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REVIEW PAPER / GYNECOLOGY

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

— 1 (Tab. 6), USG — 10, USG with other methods — 5 (Tab. 6), accelerometry — 1 (Tab. 5).

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_2O [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_2O (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.

Conflict of interest

The authors declare that they have no competing interests.

Supplementary material

None.

REFERENCES

1. Milsom I, Altman D, Cartwright R. Epidemiology of urinary incontinence (UI) and other lower urinary tract symptoms (LUTS), pelvic organ prolapse (POP) and anal (AI) incontinence. In: Abrams P, Cardozo L, Wagg A, Wein A. ed. Incontinence. 6th ed. Health Publications Ltd, Paris 2016: 17–24.

2. Woodley SJ, Lawrenson P, Boyle R, et al. Pelvic floor muscle training for preventing and treating urinary and faecal incontinence in antenatal and postnatal women. Cochrane Database Syst Rev. 2020; 5(5): CD007471, doi: 10.1002/14651858.CD007471.pub4, indexed in Pubmed: 32378735.

3. Milsom I, Gyhagen M. The prevalence of urinary incontinence. Climacteric. 2019; 22(3): 217–222, doi: 10.1080/13697137.2018.1543263, indexed in Pubmed: 30572737.

4. Aoki Y, Brown HW, Brubaker L, et al. Urinary incontinence in women. Nat Rev Dis Primers. 2017; 3: 17042, doi: 10.1038/nrdp.2017.42, indexed in Pubmed: 28681849.

5. EAU Guidelines. Edn. presented at the EAU Annual Congress Amsterdam, 2020. ISBN 978-94-92671-07-3.

6. Stangel-Wojcikiewicz K, Rogowski A, Rechberger T, et al. Urogynecology section of the polish society of gynecologists and obstetricians guidelines on the management of stress urinary incontinence in women. Ginekol Pol. 2021; 92(11): 822–828, doi: 10.5603/GP.a2021.0206, indexed in Pubmed: 34907521.

7. Albrich S, Steetskamp J, Knoechel SL, et al. Assessment of pelvic floor muscle contractility: digital palpation versus 2D and 3D perineal ultrasound. Arch Gynecol Obstet. 2016; 293(4): 839–843, doi: 10.1007/s00404-015-3897-5, indexed in Pubmed: 26408007.

8. Vesting S, Olsen MF, Gutke A, et al. Clinical assessment of pelvic floor and abdominal muscles 3 months post partum: an inter-rater reliability study. BMJ Open. 2021; 11(9): e049082, doi: 10.1136/bmjopen-2021-049082, indexed in Pubmed: 34475166.

9. Pena CC, Bø K, de la Ossa AMP, et al. Are visual inspection and digital palpation reliable methods to assess ability to perform a pelvic floor muscle contraction? An intra-rater study. Neurourol Urodyn. 2021; 40(2): 680–687, doi: 10.1002/nau.24609, indexed in Pubmed: 33476075.

10. Laycock J, Jerwood D. Pelvic floor muscle assessment: the PERFECT scheme. Physiotherapy. 2001; 87(12): 631–642, doi: 10.1016/s0031-9406(05)61108-x.

11. Navarro Brazález B, Torres Lacomba M, de la Villa P, et al. The evaluation of pelvic floor muscle strength in women with pelvic floor dysfunction: a reliability and correlation study. Neurourol Urodyn. 2018; 37(1): 269–277, doi: 10.1002/nau.23287, indexed in Pubmed: 28455942.

12. Silva JB, Sato TO, Rocha APR, et al. "Comparative intra- and inter-rater reliability of maximal voluntary contraction with unidigital and bidigital vaginal palpation and construct validity with Peritron manometer". Neurourol Urodyn. 2019; 39(2): 721–731, doi: 10.1002/nau.24263, indexed in Pubmed: 31873956.

13. Ferreira CH, Barbosa PB, de Oliveira Souza F, et al. Inter-rater reliability study of the modified Oxford Grading Scale and the Peritron manometer. Physiotherapy. 2011; 97(2): 132–138, doi: 10.1016/j.physio.2010.06.007, indexed in Pubmed: 21497247.

14. Barbosa PB, Franco MM, Souza Fd, et al. Comparison between measurements obtained with three different perineometers. Clinics (Sao Paulo). 2009; 64(6): 527–533, doi: 10.1590/s1807-59322009000600007, indexed in Pubmed: 19578656.

15. Riesco ML, Caroci Ad, de Oliveira SM, et al. Perineal muscle strength during pregnancy and postpartum: the correlation between perineometry and digital vaginal palpation. Rev Lat Am Enfermagem. 2010; 18(6): 1138–1144, doi: 10.1590/s0104-11692010000600014, indexed in Pubmed: 21340279.

16. Frawley H, Shelly B, Morin M, et al. An international continence society (ICS) report on the terminology for pelvic floor muscle assessment. Neurourol Urodyn. 2021; 40(5): 1217–1260, doi: 10.1002/nau.24658, indexed in Pubmed: 33844342.

17. El Sayed RF. Magnetic resonance imaging of the female pelvic floor: anatomy overview, indications, and imaging protocols. Radiol Clin North Am. 2020; 58(2): 291–303, doi: 10.1016/j.rcl.2019.11.005, indexed in Pubmed: 32044008.

18. Moher D, Liberati A, Tetzlaff J, et al. PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Med. 2009; 6(7): e1000097, doi: 10.1371/journal.pmed.1000097, indexed in Pubmed: 19621072.

19. Angelo PH, Varella LR, de Oliveira MC, et al. A manometry classification to assess pelvic floor muscle function in women. PLoS One. 2017; 12(10): e0187045, doi: 10.1371/journal.pone.0187045, indexed in Pubmed: 29084229.

20. Bø KL, Sherburn M, et al. Evaluation of female pelvic-floor muscle function and strength. Phys Ther. 2005; 85(3): 269–282, indexed in Pubmed: 15733051.

21. Kerschan-Schindl K, Uher E, Wiesinger G, et al. Reliability of pelvic floor muscle strength measurement in elderly incontinent women. Neurourol Urodyn. 2002; 21(1): 42–47, doi: 10.1002/nau.2099, indexed in Pubmed: 11835423.

22. Hundley AF, Wu JM, Visco AG. A comparison of perineometer to brink score for assessment of pelvic floor muscle strength. Am J Obstet Gynecol. 2005; 192(5): 1583–1591, doi: 10.1016/j.ajog.2004.11.015, indexed in Pubmed: 15902162.

23. Savage A. Handheld biofeedback devices to enhance pelvic floor muscle training. J Pelvic Obst Gynaecol Physio. 2021; 128: 54–67.

24. Herman UA. Prevention and therapy of pelvic floor muscle dysfunction in women using telemedicine. [Doctoral thesis], Cracow 2019.

25. Deegan EG, Stothers L, Kavanagh A, et al. Quantification of pelvic floor muscle strength in female urinary incontinence: A systematic review and comparison of contemporary methodologies. Neurourol Urodyn. 2018; 37(1): 33–45, doi: 10.1002/nau.23285, indexed in Pubmed: 28471486.

26. Keshwani N, McLean L. A differential suction electrode for recording electromyographic activity from the pelvic floor muscles: crosstalk evaluation. J Electromyogr Kinesiol. 2013; 23(2): 311–318, doi: 10.1016/j.jelekin.2012.10.016, indexed in Pubmed: 23218961.

27. Brækken IH, Stuge B, Tveter AT, et al. Reliability, validity and responsiveness of pelvic floor muscle surface electromyography and manometry. Int Urogynecol J. 2021; 32(12): 3267–3274, doi: 10.1007/s00192-021-04881-0, indexed in Pubmed: 34142181.

28. Martinho NM, Marques J, Silva VR, et al. Intra and inter-rater reliability study of pelvic floor muscle dynamometric measurements. Braz J Phys Ther. 2015; 19(2): 97–104, doi: 10.1590/bjpt-rbf.2014.0083, indexed in Pubmed: 25993624.

29. Nunes FR, Martins CC, Guirro EC, et al. Reliability of bidirectional and variable-opening equipment for the measurement of pelvic floor muscle strength. PMR. 2011; 3(1): 21–26, doi: 10.1016/j.pmrj.2010.10.017, indexed in Pubmed: 21257129.

30. Morin M, Gravel D, Ouellet S, et al. Influence of intraabdominal pressure on the validity of pelvic floor dynamometric measurements. Neurourol Urodyn. 2006; 25: 530–1.

31. Kam HA, Yagel S, Eisenberg VH. Ultrasonography in pelvic floor dysfunction. Obstet Gynecol Clin North Am. 2019; 46(4): 715–732, doi: 10.1016/j.ogc.2019.07.006, indexed in Pubmed: 31677751.

32. Dietz HP. Pelvic floor ultrasound: a review. Clin Obstet Gynecol. 2017; 60(1): 58–81, doi: 10.1097/GRF.0000000000000264, indexed in Pubmed: 28005595.

33. Frawley H, Galea M. Even weak pelvic floor muscles lift. Neurourol Urodyn. 2005; 24: 21.

34. Rosenblatt P, McKinney J, Rosenberg RA, et al. Evaluation of an accelerometer-based digital health system for the treatment of female urinary incontinence: a pilot study. Neurourol Urodyn. 2019; 38(7): 1944–1952, doi: 10.1002/nau.24097, indexed in Pubmed: 31310369.

35. Pereira VS, Correia GN, Driusso P. Individual and group pelvic floor muscle training versus no treatment in female stress urinary incontinence: a randomized controlled pilot study. Eur J Obstet Gynecol Reprod Biol. 2011; 159(2): 465–471, doi: 10.1016/j.ejogrb.2011.09.003, indexed in Pubmed: 21962461.

36. Pereira VS, de Melo MV, Correia GN, et al. Vaginal cone for postmenopausal women with stress urinary incontinence: randomized, controlled trial. Climacteric. 2012; 15(1): 45–51, doi: 10.3109/13697137.2011.593211, indexed in Pubmed: 22066898.

37. Lee HaNa, Lee SY, Lee YS, et al. Pelvic floor muscle training using an extracorporeal biofeedback device for female stress urinary incontinence. Int Urogynecol J. 2013; 24(5): 831–838, doi: 10.1007/s00192-012-1943-4, indexed in Pubmed: 23052631.

38. Gameiro MO, Moreira EC, Ferrari RS, et al. A comparative analysis of pelvic floor muscle strength in women with stress and urge urinary incontinence. Int Braz J Urol. 2012; 38(5): 661–666, doi: 10.1590/s1677-55382012000500011, indexed in Pubmed: 23131506.

39. Vural M, Capan N, Karan A, et al. Vaginal cone therapy in patients with stress urinary incontinence. Arch Gynecol Obstet. 2013; 288(1): 99–103, doi: 10.1007/s00404-012-2701-z, indexed in Pubmed: 23291926.

40. Hirakawa T, Suzuki S, Kato K, et al. Randomized controlled trial of pelvic floor muscle training with or without biofeedback for urinary incontinence. Int Urogynecol J. 2013; 24(8): 1347–1354, doi: 10.1007/s00192-012-2012-8, indexed in Pubmed: 23306768.

41. Ahlund S, Nordgren B, Wilander EL, et al. Is home-based pelvic floor muscle training effective in treatment of urinary incontinence after birth in primiparous women? A randomized controlled trial. Acta Obstet Gynecol Scand. 2013; 92(8): 909–915, doi: 10.1111/aogs.12173, indexed in Pubmed: 23672520.

42. Kaya S, Akbayrak T, Gursen C, et al. Short-term effect of adding pelvic floor muscle training to bladder training for female urinary incontinence: a randomized controlled trial. Int Urogynecol J. 2015; 26(2): 285–293, doi: 10.1007/s00192-014-2517-4, indexed in Pubmed: 25266357.

43. Kim GS, Kim EG, Shin KiY, et al. Combined pelvic muscle exercise and yoga program for urinary incontinence in middle-aged women. Jpn J Nurs Sci. 2015; 12(4): 330–339, doi: 10.1111/jjns.12072, indexed in Pubmed: 25705816.

44. Fitz FF, Stüpp L, da Costa TF, et al. Outpatient biofeedback in addition to home pelvic floor muscle training for stress urinary incontinence: a randomized controlled trial. Neurourol Urodyn. 2017; 36(8): 2034–2043, doi: 10.1002/nau.23226, indexed in Pubmed: 28169458.

45. Özlü A, Yıldız N, Öztekin Ö. Comparison of the efficacy of perineal and intravaginal biofeedback assisted pelvic floor muscle exercises in women with urodynamic stress urinary incontinence. Neurourol Urodyn. 2017; 36(8): 2132–2141, doi: 10.1002/nau.23257, indexed in Pubmed: 28345778.

46. Figueiredo VB, Nascimento SL, Martínez RFL, et al. Effects of individual pelvic floor muscle training vs individual training progressing to group training vs group training alone in women with stress urinary incontinence: a randomized clinical trial. Neurourol Urodyn. 2020; 39(5): 1447–1455, doi: 10.1002/nau.24370, indexed in Pubmed: 32353206.

47. Al Belushi ZI, Al Kiyumi MH, Al-Mazrui AA, et al. Effects of home-based pelvic floor muscle training on decreasing symptoms of stress urinary incontinence and improving the quality of life of urban adult Omani women: A randomized controlled single-blind study. Neurourol Urodyn. 2020; 39(5): 1557–1566, doi: 10.1002/nau.24404, indexed in Pubmed: 32483851.

48. Jose-Vaz LA, Andrade CL, Cardoso LC, et al. Can abdominal hypropressive technique improve stress urinary incontinence? an assessor-blinded randomized controlled trial. Neurourol Urodyn. 2020; 39(8): 2314–2321, doi: 10.1002/nau.24489, indexed in Pubmed: 32813928.

49. Orhan C, Akbayrak T, Özgül S, et al. Effects of vaginal tampon training added to pelvic floor muscle training in women with stress urinary incontinence: randomized controlled trial. Int Urogynecol J. 2019; 30(2): 219–229, doi: 10.1007/s00192-018-3585-7, indexed in Pubmed: 29536140.

50. Bezerra LO, de Oliveira MC, da Silva Filho EM, et al. Impact of pelvic floor muscle training isolated and associated with game therapy on mixed urinary incontinence: a randomized controlled trial. Games Health J. 2021; 10(1): 43–49, doi: 10.1089/g4h.2019.0207, indexed in Pubmed: 32716652.

51. Marques SAA, Silveira SR, Pássaro AC, et al. Effect of pelvic floor and hip muscle strengthening in the treatment of stress urinary incontinence: a randomized clinical trial. J Manipulative Physiol Ther. 2020; 43(3): 247–256, doi: 10.1016/j.jmpt.2019.01.007, indexed in Pubmed: 32703614.

52. Hwang UJ, Lee MS, Jung SH, et al. Which pelvic floor muscle functions are associated with improved subjective and objective symptoms after 8 weeks of surface electrical stimulation in women with stress urinary incontinence? Eur J Obstet Gynecol Reprod Biol. 2020; 247: 16–21, doi: 10.1016/j.ejogrb.2020.02.008, indexed in Pubmed: 32058185.

53. Celiker Tosun O, Kaya Mutlu E, Ergenoglu AM, et al. Does pelvic floor muscle training abolish symptoms of urinary incontinence? A randomized controlled trial. Clin Rehabil. 2015; 29(6): 525–537, doi: 10.1177/0269215514546768, indexed in Pubmed: 25142280.

54. Knorst MR, Resende TL, Santos TG, et al. The effect of outpatient physical therapy intervention on pelvic floor muscles in women with urinary incontinence. Braz J Phys Ther. 2013; 17(5): 442–449, doi: 10.1590/S1413-35552012005000117, indexed in Pubmed: 24173346.

55. Huebner M, Riegel K, Hinninghofen H, et al. Pelvic floor muscle training for stress urinary incontinence: a randomized, controlled trial comparing different conservative therapies. Physiother Res Int. 2011; 16(3): 133–140, doi: 10.1002/pri.489, indexed in Pubmed: 20848671.

56. Bakar Y, Cinar Özdemir O, Ozengin N, et al. The use of extracorporeal magnetic innervation for the treatment of stress urinary incontinence in older women: a pilot study. Arch Gynecol Obstet. 2011; 284(5): 1163–1168, doi: 10.1007/s00404-010-1814-5, indexed in Pubmed: 21184090.

57. Luginbuehl H, Lehmann C, Gerber R, et al. Continuous versus intermittent stochastic resonance whole body vibration and its effect on pelvic floor muscle activity. Neurourol Urodyn. 2012; 31(5): 683–687, doi: 10.1002/nau.21251, indexed in Pubmed: 22395850.

58. Burti JS, Hacad CR, Zambon JP, et al. Is there any difference in pelvic floor muscles performance between continent and incontinent women? Neurourol Urodyn. 2015; 34(6): 544–548, doi: 10.1002/nau.22613, indexed in Pubmed: 24756987.

59. Chmielewska D, Stania M, Kucab-Klich K, et al. Electromyographic characteristics of pelvic floor muscles in women with stress urinary incontinence following sEMG-assisted biofeedback training and pilates exercises. PLoS One. 2019; 14(12): e0225647, doi: 10.1371/journal.pone.0225647, indexed in Pubmed: 31790463.

60. Bertotto A, Schvartzman R, Uchôa S, et al. Effect of electromyographic biofeedback as an add-on to pelvic floor muscle exercises on neuromuscular outcomes and quality of life in postmenopausal women with stress urinary incontinence: A randomized controlled trial. Neurourol Urodyn. 2017; 36(8): 2142–2147, doi: 10.1002/nau.23258, indexed in Pubmed: 28508398.

61. Pintos-Díaz MZ, Parás-Bravo P, Alonso-Blanco C, et al. The use of disposable tampons as visual biofeedback in pelvic floor muscle training. Int J Environ Res Public Health. 2019; 16(12), doi: 10.3390/ijerph16122143, indexed in Pubmed: 31212987.

62. Ballmer C, Eichelberger P, Leitner M, et al. Electromyography of pelvic floor muscles with true differential versus faux differential electrode configuration. Int Urogynecol J. 2020; 31(10): 2051–2059, doi: 10.1007/s00192-020-04225-4, indexed in Pubmed: 32067059.

63. Junginger B, Vollhaber H, Baessler K. Submaximal pelvic floor muscle contractions: similar bladder-neck elevation, longer duration, less intra-abdominal pressure. Int Urogynecol J. 2018; 29(11): 1681–1687, doi: 10.1007/s00192-018-3725-0, indexed in Pubmed: 30069729.

64. Alves FK, Riccetto C, Adami DBV, et al. A pelvic floor muscle training program in postmenopausal women: A randomized controlled trial. Maturitas. 2015; 81(2): 300–305, doi: 10.1016/j.maturitas.2015.03.006, indexed in Pubmed: 25862491.

65. Romero-Culleres G, Peña-Pitarch E, Jané-Feixas C, et al. Intra-rater reliability and diagnostic accuracy of a new vaginal dynamometer to measure pelvic floor muscle strength in women with urinary incontinence. Neurourol Urodyn. 2017; 36(2): 333–337, doi: 10.1002/nau.22924, indexed in Pubmed: 26584652.

66. Mercier J, Morin M, Lemieux MC, et al. Pelvic floor muscles training to reduce symptoms and signs of vulvovaginal atrophy: a case study. Menopause. 2016; 23(7): 816–820, doi: 10.1097/GME.0000000000000620, indexed in Pubmed: 27219835.

67. Romero-Culleres G, Peña-Pitarch E, Jané-Feixas C, et al. Reliability and diagnostic accuracy of a new vaginal dynamometer to measure pelvic floor muscle strength. Female Pelvic Med Reconstr Surg. 2020; 26(8): 514–519, doi: 10.1097/SPV.0000000000000796, indexed in Pubmed: 31860565.

68. Mercier J, Morin M, Tang A, et al. Pelvic floor muscle training: mechanisms of action for the improvement of genitourinary syndrome of menopause. Climacteric. 2020; 23(5): 468–473, doi: 10.1080/13697137.2020.1724942, indexed in Pubmed: 32105155.

69. Chamochumbi CCM, Nunes FR, Guirro RRJ, et al. Comparison of active and passive forces of the pelvic floor muscles in women with and without stress urinary incontinence. Rev Bras Fisioter. 2012; 16(4): 314–319, doi: 10.1590/s1413-35552012005000020, indexed in Pubmed: 22499402.

70. de Abreu Etienne M, de Oliveira AL, da Silva Carramão S, et al. Pubococcygeal activity on perineal ultrasound in incontinent women. Int Urogynecol J. 2011; 22(3): 315–320, doi: 10.1007/s00192-010-1251-9, indexed in Pubmed: 20798920.

71. Chen R, Song Y, Jiang Li, et al. The assessment of voluntary pelvic floor muscle contraction by three-dimensional transperineal ultrasonography. Arch Gynecol Obstet. 2011; 284(4): 931–936, doi: 10.1007/s00404-010-1795-4, indexed in Pubmed: 21161256.

72. Maher RM, Caulfield B. A novel externally applied neuromuscular stimulator for the treatment of stress urinary incontinence in women — a pilot study. Neuromodulation. 2013; 16(6): 590–594; discussion 594, doi: 10.1111/j.1525-1403.2012.00509.x, indexed in Pubmed: 23009698.

73. McLean L, Varette K, Gentilcore-Saulnier E, et al. Pelvic floor muscle training in women with stress urinary incontinence causes hypertrophy of the urethral sphincters and reduces bladder neck mobility during coughing. Neurourol Urodyn. 2013; 32(8): 1096–1102, doi: 10.1002/nau.22343, indexed in Pubmed: 23861324.

74. Kim S, Wong V, Moore KH. Why are some women with pelvic floor dysfunction unable to contract their pelvic floor muscles? Aust N Z J Obstet Gynaecol. 2013; 53(6): 574–579, doi: 10.1111/ajo.12133, indexed in Pubmed: 24116976.

75. Czyrnyj CS, Labrosse MR, Graham RB, et al. UROKIN: a software to enhance our understanding of urogenital motion. Ann Biomed Eng. 2018; 46(5): 726–735, doi: 10.1007/s10439-018-1989-7, indexed in Pubmed: 29417352.

76. Yang E, Yang SH, Huang WC, et al. Association of baseline pelvic floor muscle activities with sexual and urinary functions in female stress urinary incontinence. J Sex Med. 2021; 18(10): 1698–1704, doi: 10.1016/j.jsxm.2021.07.013, indexed in Pubmed: 34452865.

77. Legendre G, Gonzalves A, Levaillant JM, et al. Impact of at-home self-rehabilitation of the perineum on pelvic floor function in patients with stress urinary incontinence: Results from a prospective study using three-dimensional ultrasound. J Gynecol Obstet Biol Reprod (Paris). 2016; 45(2): 139–146, doi: 10.1016/j.jgyn.2015.07.001, indexed in Pubmed: 26321621.

78. Junginger B, Seibt E, Baessler K. Bladder-neck effective, integrative pelvic floor rehabilitation program: follow-up investigation. Eur J Obstet Gynecol Reprod Biol. 2014; 174: 150–153, doi: 10.1016/j.ejogrb.2013.12.022, indexed in Pubmed: 24461138.

79. Yang JM, Yang SH, Huang WC, et al. Impact of two reflex pelvic floor muscle contraction patterns on female stress urinary incontinence. Ultraschall Med. 2013; 34(4): 335–339, doi: 10.1055/s-0032-1313206, indexed in Pubmed: 23023456.

80. Hung HC, Hsiao SM, Chih SY, et al. Effect of pelvic-floor muscle strengthening on bladder neck mobility: a clinical trial. Phys Ther. 2011; 91(7): 1030–1038, doi: 10.2522/ptj.20100186, indexed in Pubmed: 21566065.

81. Tosun ÖÇ, Mutlu EK, Tosun G, et al. Do stages of menopause affect the outcomes of pelvic floor muscle training? Menopause. 2015; 22(2): 175–184, doi: 10.1097/GME.0000000000000278, indexed in Pubmed: 25003623.

82. Shin DC, Shin SHo, Lee MMo, et al. Pelvic floor muscle training for urinary incontinence in female stroke patients: a randomized, controlled and blinded trial. Clin Rehabil. 2016; 30(3): 259–267, doi: 10.1177/0269215515578695, indexed in Pubmed: 25862769.

83. Baessler K, Metz M, Junginger B. Valsalva versus straining: There is a distinct difference in resulting bladder neck and puborectalis muscle position. Neurourol Urodyn. 2017; 36(7): 1860–1866, doi: 10.1002/nau.23197, indexed in Pubmed: 28139845.

84. Cacciari LP, Morin M, Mayrand MH, et al. Pelvic floor morphometrical and functional changes immediately after pelvic floor muscle training and at 1-year follow-up, in older incontinent women. Neurourol Urodyn. 2021; 40(1): 245–255, doi: 10.1002/nau.24542, indexed in Pubmed: 33075192.

85. Wang X, Xu X, Luo J, et al. Effect of app-based audio guidance pelvic floor muscle training on treatment of stress urinary incontinence in primiparas: A randomized controlled trial. Int J Nurs Stud. 2020; 104: 103527, doi: 10.1016/j.ijnurstu.2020.103527, indexed in Pubmed: 32058140.

86. Herschorn S. Female pelvic floor anatomy: the pelvic floor, supporting structures, and pelvic organs. Rev Urol. 2004; 6(Suppl 5): S2–SS10, indexed in Pubmed: 16985905.

87. Abrams P, Cardozo L, Wagg A, Wein A. Incontinence 6th Edition. ICI-ICS. International Continence Society, Bristol UK 2017.

88. Frawley HC, Galea MP, Phillips BA, et al. Reliability of pelvic floor muscle strength assessment using different test positions and tools. Neurourol Urodyn. 2006; 25(3): 236–242, doi: 10.1002/nau.20201, indexed in Pubmed: 16299815.

89. Da Roza T, Mascarenhas T, Araujo M, et al. Oxford Grading Scale vs manometer for assessment of pelvic floor strength in nulliparous sports students. Physiotherapy. 2013; 99(3): 207–211, doi: 10.1016/j.physio.2012.05.014, indexed in Pubmed: 23219628.

90. Ferreira CH, Barbosa PB, de Oliveira Souza F, et al. Inter-rater reliability study of the modified Oxford Grading Scale and the Peritron manometer. Physiotherapy. 2011; 97(2): 132–138, doi: 10.1016/j.physio.2010.06.007, indexed in Pubmed: 21497247.

91. Angelo PH, Varella LR, de Oliveira MC, et al. A manometry classification to assess pelvic floor muscle function in women. PLoS One. 2017; 12(10): e0187045, doi: 10.1371/journal.pone.0187045, indexed in Pubmed: 29084229.

92. Adamiak-Godlewska A, Rechberger T. Nowoczesne techniki oceny anatomii i funkcji dna miednicy u kobiet. Prz Menopauzalny. 2012; 4: 259–263, doi: 10.5114/pm.2012.30225.

93. Ribeiro A, Mateus-Vasconcelos E, Silva T, et al. Functional assessment of the pelvic floor muscles by electromyography: is there a normalization in data analysis? A systematic review. Fisioterapia e Pesquisa. 2018; 25(1): 88–99, doi: 10.1590/1809-2950/16559525012018.

94. Sherburn M, Murphy CA, Carroll S, et al. Investigation of transabdominal real-time ultrasound to visualise the muscles of the pelvic floor. Aust J Physiother. 2005; 51(3): 167–170, doi: 10.1016/s0004-9514(05)70023-4, indexed in Pubmed: 16137242.

95. Bø K, Sherburn M, Allen T. Transabdominal ultrasound measurement of pelvic floor muscle activity when activated directly or via a transversus abdominis muscle contraction. Neurourol Urodyn. 2003; 22(6): 582–588, doi: 10.1002/nau.10139, indexed in Pubmed: 12951667.

96. Kelly M, Tan BK, Thompson J, et al. Healthy adults can more easily elevate the pelvic floor in standing than in crook-lying: an experimental study. Aust J Physiother. 2007; 53(3): 187–191, doi: 10.1016/s0004-9514(07)70026-0, indexed in Pubmed: 17725476.

97. van Reijn-Baggen DA, Han-Geurts IJM, Voorham-van der Zalm PJ, et al. Pelvic floor physical therapy for pelvic floor hypertonicity: a systematic review of treatment efficacy. Sex Med Rev. 2022; 10(2): 209–230, doi: 10.1016/j.sxmr.2021.03.002, indexed in Pubmed: 34127429.

98. Naess I, Bø K. Can maximal voluntary pelvic floor muscle contraction reduce vaginal resting pressure and resting EMG activity? Int Urogynecol J. 2018; 29(11): 1623–1627, doi: 10.1007/s00192-018-3599-1, indexed in Pubmed: 29532122.

99. Deegan EG, Stothers L, Kavanagh A, et al. Quantification of pelvic floor muscle strength in female urinary incontinence: A systematic review and comparison of contemporary methodologies. Neurourol Urodyn. 2018; 37(1): 33–45, doi: 10.1002/nau.23285, indexed in Pubmed: 28471486.

100. Bø K, Raastad R, Finckenhagen HB. Does the size of the vaginal probe affect measurement of pelvic floor muscle strength? Acta Obstet Gynecol Scand. 2005; 84(2): 129–133, doi: 10.1111/j.0001-6349.2005.00676.x, indexed in Pubmed: 15683371.

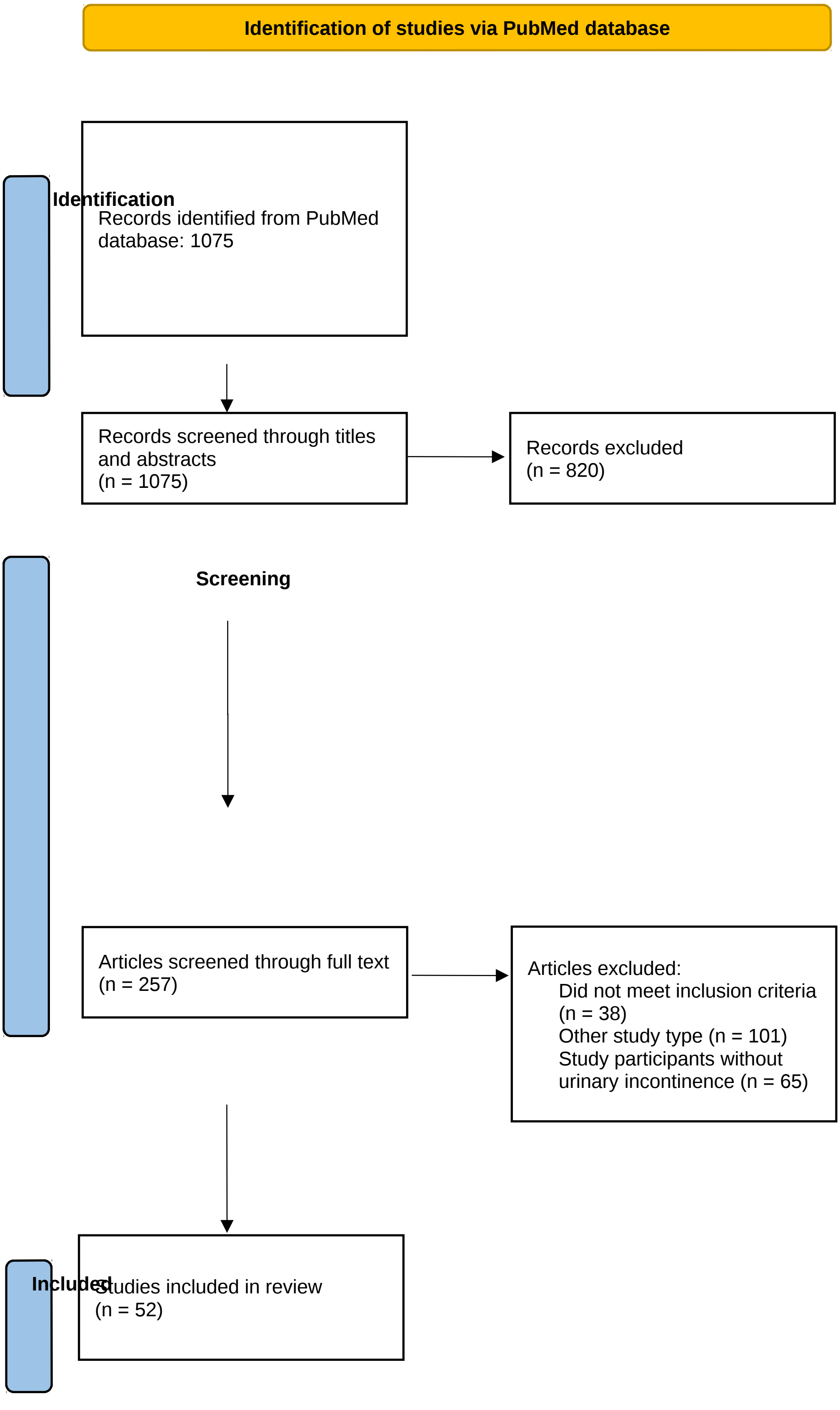

Figure 1. PRISMA flow diagram of studies selected for systematic review

Table 1. Articles using manometry as pelvic floor muscle assessment method

Author	Study design	n	Study group	Method	Measurement	PFM property	Position
Pereira et al. [35]	Randomized controlled pilot study	49	UI	Pressure perineometer (vaginal probe)	Pressure measured in cmH_2O	Strength	Supine, with hip and knee flexion
Pereira et al. [36]	Randomized, controlled study	45	UI	Pressure perineometer (vaginal probe)	Pressure measured in cmH_2O	Strength	Supine, with hip and knee flexion
Lee et al. [37]	Prospective, single-arm study	106	UI	Pressure perineometer (extracorporeal biofeedback)	Pressure measured in cmH_2O	Strength	Sitting
Gameiro et al. [38]	N/a	51	UI	Pressure perineometer (vaginal probe)	Pressure measured in cmH_2O	Strength and endurance	Supine
Vural et al. [39]	Prospective controlled study	22	SUI	Perineometer (vaginal probe)	N/a	Strength	N/a
Hirakawa et al. [40]	Randomized controlled trial	46	UI	Pressure perineometer (vaginal probe)	Pressure measured in cmH_2O	Strength	N/a
Ahlund et al. [41]	Randomized controlled trial	100	SUI	Pressure perineometer (vaginal probe)	Pressure measured in cmH_2O	Strength and endurance	N/a
Kaya et al. [42]	Randomized controlled trial	108	SUI, UUI or MUI	Perineometer (vaginal probe)	Arbitrary scale of 0–12	Strength	Supine, with hip and knee flexion
Gwang Suk et al. [43]	One group pretest–post-test	55	UI	Pressure perineometer (vaginal probe)	Pressure measured in cmH_2O	Strength and endurance	N/a
Fitz et al. [44]	Randomized controlled trial	72	UI	Pressure perineometer (vaginal probe)	Pressure measured in cmH_2O	Strength	N/a
Ozlu et al. [45]	Prospectively randomized, controlled	53	SUI	Pressure perineometer (vaginal probe)	Pressure measured in cmH_2O	Strength	Supine, with hip and knee flexion

	trial						
Figueiredo et al. [46]	Randomized controlled and pragmatic clinical trials	90	SUI	Pressure perineometer (vaginal probe)	Pressure measured in cmH_2O	Strength	N/a
Belushi et al. [47]	Prospective, single-blinded, randomized, controlled, two-parallel group clinical trial	73	SUI	Pressure perineometer (vaginal probe)	Pressure measured in cmH_2O	Strength	Supine, with hip and knee flexion
Jose-Vaz et al. [48]	Assessor-blinded randomized controlled trial	90	UI	Pressure perineometer (vaginal probe)	Pressure measured in cmH_2O	Strength	N/a
Orhan et al. [49]	Randomized controlled trial	48	UI	Pressure perineometer (vaginal probe)	Pressure	Strength and endurance	N/a
Bezerra et al. [50]	Randomized controlled trial	32	MUI	Pressure perineometer (vaginal probe)	Pressure measured in cmH_2O	Strength	Lithotomy position
Marques et al. [51]	Randomized controlled trial	47	SUI	Pressure perineometer (vaginal probe)	Pressure measured in cmH_2O	Strength	Supine, with hip and knee flexion
Hwang et al. [52]	N/a	34	SUI	Pressure perineometer (vaginal probe)	Pressure measured in mmH_2O	Strength, power (speed), endurance	Supine, with hip and knee flexion
Celiker Tosun et al. [53]	Prospective randomized controlled clinical trial	130	SUI and MUI	Pressure perineometer (vaginal probe)	Pressure measured in cmH_2O	Strength	Supine, with hip and knee flexion
Knorst et al. [54]	Quasi-experimental before-and-after study	82	UI	Pressure perineometer (vaginal probe)	Pressure measured in cmH_2O	Strength	N/a

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

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

[63]				attached to a sponge	measured in microvolts µV	endurance	
Alves et al. [64]	Randomized controlled trial	46	UI	Intravaginal EMG	Electrical activity measured in microvolts µV	MVC	Supine, with hip and knee flexion

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 3. Articles using dynamometry as pelvic floor muscle assessment method

Author	Study design	n	Study group	Method	Measurement	PFM property	Position
Romero-Culleres et al. [65]	Test-retest reliability study	104	SUI	Intravaginal dynamometric speculum	Force measured in Newtons	Strength	Lithotomy position
Mercier et al. [66]	Case study	1	SUI	Intravaginal dynamometric speculum	Force measured in Newtons	Passive forces	N/a
Romero-Culleres et al. [67]	Test-retest reliability study	122	UI	Intravaginal dynamometric speculum	Force measured in Newtons	Strength	Lithotomy position
Mercier et al. [68]	Secondary data analysis	29	UI	Intravaginal dynamometric speculum	Force measured in Newtons	Passive forces, strength, speed of relaxation	Supine, with hip and knee flexion
Chamochumbi et al. [69]	N/a	16	SUI	Intravaginal dynamometric speculum	Force measured in Newtons	Active and passive forces	Lithotomy position

PFM — pelvic floor muscle; SUI — stress urinary incontinence; UI — urinary incontinence

Table 4. Articles using ultrasonography as pelvic floor muscle assessment method

Author	Study design	n	Study group	Method	Measurement	PFM property	Position
de Abreu Etienne et al. [70]	Pilot study	30	SUI or MUI	Transperineal ultrasound with a curved 3.5 MHz transducer	Angle (degrees) between pubococcygeal muscle lateral bundle	Initial angle at rest, during contraction, at rest after contraction, during straining	Lithotomy position
Chen et al. [71]	N/a	36	SUI	Transperineal ultrasound with an RAB 8–4 MHz transducer	Levator function	Displacement of bladder neck, sagittal hiatal diameter, levator hiatal angle	Supine
Maher et al. [72]	Prospective pilot study	9	SUI	Transabdominal ultrasound with a curvilinear transducer	Pelvic floor muscle contraction	Cranial encroachment of the PFM on the bladder	Supine or standing position
McLean et al. [73]	N/a	40	SUI	Transperineal ultrasound 3D mechanical with 6.5–10 MHz curvilinear probe	Position of the pubic symphysis, the bladder, the urethra, and the anorectal angle	Maximal effort cough and maximal effort Valsalva maneuver	Lithotomy position, standing position
Kim et al. [74]	N/a	625	UI	Transperineal ultrasound with RAB 8–4 MHz transducer	Levator hiatal area	Pelvic floor muscle contraction and Valsalva maneuver	Supine

Czyrnyj et al. [75]	A secondary analysis	20	SUI	Transperineal ultrasound with RAB 4–8 MHz curvilinear probe	Motion of the anorectal angle or urethra	Pelvic floor muscle maximal contraction	Lithotomy position
Yang et al. [76]	N/a	125	SUI	Transvaginal ultrasound with 5.0–9.0 MHz transvaginal probe	Volitional and reflex PFM activity	Inward clitoral motion and anorectal lift	Lithotomy position
Legendre et al. [77]	Prospective study	10	SUI	Transperineal 3D-ultrasound with 4–8 MHz convex probe	Biometric of the levator ani	Pubovisceral muscle thickness, angle of the urogenital hiatus	N/a
Junginger et al. [78]	N/a	46	SUI	Transperineal ultrasound with 5–2 MHz curved transducer	Pelvic floor contraction	Bladder neck position at rest, during breathing, speaking, coughing and during a voluntary PFM contraction	N/a
Yang et al. [79]	N/a	208	SUI	Transperineal ultrasound with 5–9 MHz endovaginal probe	Reflex pelvic floor muscle contraction	Movement of the pelvic floor structures during coughing	Supine

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

Author	Study design	n	Study group	Method	Measurement	PFM property	Position
Rosenblatt et al. [34]	Prospective, single-center, open-label study	23	SUI or MUI	Accelerometer	Movement (lift or descent) of the PFM in degrees	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	N/a

MUI — mixed urinary incontinence; PFM — pelvic floor muscle; SUI — stress urinary incontinence

Table 6. Articles using multiple methods of pelvic floor muscle assessment

Author	Study design	n	Study group	Method	Measurement	PFM property	Position
Hung et al. [80]	Single group pretest-posttest design	23	SUI	Transperineal ultrasonography 5 MHz curved linear array transducer	Bladder neck position and mobility	Maximal cough, Valsalva maneuver, and a PFM contraction	Lithotomy position
				Pressure perineometer (vaginal probe)	Pressure measured in cmH_2O	Strength	Supine, with hip and knee flexion
Tosun et al. [81]	Prospective controlled study	122	SUI	Pressure perineometer (vaginal probe)	Pressure measured in cmH_2O	Strength	N/a
				Transabdominal ultrasound with a 3.5 MHz curved array transducer	Bladder base movement	PFM contraction	N/a
Shin et al. [82]	Randomized, controlled and blinded trial	31	SUI	Pressure perineometer (vaginal probe)	Pressure measured in mmHg	Strength	Supine, with hip and knee flexion
				Intravaginal EMG	Electrical activity measured in microvolts μV	MVC	N/a
Baessler et al. [83]	N/a	85	SUI	Intravaginal EMG	Electrical activity measured in microvolts μV	MVC	Standing
				Transperineal ultrasonography 5 MHz curved linear array transducer	Bladder neck and puborectalis muscle position and movements	Valsalva maneuver and straining	Standing
Cacciari et al. [84]	Secondary data	362	SUI or	Transperineal	Pelvic floor	At rest, during	Supine, with hip

	analysis		MUI	ultrasound with 3–5 MHz curvilinear three-dimensional (3D)/4D probe or with a 2–6 MHz curvilinear 3D/4D probe	morphometry: levator hiatal area, bladder neck and pelvic floor muscles	MVC, during a single cough	and knee flexion
				Montreal dynamometer	Force measured in Newtons	Maximal vaginal aperture (mm), strength, speed of contraction, speed of relaxation	Supine, with hip and knee flexion
Wang et al. [85]	Randomized controlled trial	108	SUI	Surface EMG	Electrical activity measured in microvolts μV	Strength and endurance	Supine, with hip and knee flexion
				Transperineal ultrasound	Bladder neck mobility	At rest and during Valsalva maneuver	Supine, with hip and knee flexion

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