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Quantitative tools to assess pelvic floor muscle function — systematic review

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ABSTRACT

Objectives: Urinary incontinence is pelvic floor muscles dysfunction, most often caused by a weakening of their strength. There are no guidelines on how to evaluate pelvic floor muscle function. Palpation is the most popular method of assessing pelvic floor muscle function, but it is subjective. The aim of the study was to review the objective methods used in the assessment of pelvic floor muscle function in women with urinary incontinence.

Material and methods: A systematic literature review of the PubMed database was performed using the following keywords: [“Pelvic Floor” (mh)] AND [“Pelvic Floor Disorders” (mh)] OR [“Urinary Incontinence” (mh)]. The search was limited to English-language works published from 2011 to 2021. The inclusion criteria were interventional studies in which the pelvic floor muscle function of women with urinary incontinence was
assessed using quantitative tools. Methods that cannot be used in the clinic were excluded from the analysis.

**Results:** Fifty-two articles were included in the analysis and five methods assessing the function of pelvic floor muscle were distinguished: manometry, electromyography (EMG), ultrasonography (USG), dynamometry, accelerometry.

**Conclusions:** Manometry, EMG and USG are the most common objective methods of assessing pelvic floor muscle function. When taking measurements, it is important to choose the right position of the patient. The use of objective tools to assess the function of the pelvic floor muscle and obtaining quantitative and/or qualitative data allows us to precisely diagnose and monitor the treatment and rehabilitation progress.

**Keywords:** manometry; electromyography; ultrasonography; accelerometry; dynamometry; pelvic floor muscle

**INTRODUCTION**

One of the most common pelvic floor muscle (PFM) dysfunctions among women is urinary incontinence. The research shows that the prevalence of urinary incontinence varies widely from about 5 to 70%, but mostly it is within the range of 25 to 45% [1, 2]. Such a large discrepancy is mainly caused using different definitions and methods in the assessment of urinary incontinence [3]. Urinary incontinence is most often caused by dysfunction of the bladder or pelvic floor muscles [4]. The risk factors include the age and body mass index (BMI) of the mother, number and type of births, incontinence before pregnancy and weight of the newborn [2]. According to the recommendations, intensive, supervised PFM training is the first-line treatment in stress and mixed urinary incontinence [5, 6].

Assessment of pelvic floor muscle function (PFMF) is an important part of conservative treatment [7]. However, currently, there is no gold standard for PFMF evaluation [8]. A digital palpation is a low-cost tool commonly used in practice [9]. It does not require any equipment. The PERFECT Scheme and Oxford Score are used to assess the PFMF during digital examination [10]. Although most of the research has shown good intra-rater reliability, the inter-rater reliability is poor [11–13].
In recent years, there has been a growing interest in objective methods evaluating PFMF [14, 15]. The International Continence Society points out that clinical conclusions from a subjective examination, such as digital palpation, should be drawn with caution. Therefore, the use of quantitative assessment tools is recommended [16]. They are essential for diagnosis, as well as for monitoring and comparing treatment outcomes. The most accurate tool is magnetic resonance imaging, which can be used in both static and dynamic examinations, however, this examination is of limited use in screening [17].

The objective tools that enable the functional assessment of PFM in clinical practice include dynamometry, manometry, ultrasonography (USG) and electromyography (EMG). The aim of the systematic review was to compare the measurements that could be made with the in-office PFM assessment tools.

MATERIAL AND METHODS

A systematic literature review of the PubMed database was performed using the following keywords: [“Pelvic Floor” (mh)] AND [“Pelvic Floor Disorders” (mh)] OR [“Urinary Incontinence” (mh)] according to the PRISMA guidelines [18] (Fig. 1). The search was limited to English-language works published from January 2011 to December 2021. The inclusion criteria were interventional studies in which the PFMF of women with urinary incontinence was assessed using quantitative tools. Methods that cannot be used in the clinic were excluded from the analysis.

RESULTS

A total of 1075 articles were found in the PubMed database using the search strategy, 52 of which met the inclusion criteria. Among the qualified articles, the most frequently used tool to assess PFMF was manometry (44% of the analyzed literature), also as a standalone device. Another common tool was the EMG. In total, 5 methods were distinguished to evaluate the PFMF (Tab. 1–6).

The frequency of using particular methods in the articles is as follows: manometry — 20 (Tab. 1), manometry with other methods — 3 (Tab. 6), EMG — 10 (Tab. 2), EMG with other methods — 3 (Tab. 6), dynamometry — 5 (Tab. 3), dynamometry with other methods
Manometry

Manometry is used to register changes in the intravaginal pressure as a result of PFM activity. The intravaginal probe equipped with a manometric sensor is used for measurements [19]. The result is obtained in mmHg or cmH$_2$O [20]. The measurement is usually performed in a lying position. Maximum voluntary contraction (MVC) is defined as the largest difference between pressure before muscle activation and the highest-pressure value obtained during contraction [20, 21]. Manometry shows good intra- and inter-rater reliability [11, 22]. However, the result is influenced by the intra-abdominal pressure [16]. Manometric sensors are commonly available to medical professionals and are used in advanced systems for telerehabilitation of the PFM (e.g., PelviFly) [23, 24].

Manometry was the most common method used to evaluate PFMF. It was used in a total of 23 articles. Twenty-two articles used an intravaginal probe and one article used a pressure sensor in an external device. In 18 studies maximum muscle strength was measured, in four studies maximum muscle strength and endurance, and in 1 study muscle strength, endurance and speed were measured (Tab. 1, 6). Measurements were performed in the following positions: lying with hips and knees bent (10 articles), sitting (1 article), lying (1 article), and lithotomy (1 article). In 11 articles the position was not mentioned. The pressure results were obtained in various units: cmH$_2$O (18 articles), mmHg (2 articles), and scale 0–12 (1 article). The unit was not reported in two studies.

Electromyography

Electromyography (EMG) allows the assessment of the bioelectrical activity of muscles, but it cannot be used to determine the force of contraction [25, 26]. Currently, new devices have a screen which enables us to observe the ability to contract and relax in real-time (biofeedback) [27]. In clinical practice, EMG is used in the form of electrodes attached to the skin (surface EMG) or a vaginal probe. Studies show that the measurement with the vaginal probe is more precise than with the adhesive electrodes [11, 20].

Electromyography was used in 13 articles (Tab. 2). Muscle activity during maximum contraction was assessed in 12 studies. Additional measures included endurance (5 items), muscle activity at rest (1 item), and muscle contractility (1 item). The measurements were
performed in the following positions lying with hips and knees bent (6 articles), standing (6 articles), lithotomy (1 article). In two articles the position was not specified.

**Dynamometry**

Dynamometry is used to measure force directly using an intravaginal speculum. The studies showed good reliability of the measurements [28, 29], and the influence of the intra-abdominal pressure on the results was minimal [30]. Using a dynamometer, both reactive and active forces can be assessed [25].

Dynamometry was used only in six studies (Tab. 3, 6). Muscle strength (4 articles), passive forces (3 articles), active forces (1 article), relaxation speed (1 article) were assessed. All force values are expressed in Newtons. The exercise positions were lithotomy (3 articles), supine with the hips and knees bent (2 articles). In one study the position was not reported.

**Ultrasonography**

Ultrasonography (USG) enables a dynamic assessment of the PFM structures during rest and activation of the PFM (voluntary and reflex) [20, 31]. One of the most important measurements is bladder neck movement relative to the pubic symphysis during PFM contraction and the Valsalva maneuver [32]. Measurement of the elevation of the PFM during contraction using ultrasound (US) is more reliable than that obtained during digital palpation [33]. It is not possible to obtain quantitative data on the strength of contraction from US [20].

The US examination was used in 15 articles. In 12 of them, transperineal US was used, in one transvaginal US, and in two studies the type of US was not specified. The US measurements are varied and are shown in Tables 4 and 6. An examination can be performed in different positions. The following positions were used: lying (3 articles), lying with legs and knees bent (2 articles), lithotomy (5 articles), standing (2 articles), and lying or standing (1 article). In two articles the position was not mentioned.

**Accelerometry**

There was only one study describing an intravaginal accelerometer-based system (The leva Pelvic Digital Health System) that registers PFM activity. The intravaginal sensor consists of six accelerometers that evaluate the movement of the sensor relative to the earth and relative to each accelerometer. It enables the observation of elevation which is an important component of the correct activation of the PFM. This movement stabilizes the bladder neck and provides urethral support. During the correct activation of the PFM the
vaginal axis increases, while it decreases during the Valsalva maneuver. With accelerometers, it is possible to obtain data on the lift or descent of the PFM [34].

In this article, the angle of the PFM during rest, the tension and proper activation of the PFM, as well as their endurance and the number of contractions of the PFM over 15 seconds were assessed (Tab. 5). The measurement was most likely taken while standing, but this is not stated.

**DISCUSSION**

The PFM play important role in bladder control; therefore, they should be included in the therapeutic management of urinary incontinence and other pelvic floor dysfunctions [20, 86]. The International Continence Society points to PFM exercise as an important element of urinary incontinence treatment [87]. According to the European Association of Urology, pelvic floor muscle training should be supervised, intensive, and should last at least three months [5].

The correct scheme for activating the PFM consists of two elements: contraction and lift [20, 71]. Both parameters must be considered in the functional assessment of the pelvic floor. The position in which the measurements are made is also important. In the lying position, the measurements are reliable due to the stable position. Higher positions (bent knee, sitting and standing) are also used but they may worsen the symptoms of urinary incontinence or organ prolapse during the examination [88].

Assessment of PFMF is essential to diagnose and measure the treatment outcomes. One of the basic methods for assessing PFMF is digital palpation. It is widely used in clinical practice [11]. Thanks to the use of the Oxford Score and PERFECT Scheme, it is possible to assess the strength of muscle contraction and its quality, endurance and reflex activation [20]. The International Continence Society indicates the importance of using objective evaluation methods [16]. Results of this study show that manometry, USG and EMG are common and reliable tools to assess PFM function.

Using manometry, we can measure the effect of PFM activation on the change in vaginal pressure and thus evaluate the MVC and endurance. EMG measures the electrical activity of muscles. In research, it is used to assess the strength, endurance and speed of PFM contraction. US can be performed transabdominally, transperineally and endovaginally. The basic measurement is the movement of the pelvic floor structures during contraction,
coughing, Valsalva maneuver or straining. It allows evaluating if the muscle activation is correct.

The most significant advantage of the described methods is the obtained results and their reference to norms. This allows for the assessment of pelvic floor muscle function and the selection of appropriate treatment methods. Subsequently, through the repeatability of measurements, progress can be monitored. In studies, the strength of muscle contractions measured with the manometer is frequently compared and shows a high level of agreement when compared to the Oxford Scale [89, 90]. Additionally, Angelo et al. [91] created a 5-level classification of muscle strength based on their results, providing ranges of manometric results. Data from EMG electrodes can be disturbed by internal or external factors [92]. To analyze and compare the results, normalization is necessary to reduce interference. The most used method is measuring MVC (maximum voluntary contraction), where patients are instructed to perform three MVCs, and the highest recorded value is chosen [93]. Procedures for assessing pelvic floor muscle function in USG examinations are well-documented [94–96].

An essential element in assessing pelvic floor muscle function is the tone of the pelvic floor muscles because excessive muscle tension can affect pelvic floor muscle function [97]. Electromyography can be used to assess greater tone by evaluating the inability to relax after contraction or greater EMG activity at rest after contraction [98]. In measurements with a dynamometer and manometer at rest, the pressure of the tissues surrounding the device is measured. Therefore, it is important to individually adjust the dynamometer aperture [99] and manometry pressure [100].

These methods enable advanced assessment of PFMF and are available in clinical practice. It is necessary to be aware of the possibilities offered by these devices in order to choose the ones that suit clinician’s needs.

Limitations of the study

The limitation of this systematic review is the inclusion of English-language articles in which participants suffered from urinary incontinence and included evaluation of pelvic floor muscle function using objective tools that can be applied in clinical practice. An additional limitation is the use of only one database and the consideration of only interventional studies. Every effort was made to ensure that the articles were correctly qualified for the review.
CONCLUSIONS

There are several types of objective tools for assessing PFMF giving different measurements. The most used method was manometry, EMG and USG. When taking measurements, it is also important to choose the correct position in which they are performed. The use of objective tools to assess the function of the PFM and obtaining quantitative and/or qualitative data allows for precise diagnosis and monitoring the progress of treatment and rehabilitation.

Article information and declarations

Author contributions

DM — concept, assumptions, study design, acquisition of data, analysis and interpretation of data, article draft, revised article critically, approved the final manuscript; UH, KSW — concept, analysis and interpretation of data, revised article critically, approved the final manuscript.

Conflicts of interest

The authors declare that they have no competing interests.

Supplementary material

None.
REFERENCES


Figure 1. PRISMA flow diagram of studies selected for systematic review
Table 1. Articles using manometry as pelvic floor muscle assessment method

<table>
<thead>
<tr>
<th>Author</th>
<th>Study design</th>
<th>n</th>
<th>Study group</th>
<th>Method</th>
<th>Measurement</th>
<th>PFM property</th>
<th>Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pereira et al. [35]</td>
<td>Randomized controlled pilot study</td>
<td>49</td>
<td>UI</td>
<td>Pressure perineometer (vaginal probe)</td>
<td>Pressure measured in cmH₂O</td>
<td>Strength</td>
<td>Supine, with hip and knee flexion</td>
</tr>
<tr>
<td>Pereira et al. [36]</td>
<td>Randomized, controlled study</td>
<td>45</td>
<td>UI</td>
<td>Pressure perineometer (vaginal probe)</td>
<td>Pressure measured in cmH₂O</td>
<td>Strength</td>
<td>Supine, with hip and knee flexion</td>
</tr>
<tr>
<td>Lee et al. [37]</td>
<td>Prospective, single-arm study</td>
<td>106</td>
<td>UI</td>
<td>Pressure perineometer (extracorporeal biofeedback)</td>
<td>Pressure measured in cmH₂O</td>
<td>Strength</td>
<td>Sitting</td>
</tr>
<tr>
<td>Gameiro et al. [38]</td>
<td>N/a</td>
<td>51</td>
<td>UI</td>
<td>Pressure perineometer (vaginal probe)</td>
<td>Pressure measured in cmH₂O</td>
<td>Strength and endurance</td>
<td>Supine</td>
</tr>
<tr>
<td>Vural et al. [39]</td>
<td>Prospective controlled study</td>
<td>22</td>
<td>SUI</td>
<td>Perineometer (vaginal probe)</td>
<td>N/a</td>
<td>Strength</td>
<td>N/a</td>
</tr>
<tr>
<td>Hirakawa et al. [40]</td>
<td>Randomized controlled trial</td>
<td>46</td>
<td>UI</td>
<td>Pressure perineometer (vaginal probe)</td>
<td>Pressure measured in cmH₂O</td>
<td>Strength</td>
<td>N/a</td>
</tr>
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<td>Ahlund et al. [41]</td>
<td>Randomized controlled trial</td>
<td>100</td>
<td>SUI</td>
<td>Pressure perineometer (vaginal probe)</td>
<td>Pressure measured in cmH₂O</td>
<td>Strength and endurance</td>
<td>N/a</td>
</tr>
<tr>
<td>Kaya et al. [42]</td>
<td>Randomized controlled trial</td>
<td>108</td>
<td>SUI, UUI or MUI</td>
<td>Perineometer (vaginal probe)</td>
<td>Arbitrary scale of 0–12</td>
<td>Strength</td>
<td>Supine, with hip and knee flexion</td>
</tr>
<tr>
<td>Gwang Suk et al. [43]</td>
<td>One group pretest–post-test</td>
<td>55</td>
<td>UI</td>
<td>Pressure perineometer (vaginal probe)</td>
<td>Pressure measured in cmH₂O</td>
<td>Strength and endurance</td>
<td>N/a</td>
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<tr>
<td>Fitz et al. [44]</td>
<td>Randomized controlled trial</td>
<td>72</td>
<td>UI</td>
<td>Pressure perineometer (vaginal probe)</td>
<td>Pressure measured in cmH₂O</td>
<td>Strength</td>
<td>N/a</td>
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<tr>
<td>Ozlu et al. [45]</td>
<td>Prospectively randomized, controlled</td>
<td>53</td>
<td>SUI</td>
<td>Pressure perineometer (vaginal probe)</td>
<td>Pressure measured in cmH₂O</td>
<td>Strength</td>
<td>Supine, with hip and knee flexion</td>
</tr>
<tr>
<td>Trial Description</td>
<td>Sample Size</td>
<td>Incontinence Type</td>
<td>Measurement Device</td>
<td>Measurement Units</td>
<td>Measurement Parameters</td>
<td>Position</td>
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<tr>
<td>Figueiredo et al. [46]</td>
<td>Randomized controlled and pragmatic clinical trials</td>
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<td>SUI</td>
<td>Pressure perineometer (vaginal probe)</td>
<td>Pressure measured in cmH₂O</td>
<td>Strength</td>
<td>N/a</td>
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<tr>
<td>Belushi et al. [47]</td>
<td>Prospective, single-blinded, randomized, controlled, two-parallel group clinical trial</td>
<td>73</td>
<td>SUI</td>
<td>Pressure perineometer (vaginal probe)</td>
<td>Pressure measured in cmH₂O</td>
<td>Strength</td>
<td>Supine, with hip and knee flexion</td>
</tr>
<tr>
<td>Jose-Vaz et al. [48]</td>
<td>Assessor-blinded randomized controlled trial</td>
<td>90</td>
<td>UI</td>
<td>Pressure perineometer (vaginal probe)</td>
<td>Pressure measured in cmH₂O</td>
<td>Strength</td>
<td>N/a</td>
</tr>
<tr>
<td>Orhan et al. [49]</td>
<td>Randomized controlled trial</td>
<td>48</td>
<td>UI</td>
<td>Pressure perineometer (vaginal probe)</td>
<td>Pressure</td>
<td>Strength and endurance</td>
<td>N/a</td>
</tr>
<tr>
<td>Bezerra et al. [50]</td>
<td>Randomized controlled trial</td>
<td>32</td>
<td>MUI</td>
<td>Pressure perineometer (vaginal probe)</td>
<td>Pressure measured in cmH₂O</td>
<td>Strength</td>
<td>Lithotomy position</td>
</tr>
<tr>
<td>Marques et al. [51]</td>
<td>Randomized controlled trial</td>
<td>47</td>
<td>SUI</td>
<td>Pressure perineometer (vaginal probe)</td>
<td>Pressure measured in cmH₂O</td>
<td>Strength</td>
<td>Supine, with hip and knee flexion</td>
</tr>
<tr>
<td>Hwang et al. [52]</td>
<td>N/a</td>
<td>34</td>
<td>SUI</td>
<td>Pressure perineometer (vaginal probe)</td>
<td>Pressure measured in mmH₂O</td>
<td>Strength, power (speed), endurance</td>
<td>Supine, with hip and knee flexion</td>
</tr>
<tr>
<td>Celiker Tosun et al. [53]</td>
<td>Prospective randomized controlled clinical trial</td>
<td>130</td>
<td>SUI and MUI</td>
<td>Pressure perineometer (vaginal probe)</td>
<td>Pressure measured in cmH₂O</td>
<td>Strength</td>
<td>Supine, with hip and knee flexion</td>
</tr>
<tr>
<td>Knorst et al. [54]</td>
<td>Quasi-experimental before-and-after study</td>
<td>82</td>
<td>UI</td>
<td>Pressure perineometer (vaginal probe)</td>
<td>Pressure measured in cmH₂O</td>
<td>Strength</td>
<td>N/a</td>
</tr>
</tbody>
</table>

MUI — mixed urinary incontinence; PFM — pelvic floor muscle; SUI — stress urinary incontinence; UI — urinary incontinence
### Table 2. Articles using electromyography as pelvic floor muscle assessment method

<table>
<thead>
<tr>
<th>Author</th>
<th>Study design</th>
<th>n</th>
<th>Study group</th>
<th>Method</th>
<th>Measurement</th>
<th>PFM property</th>
<th>Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Huebner et al. [55]</td>
<td>Three-arm randomized controlled trial</td>
<td>108</td>
<td>SUI and MUI</td>
<td>Intravaginal EMG</td>
<td>Electrical activity measured in microvolts μV</td>
<td>Contractility of PFM</td>
<td>Supine, with hip and knee flexion</td>
</tr>
<tr>
<td>Bakar et al. [56]</td>
<td>N/a</td>
<td>13</td>
<td>SUI</td>
<td>Intravaginal EMG</td>
<td>Electrical activity measured in microvolts μV</td>
<td>Activity at rest and during a MVC</td>
<td>Supine, with hip and knee flexion</td>
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<tr>
<td>Luginbuehl et al. [57]</td>
<td>Randomized cross-over trial</td>
<td>50</td>
<td>SUI</td>
<td>Intravaginal EMG</td>
<td>Electrical activity</td>
<td>MVC</td>
<td>Standing</td>
</tr>
<tr>
<td>Burti et al. [58]</td>
<td>Prospective case-control clinical trial</td>
<td>30</td>
<td>SUI</td>
<td>Intravaginal surface EMG</td>
<td>Electrical activity measured in microvolts μV</td>
<td>MVC and endurance</td>
<td>N/a</td>
</tr>
<tr>
<td>Chmielewska et al. [59]</td>
<td>N/a</td>
<td>31</td>
<td>SUI</td>
<td>Intravaginal EMG</td>
<td>Electrical activity measured in microvolts μV</td>
<td>MVC</td>
<td>Supine, with hip and knee flexion</td>
</tr>
<tr>
<td>Bertotto et al. [60]</td>
<td>Randomized controlled trial</td>
<td>49</td>
<td>SUI</td>
<td>Intravaginal EMG</td>
<td>Electrical activity measured in microvolts μV</td>
<td>MVC and endurance</td>
<td>Lithotomy position</td>
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<tr>
<td>Pintos-Díaz et al. [61]</td>
<td>Non-randomized controlled trial</td>
<td>38</td>
<td>UI</td>
<td>Surface EMG</td>
<td>Electrical activity measured in microvolts μV</td>
<td>MVC and endurance</td>
<td>Supine, with hip and knee flexion</td>
</tr>
<tr>
<td>Ballmer et al. [62]</td>
<td>Secondary data analysis</td>
<td>22</td>
<td>SUI</td>
<td>Intravaginal EMG</td>
<td>Electrical activity measured in microvolts μV</td>
<td>MVC and FVC</td>
<td>Standing</td>
</tr>
<tr>
<td>Junginger et al.</td>
<td>Randomized controlled trial</td>
<td>68</td>
<td>UI</td>
<td>EMG electrode</td>
<td>Electrical activity</td>
<td>MVC and FVC</td>
<td>Standing</td>
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<tr>
<td>Alves et al. [64]</td>
<td>Randomized controlled trial</td>
<td>46</td>
<td>UI</td>
<td>Intravaginal EMG</td>
<td>Electrical activity measured in microvolts µV</td>
<td>MVC</td>
<td>Supine, with hip and knee flexion</td>
</tr>
</tbody>
</table>

**EMG** — electromyography; **FVC** — fast voluntary contractions; **MUI** — mixed urinary incontinence; **MVC** — maximum voluntary contraction; **PFM** — pelvic floor muscle; **SUI** — stress urinary incontinence; **UI** — urinary incontinence
<table>
<thead>
<tr>
<th>Author</th>
<th>Study design</th>
<th>n</th>
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<th>Method</th>
<th>Measurement</th>
<th>PFM property</th>
<th>Position</th>
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<tr>
<td>Romero-Cullerés et al.</td>
<td>Test-retest reliability study</td>
<td>104</td>
<td>SUI</td>
<td>Intravaginal dynamometric speculum</td>
<td>Force measured in Newtons</td>
<td>Strength</td>
<td>Lithotomy position</td>
</tr>
<tr>
<td>Mercier et al. [66]</td>
<td>Case study</td>
<td>1</td>
<td>SUI</td>
<td>Intravaginal dynamometric speculum</td>
<td>Force measured in Newtons</td>
<td>Passive forces</td>
<td>N/a</td>
</tr>
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<td>Romero-Cullerés et al.</td>
<td>Test-retest reliability study</td>
<td>122</td>
<td>UI</td>
<td>Intravaginal dynamometric speculum</td>
<td>Force measured in Newtons</td>
<td>Strength</td>
<td>Lithotomy position</td>
</tr>
<tr>
<td>Mercier et al. [68]</td>
<td>Secondary data analysis</td>
<td>29</td>
<td>UI</td>
<td>Intravaginal dynamometric speculum</td>
<td>Force measured in Newtons</td>
<td>Passive forces, speed of relaxation</td>
<td>Supine, with hip and knee flexion</td>
</tr>
<tr>
<td>Chamochumbi et al. [69]</td>
<td>N/a</td>
<td>16</td>
<td>SUI</td>
<td>Intravaginal dynamometric speculum</td>
<td>Force measured in Newtons</td>
<td>Active and passive forces</td>
<td>Lithotomy position</td>
</tr>
</tbody>
</table>

PFM — pelvic floor muscle; SUI — stress urinary incontinence; UI — urinary incontinence
<table>
<thead>
<tr>
<th>Author</th>
<th>Study design</th>
<th>n</th>
<th>Study group</th>
<th>Method</th>
<th>Measurement</th>
<th>PFM property</th>
<th>Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>de Abreu Etienne et al. [70]</td>
<td>Pilot study</td>
<td>30</td>
<td>SUI or MUI</td>
<td>Transperineal ultrasound with a curved 3.5 MHz transducer</td>
<td>Angle (degrees) between pubococcygeal muscle lateral bundle</td>
<td>Initial angle at rest, during contraction, at rest after contraction, during straining</td>
<td>Lithotomy position</td>
</tr>
<tr>
<td>Chen et al. [71]</td>
<td>N/a</td>
<td>36</td>
<td>SUI</td>
<td>Transperineal ultrasound with an RAB 8–4 MHz transducer</td>
<td>Levator function</td>
<td>Displacement of bladder neck, sagittal hiatal diameter, levator hiatal angle</td>
<td>Supine</td>
</tr>
<tr>
<td>Maher et al. [72]</td>
<td>Prospective pilot study</td>
<td>9</td>
<td>SUI</td>
<td>Transabdominal ultrasound with a curvilinear transducer</td>
<td>Pelvic floor muscle contraction</td>
<td>Cranial encroachment of the PFM on the bladder</td>
<td>Supine or standing position</td>
</tr>
<tr>
<td>McLean et al. [73]</td>
<td>N/a</td>
<td>40</td>
<td>SUI</td>
<td>Transperineal ultrasound 3D mechanical with 6.5–10 MHz curvilinear probe</td>
<td>Position of the pubic symphysis, the bladder, the urethra, and the anorectal angle</td>
<td>Maximal effort cough and maximal effort Valsalva maneuver</td>
<td>Lithotomy position, standing position</td>
</tr>
<tr>
<td>Kim et al. [74]</td>
<td>N/a</td>
<td>625</td>
<td>UI</td>
<td>Transperineal ultrasound with RAB 8–4 MHz transducer</td>
<td>Levator hiatal area</td>
<td>Pelvic floor muscle contraction and Valsalva maneuver</td>
<td>Supine</td>
</tr>
<tr>
<td>Authors</td>
<td>Study Design</td>
<td>Sample Size</td>
<td>Diagnosis</td>
<td>Imaging Method</td>
<td>Findings</td>
<td>Position</td>
<td></td>
</tr>
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<td>-------------------------------------------------------------------------------</td>
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</tr>
<tr>
<td>Czynnyj et al. [75]</td>
<td>A secondary analysis</td>
<td>20</td>
<td>SUI</td>
<td>Transperineal ultrasound with RAB 4–8 MHz curvilinear probe</td>
<td>Motion of the anorectal angle or urethra</td>
<td>Lithotomy</td>
<td></td>
</tr>
<tr>
<td>Yang et al. [76]</td>
<td>N/a</td>
<td>125</td>
<td>SUI</td>
<td>Transvaginal ultrasound with 5.0–9.0 MHz transvaginal probe</td>
<td>Volitional and reflex PFM activity</td>
<td>Lithotomy</td>
<td></td>
</tr>
<tr>
<td>Legendre et al. [77]</td>
<td>Prospective study</td>
<td>10</td>
<td>SUI</td>
<td>Transperineal 3D-ultrasound with 4–8 MHz convex probe</td>
<td>Biometric of the levator ani</td>
<td>N/a</td>
<td></td>
</tr>
<tr>
<td>Junginger et al. [78]</td>
<td>N/a</td>
<td>46</td>
<td>SUI</td>
<td>Transperineal ultrasound with 5–2 MHz curved transducer</td>
<td>Pelvic floor contraction</td>
<td>N/a</td>
<td></td>
</tr>
<tr>
<td>Yang et al. [79]</td>
<td>N/a</td>
<td>208</td>
<td>SUI</td>
<td>Transperineal ultrasound with 5–9 MHz endovaginal probe</td>
<td>Reflex pelvic floor muscle contraction</td>
<td>Supine</td>
<td></td>
</tr>
</tbody>
</table>

MUI — mixed urinary incontinence; MVC — maximum voluntary contraction; PFM — pelvic floor muscle; SUI — stress urinary incontinence; UI — urinary incontinence; USG — ultrasonography
Table 5. Articles using accelerometry as pelvic floor muscle assessment method

<table>
<thead>
<tr>
<th>Author</th>
<th>Study design</th>
<th>n</th>
<th>Study group</th>
<th>Method</th>
<th>Measurement</th>
<th>PFM property</th>
<th>Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rosenblatt et al. [34]</td>
<td>Prospective, single-center, open-label study</td>
<td>23</td>
<td>SUI or MUI</td>
<td>Accelerometer</td>
<td>Movement (lift or descent) of the PFM in degrees</td>
<td>Pelvic floor angle, measurements at rest, with strain, and with PFM contraction, measured by cueing each participant to give maximal effort to lift and squeeze PFM</td>
<td>N/a</td>
</tr>
</tbody>
</table>

MUI — mixed urinary incontinence; PFM — pelvic floor muscle; SUI — stress urinary incontinence
Table 6. Articles using multiple methods of pelvic floor muscle assessment

<table>
<thead>
<tr>
<th>Author</th>
<th>Study design</th>
<th>n</th>
<th>Study group</th>
<th>Method</th>
<th>Measurement</th>
<th>PFM property</th>
<th>Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hung et al. [80]</td>
<td>Single group pretest-posttest</td>
<td>23</td>
<td>SUI</td>
<td>Transperineal ultrasonography 5 MHz curved linear array transducer</td>
<td>Bladder neck position and mobility</td>
<td>Maximal cough, Valsalva maneuver, and a PFM contraction</td>
<td>Lithotomy position</td>
</tr>
<tr>
<td></td>
<td>design</td>
<td></td>
<td></td>
<td>Pressure perineometer (vaginal probe)</td>
<td>Pressure measured in cmH₂O</td>
<td>Strength</td>
<td>Supine, with hip and knee flexion</td>
</tr>
<tr>
<td>Tosun et al. [81]</td>
<td>Prospective controlled study</td>
<td>122</td>
<td>SUI</td>
<td>Pressure perineometer (vaginal probe)</td>
<td>Pressure measured in cmH₂O</td>
<td>Strength</td>
<td>N/a</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Transabdominal ultrasound with a 3.5 MHz curved array transducer</td>
<td>Bladder base movement</td>
<td>PFM contraction</td>
<td>N/a</td>
</tr>
<tr>
<td>Shin et al. [82]</td>
<td>Randomized, controlled and blinded trial</td>
<td>31</td>
<td>SUI</td>
<td>Pressure perineometer (vaginal probe)</td>
<td>Pressure measured in mmHg</td>
<td>Strength</td>
<td>Supine, with hip and knee flexion</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td>Intravaginal EMG</td>
<td>Electrical activity measured in microvolts μV</td>
<td>MVC</td>
<td>N/a</td>
</tr>
<tr>
<td>Baessler et al. [83]</td>
<td>N/a</td>
<td>85</td>
<td>SUI</td>
<td>Intravaginal EMG</td>
<td>Electrical activity measured in microvolts μV</td>
<td>MVC</td>
<td>Standing</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Transperineal ultrasonography 5 MHz curved linear array transducer</td>
<td>Bladder neck and puborectalis muscle position and movements</td>
<td>Valsalva maneuver and straining</td>
<td>Standing</td>
</tr>
<tr>
<td>Cacciari et al. [84]</td>
<td>Secondary data</td>
<td>362</td>
<td>SUI or SUI</td>
<td>Transperineal</td>
<td>Pelvic floor</td>
<td>At rest, during</td>
<td>Supine, with hip</td>
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<tr>
<td>Study</td>
<td>Type</td>
<td>N</td>
<td>Incontinence</td>
<td>Measure 1</td>
<td>Measure 2</td>
<td>Measurement 3</td>
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<td></td>
</tr>
<tr>
<td>Wang et al. [85]</td>
<td>Randomized controlled trial</td>
<td>108</td>
<td>SUI</td>
<td>Surface EMG</td>
<td>Electrical activity measured in microvolts μV</td>
<td>Strength and endurance</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Transperineal ultrasound</td>
<td>Bladder neck mobility</td>
<td>At rest and during Valsalva maneuver</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Supine, with hip and knee flexion</td>
<td></td>
</tr>
</tbody>
</table>

EMG — electromyography; MUI — mixed urinary incontinence; MVC — maximum voluntary contractio; PFM — pelvic floor muscle; SUI — stress urinary incontinence; USG — ultrasonography