symptoms of SUI and 13 who were asymptomatic. Morin et al[74] confirmed these findings, showing that digital palpation categories did not correspond with measurement with a dynamometer.

The results from studies evaluating intratester and intertester reliability of vaginal palpation strength measurements[49,73,75–78] are conflicting. Isherwood and Rane[75] found high intertester reliability, whereas Jeyaseelan et al[76] concluded that intertester reliability should not be assumed and needs to be established when 2 or more clinicians are involved in pretreatment and posttreatment assessment. Bø and Finckenhagen[73] and Laycock and Jerwood[77] found agreement between testers in only 45% and 47% of the tested cases, respectively, using Laycock's modified Oxford scale. Several investigators[73,74,78–81] have compared vaginal palpation and vaginal squeeze pressure using a pressure manometer. Isherwood and Rane[75] measured vaginal palpation using the Oxford Grading System and compared the measurements with those obtained using a "perineometer" with an arbitrary scale of 1 to 12. They found a high kappa value of .73. Heitner[69] tested 39 women with SUI (mean age=49 years, SD=12) to determine the reliability of data obtained with intravaginal surface EMG and vaginal palpation and concluded that lift was most reliably tested with palpation and that all other measures of muscle function were better tested with EMG.

Manometry. Kegel[9] used a vaginal pressure device connected to a manometer (the perineometer), showing the pressure (in millimeters of mercury) as a measure of PFM strength. He did not report any data about responsiveness, reliability, or validity for his method. The term "perineometer" is somewhat misleading because the pressure-sensitive region of the probe of the manometer is not placed at the perineum, but in the vagina at the level of the levator ani muscles. Currently, several types of vaginal pressure devices are available to measure vaginal squeeze pressure, all with different device sizes and technical parameters[82–84] (Figs. 6, 7). Thus, measurements obtained with different methods cannot be compared.[47] In newer types of apparatus, a specialized balloon catheter connected to a fiberoptic microtip and strain-gauge pressure transducer has shown high responsiveness.[82–87]

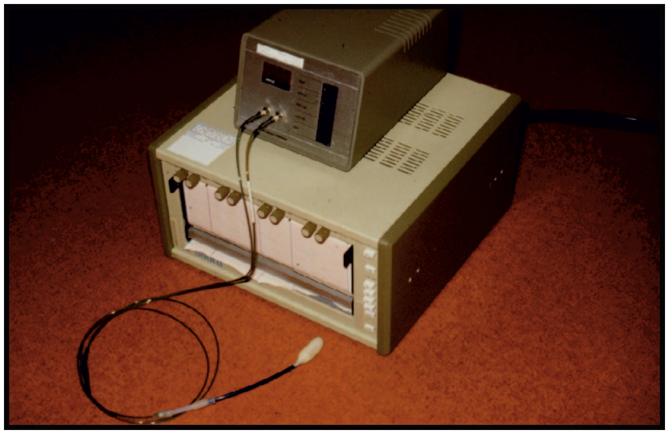

Figure 6.
Vaginal squeeze pressure measured with a vaginal balloon connected to a microtip pressure transducer (Camtech AS, Sandvika, Norway).

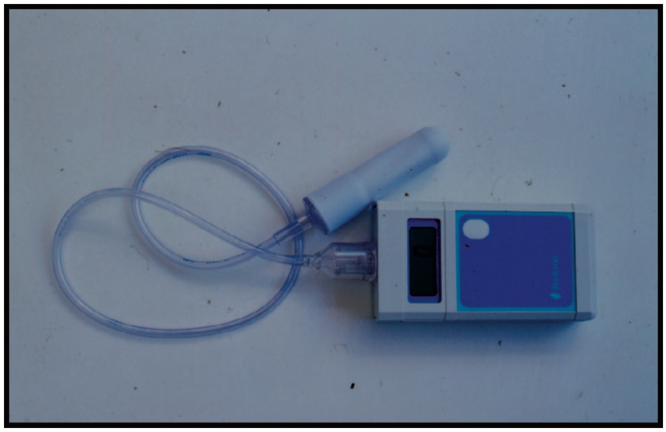

Figure 7.
One commonly used "perineometer," the Peritron with vaginal probe (NEEN HealthCare, Dereham, Norfolk, United Kingdom).

Of the 3 pelvic canals, measurement across the urethra has the best face and content validity for measuring the closure pressure caused by the force of muscle contraction. This location is where the increased pressure created by the muscle contraction is required. However, because of the risk of infection and the lack of equip-

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ment availability in most physical therapy clinics, this method has mostly been used for research purposes.[26,34] Rectal pressure may not be a valid measure of the PFM in relation to urinary incontinence because this measure also includes contraction of the anal sphincter muscle. Therefore, vaginal squeeze pressure is used clinically.

A common reliability and validity problem is placement of the pressure transducer in the urethra, vagina, or rectum. The balloon or transducer has to be placed at the same anatomical level and where the PFM are located. In the urethra, the most common placement of the transducer is at the highest pressure point.[26] Kegel[9,22] suggested that the PFM were located in the distal third of the vagina, and Bø[88] found that most women had the highest pressure rise when the middle of the balloon was placed 3.5 cm inside the introitus of the vagina. However, individual differences were found.[88]

Squeeze pressure measurements obtained from all the 3 canals can be invalid because an increase in abdominal pressure will increase the measured pressures. The PFM create one wall of the abdominopelvic cavity, and all rises in abdominal pressure will increase the pressure measured in the urethra, vagina, and rectum. Both Bø et al[36] and Bump et al[37] have shown that straining is a common error when women attempt to contract their PFM, and therefore an erroneous measurement can be registered. However, because a correct contraction involves an observable inward movement of the perineum or the instrument, and straining creates a downward movement, some authors[24,89] have suggested that a valid measurement can be ensured by simultaneous observation of inward movement of the perineum.

Some researchers[90] have tried to avoid co-contraction of the abdominal muscles interfering with measurement of PFM strength by use of surface EMG on the rectus abdominis muscle to train subjects to relax their abdominal muscles or by simultaneous abdominal pressure measurement. Several researchers,[24,25,91,92] however, have shown that there is a co-contraction of the abdominal muscles (lower transversus abdominis and internal oblique) during attempts of a correct, maximal contraction. Performance of a near-maximum PFM contraction is important to achieve the best training effect.[29,93] A normal co-contraction of the lower abdominal wall, therefore, should be taught. Dougherty et al[91] allowed an increase in abdominal pressure of 5 mm Hg only, to ensure the least abdominal pressure interference with the measurement results. Bø et al[24] used a more clinically useful method of standardizing the testing by not allowing any movement of the pelvis during measurement. Contraction of other muscles such as the hip adductor and external rotator muscles and the gluteal muscles, also alters intravaginal pressure measurement.[24,55] Bø and Stien[66] showed with concentric needle EMG in women without urinary incontinence that contraction of these other muscles increased muscle activity in both the striated urethral wall muscle and the PFM. However, this gross motor pattern is not the normal neuromotor action of the PFM and lower transversus abdominis muscles and is therefore discouraged.

Results reported from different squeeze pressure and EMG apparatuses may not be able to be compared due to differences in the diameter of the vaginal probes. It is unknown whether these size differences may give different results or alter muscle function. There is discussion on both the optimum diameter of vaginal devices and whether 1 or 2 fingers should be used for vaginal palpation.[47] Most women use vaginal tampons, which are the size of one finger. Although vaginal birth may have stretched the PFM and endopelvic fascia, time may have normalized this stretched fascia in many women. When palpating, the anterior and posterior vaginal walls are always in apposition and in contact with the finger. However, the urogenital hiatus can be markedly widened in some women, and using 1 or 2 fingers to palpate will depend on the width of this urogenital hiatus. It is unknown whether a wide-diameter vaginal device or 2-finger palpation stretches the PFM, inhibiting its activity or, conversely, increasing its activity by providing firm proprioceptive feedback.

Several authors[78,82,83,94] have shown that vaginal squeeze pressure can be measured with satisfactory reliability. However, Dougherty et al[91] reported a within-subjects mean of 15.5 mm Hg (SD=3.9) for vaginal squeeze pressure and a between-subjects mean of 132.4 mm Hg (SD=11.5) in subjects without urinary incontinence aged 19 to 61 years. This variation was confirmed by Bø et al,[83] who also showed that at the first attempt some women needed some time to find and recruit motor units, whereas other women fatigued, causing the strength to drop considerately after only a few attempts. However, comparing the results of the whole group of women on 2 different occasions 14 days apart, reproducible results were found. Wilson et al[94] also found a difference between first and last contractions. They did not find any difference between measurements obtained with a full or empty bladder or during the menstrual cycle. Dougherty et al[91] did not find any difference when muscle strength was measured on different days, at different times of the day, or during stress. In summary, vaginal squeeze pressure is a clinically useful measurement technique when used with careful instructions to the patient and visual observation of the perineum by the physical therapist.

Dynamometers. Sampselle et al[95] were the first to report on the use of a dynamometric speculum to

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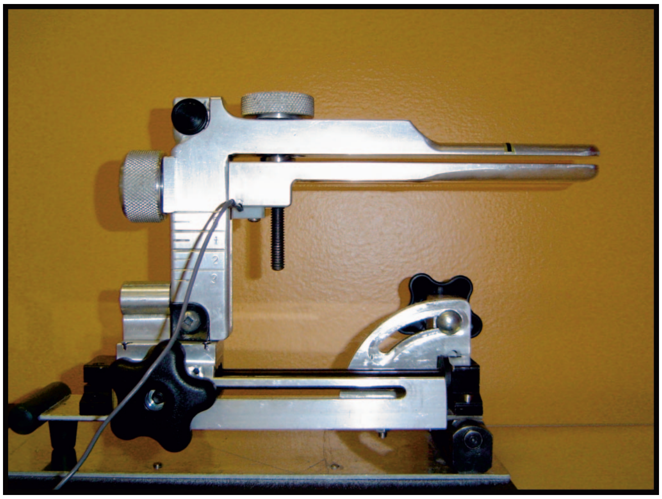

Figure 8.
Vaginal dynamometer. Printed with permission from Dumoulin et al, Montreal, Quebec, Canada.

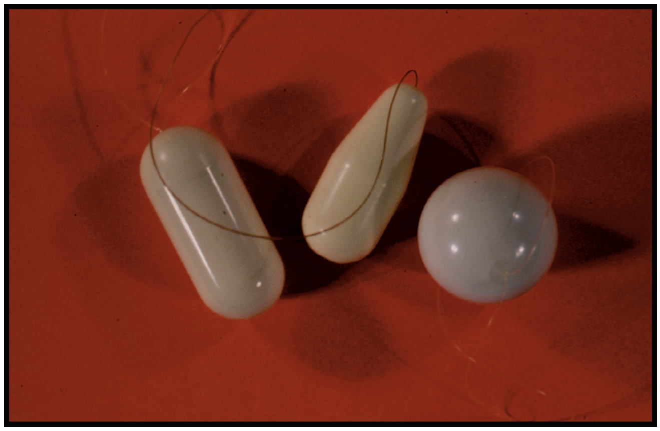

Figure 9.
Different sizes and shapes of vaginal cones.

measure PFM strength. This dynamometer measures the dorsoventral muscle force (in newtons) directly. However, so far, no report of responsiveness, reliability, and validity has been published on this apparatus. The dynamometric speculum developed by Dumoulin et al[96] was shown to yield data with satisfactory reliability and to be a sensitive tool for measuring dorsoventral PFM force (Fig. 8). This dynamometer comprises 2 parallel aluminum branches—one fixed and one adjustable to different vaginal diameters—and a computerized central unit.[97] The voltage output was found to be linearly correlated with a force of 0 to 15 N applied to the speculum arms (R^2=.999). This dynamometer also was found to have best reliability at an opening of 1 cm, with a coefficient of dependency of .88 (SEM=1.49 N). In contrast to the speculums developed by Sampselle et al[95] and Dumoulin et al,[97] Verelst and Leivseth[98] recently developed a dynamometer to measure mediolateral PFM contraction force. Their dynamometric speculum also has 2 nonflexible, adjustable parallel branches, one of these containing the strain gauges, and has been tested for linearity to 60 N (±2% nonlinearity), with best reliability at an opening of 40 mm. One disadvantage that dynamometric speculums share with most tools for measuring PFM strength is that they measure only one function (squeeze and not lift). In addition, clinical experience has shown that they have the same disadvantage as manometers, in that the force measured by the dynamometer also can be affected by intra-abdominal pressure rises or contractions of other muscle groups such as the adductor or gluteal muscles.

Vaginal weights/cones. Plevnik[99] developed vaginal cones in 1985. The cones were meant to be both a measuring tool and a training method. The original set of cones consisted of 9 weights with equal volume but with increasing weight from 20 to 100 g. In newer versions, packages of 3 and 5 cones are common, and they come in differing sizes and shapes (Fig. 9). The heaviest weight that a woman can hold for 1 minute without voluntarily contracting the PFM is termed the "resting PFM strength" or "passive PFM strength." The weight that can be held for 1 minute with voluntary contraction is termed "active PFM strength."[99]

Cones have not been tested for responsiveness, and it could be argued whether 9, 5, or 3 cones are the most suitable number to grade muscle strength. The responsiveness, therefore, may be too low to detect small differences. The muscle force that is required to hold each of the cones is not known. No studies have been found that have addressed intrarater or interrater reliability or placement of the cone within the vagina in relation to the PFM.

Deindl et al[65] applied wire EMG within the PFM and showed that insertion of the cone did increase the overall motor unit activity. Hahn et al[79] found low correlations between weight of the cones and vaginal squeeze pressure measurement (r=.10) and between vaginal digital palpation and cone weight (r=.18) in women with incontinence. Twenty percent of the women had low palpation scores and low vaginal pressure measurements despite the fact that they could retain the heaviest cone. Radiography showed that the cone was resting on the coccyx in some women. In addition, other muscles such as the gluteal, hip adductor, and the external rotator muscles can be contracted instead of the PFM to keep the cone in place. Kerschan-Schindl et al[80] found there was only a weak correlation between maximal PFM contraction force and ability to hold the cones. No studies have been found that compared the actual weight of the cone with measurement of voluntary maximum PFM contraction force in individual women. In a study by Olah et al,[100] 17% of the subjects were not able to use the cones because they were either too large or too small in relation to the vagina. In

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summary, the use of cones is to be approached with caution until further good-quality research is forthcoming.

Measurement of Lift

Some attempts have been made to measure the lifting aspect of PFM function.[101] Ultrasound[27,45,46,59,81] and MRI[23,52–54] are newer technologies, where the actual lift inside the pelvis can be seen. These methods yield data with strong face and content validity, and both perineal and transabdominal applications of ultrasound have been tested for reliability.[58,102] Artibani et al,[56] however, concluded that only a few of the imaging techniques have been properly evaluated with respect to specificity, sensitivity, and predictive value for use in diagnosis and management of urinary incontinence and that the use is often based more on expert opinion, common sense, local expertise, and availability than on research data.

Pelvic-floor muscle location, volume, and anatomy can be measured with ultrasound and MRI.[56,103] In a systematic review of studies of real-time ultrasound as an objective measure of muscle size, not necessarily the PFM, Perkin et al[103] concluded that ultrasound yielded valid and reliable measurements of skeletal muscle size under controlled conditions. However, they identified fat, fascia orientation, muscle shape, and pathology as confounding factors. More research is needed to obtain normative data for PFM size for both MRI and ultrasound.

Whether measurement of lift is a good measure of PFM strength warrants some discussion. For instance, is lifting through a large distance a measure of greater PFM force, or might it indicate a stretched or ruptured investing fascia within which the PFM can lift a great distance? A large displacement may not therefore be a measure of greater strength. Most likely a well-positioned pelvic floor with high volume and strength will be in a position where little voluntary lift can be added. Peschers et al[104] demonstrated that there was downward movement of the PFM during coughing even in women without urinary incontinence, and a large lift during voluntary contraction has been shown in women without urinary incontinence.[23,59] The role of the fascia covering the PFM is not yet fully appreciated in displacement data obtained for PFM lift. Ongoing research evaluating the utility of ultrasound for PFM imaging may combine with increasing availability of this technology to create a useful clinical tool for physical therapists.

Discussion

Assessment of PFM function is not an easy task, and to date no single method has been shown to measure both functions of the muscles: elevation and compression force. Most methods available are influenced by subjective judgment. Skill and clinical experience, therefore, may play an important role in determining the reliability and validity of the results now and in the future.[38,73,76]

Observing the inward movement of a correct PFM contraction is the starting point for measurement of PFM function. However, this inward movement of the skin may be created by contraction of the superficial perineal muscles and have no influence on the urethral closure mechanism. Conversely, there may be palpable PFM contraction with no visible outside movement. Particularly in women who are obese, a correct lift can be difficult to observe from the outside. In the future, ultrasound may overtake the role of clinical observation, and would also serve as a biofeedback and teaching tool.

Whether the muscle action observed by clinical observation or ultrasound is sufficiently strong to increase urethral closure pressure can only be measured by urodynamic assessment in the urethra and bladder. Most interestingly, Bump et al[37] found that, although contracting correctly, only 50% of subjects who were continent were able to voluntarily contract the PFM with enough force to increase urethral pressure.

Today, most physical therapists use vaginal palpation and the modified Oxford scale to evaluate PFM function and strength because both squeeze pressure and lift can be registered. As stated by Kegel,[9] vaginal palpation is a good method to qualitatively report whether there is a PFM contraction or not. However, whether palpation is adequate for clinical outcome measurement and for scientific purposes to measure muscle force is questionable. Even experienced assessors have been found to have low agreement.[73,77]

Because all increases in abdominal pressure will affect urethral, vaginal, and rectal pressures, squeeze pressure cannot be used alone. With simultaneous observation of inward movement of the perineum, it is likely that a correct contraction is measured.[31] Cautious teaching of the patient, standardization of instruction and motivation, and standardization of the patient's position and performance are mandatory. If the aim is to measure the ability to close the urethra, urethral pressure should be measured. If overall PFM strength is the aim of the investigation, vaginal squeeze pressure (pressure manometry or dynamometric force) is preferred because this is the least invasive method with no known risk of infection.

Muscle strength measurement may be considered an indirect measure of PFM function in real-life activities. Women with no leakage do not contract voluntarily before coughing or jumping. Their PFM contraction is considered to be an automatic co-contraction occurring as a quick and strong activation of an intact neural

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system. Other important factors for a quick and strong contraction are the location of the pelvic floor within the pelvis, the muscle bulk, and intact connective tissue. A stretched and weak pelvic floor may be positioned lower within the pelvis compared with a well-trained or non-injured pelvic floor.[27] The time for stretched muscles to reach an optimal contraction may be too slow to be effective in preventing descent against increased abdominal pressure (eg, sneeze), thereby allowing leakage to occur. Several case control studies comparing PFM strength in women with and without incontinence have demonstrated that women who are continent have better function and strength in the PFM than women who are incontinent and that there is an association between improvement in muscle strength and reduction in urinary incontinence.[98,105,106]

Future measurement of both pathophysiological and impairment levels (ICF classification) could include ultrasound, MRI, and intramuscular EMG. To date, PFM function and strength seem to be best measured by a combination of observation, vaginal palpation, and urethral or vaginal squeeze pressures. In measurement of disability, pad tests, leakage episodes, and women's reports are the "gold standard" recommended by the International Continence Society.[1] Finally, the activity/participation domain can be measured by general and disease-specific quality-of-life questionnaires.[107,108]

Clinical Recommendations

On the basis of our review of the literature, we believe the following clinical recommendations can be made:

- Pelvic-floor muscle palpation is the recommended technique for use by the physical therapist to understand, teach, and give feedback to patients about correctness of the contraction. Position of the patient, instructions given, and the use of 1 or 2 fingers have to be standardized and reported.
- Ultrasound applied at the perineum, and particularly suprapubically, is a noninvasive method and likely to be an important tool in the future for physical therapists to assess correctness of the PFM contraction, its anatomical position, and muscle volume; for biofeedback; and for measurement of PFM activity. It is especially valuable in circumstances where an invasive technique is inappropriate.
- Measurement of vaginal squeeze pressure is difficult, and clinical skills and experience are important factors in achieving reproducible and valid results. The method has to be used with caution. Only contractions with visible inward movement of the measurement device can be considered valid measurements of PFM strength.
- The use of dynamometers may be a future valid, reliable, and responsive method of measuring PFM force.

No single measurement tool gives a full picture of PFM strength or function. In addition, to date, there are no measurement tools with demonstrated responsiveness, reliability, and validity that are capable of measuring the automatic action of the PFM in real-life situations as a response to increased abdominal pressure. Future technological developments may provide the possibility of measuring PFM function during different forms of physical exertion. Physical therapists need to be aware of the advantages and disadvantages of current technology to become less reliant on manual palpation skills alone.

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