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REVIEW

Pelvic floor muscle training for prevention and treatment of urinary incontinence during pregnancy and after childbirth and its effect on urinary system and supportive structures assessed by objective measurement techniques

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Abstract

Purpose During the second and the third trimesters of pregnancy and in the first 3 months following childbirth, about one-third of women experience urinary incontinence (UI). During pregnancy and after delivery, the strength of the pelvic floor muscles may decrease following hormonal and anatomical changes, facilitating musculoskeletal alterations that could lead to UI. Pelvic floor muscle training (PFMT) consists in the repetition of one or more sets of voluntary contractions of the pelvic muscles. By building muscles volume, PFMT elevates the pelvic floor and the pelvic organs, closes the levator hiatus, reduces pubovisceral length and elevates the resting position of the bladder. Objective of this review is to evaluate the efficacy of PFMT for prevention and treatment of UI during pregnancy and after childbirth and its effect on urinary system and supportive structures assessed by objective measurement techniques.

Methods The largest medical information databases (Medline–Pubmed, EMBASE, Lilacs, Cochrane Library and Physiotherapy Evidence Database) were searched using the medical subject heading terms "pelvic floor muscle training", "prevention", "urinary incontinence", "urinary stress incontinence", "objective measurement techniques", "pregnancy, "exercise", "postpartum" and "childbirth" in different combinations.

Results and conclusions Overall, the quality of the studies was low. At the present time, there is insufficient evidence to state that PFMT is effective in preventing and treating UI during pregnancy and in the postpartum. However, based on the evidence provided by studies with large sample size, well-defined training protocols, high adherence rates and close follow-up, a PFMT program following general strength-training principles can be recommended both during pregnancy and in the postnatal period.

Keywords Childbirth · Urinary incontinence · Pelvic floor muscle training · Pregnancy · Objective measurement technique

Background

During the second and the third trimesters of pregnancy and in the first 3 months following childbirth, about one-third of women experience urinary incontinence (UI), which is the most common symptom associated with pelvic floor dysfunction [1]. During pregnancy and after delivery, the strength of the pelvic floor muscle (PFM) may decrease following hormonal and anatomical changes (both in the position of the pelvis and in the shape of the PFM), facilitating musculoskeletal alterations that could lead to UI. It is estimated that > 300% PFM strain is necessary for vaginal childbirth [2] and such effort exceeds the physiological limit that striated muscles can sustain, predisposing to muscles injuries. Indeed, several studies report that 20–26% of women show major injuries to the PFM after vaginal delivery (evaluated with ultrasound and MRI) [3–5]. Therefore, it seems plausible to compare vaginal delivery to a major sport injury. In the daily practice, more attention should be paid for prevention and treatment of its possible sequelae.

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Urinary incontinence

According to the International Continence Society, UI is "a complaint of any involuntary leakage of urine" [6] and represents a common problem that deeply impacts the quality of life. The most common types of UI among women are:

(i) *stress urinary incontinence (SUI)* unintentional urine leakage that happens when a physical movement or activity (e.g., sneezing, coughing, running, heavy lifting, childbirth) causes an increase in the abdominal pressure. Generally, it is caused by a loss of anatomical support of the urethrovesical junction (e.g., deficiency of the urethral sphincter, urethral hypermobility) (Fig. 1) and is the most commonly associated with pregnancy and postpartum period;

(ii) *urge urinary incontinence* unintentional urine leakage usually associated with a sudden, strong need to void that can not be postponed. It is generally caused by an "overactive" bladder.

When patients experience both symptoms of stress and urge urinary incontinence, we face the condition that is called mixed urinary incontinence.

The prevalence of UI increases during pregnancy, especially in the second trimester, and gently decreases during the first postpartum year [7]. The overall prevalence (all types of UI) during pregnancy is estimated to be around 58% and SUI affects about 31–42% of women (nulliparous and multiparous) [8]. The percentage of persistence of UI in the first 3 months of the postpartum period is circa 30% [9]. Several factors are associated with postpartum UI, such as parity, age, maternal obesity, chronic lung disease, smocking, duration of the first and second stages of labor, type of delivery (spontaneous or operative), UI before or during pregnancy, high fetal weight and perineal trauma [10].

Effect of pregnancy, labor and type of delivery on PFM

The pathophysiology of UI during pregnancy, delivery and puerperium is multifactorial and still not fully defined. It involves hormonal changes, PFM and connective tissue modifications, bladder neck widening (due to the weight of both the uterus and the growing fetus) and anatomical injuries during delivery [11, 12]. Relaxin is a protein hormone which is produced during pregnancy. It is known to mediate the hemodynamic changes and to soften pelvic muscles and ligaments to prepare for delivery. Consequently, as the fetus grows and the uterus gains weight, PFM weakens [13]. In addition, constipation, which is a frequent complaint during pregnancy, may also increase the pressure on pelvic muscles [14]. During labor, PFM undergoes significant strain and the levator ani (the major muscle of the pelvic floor) has to distend at least five time its original

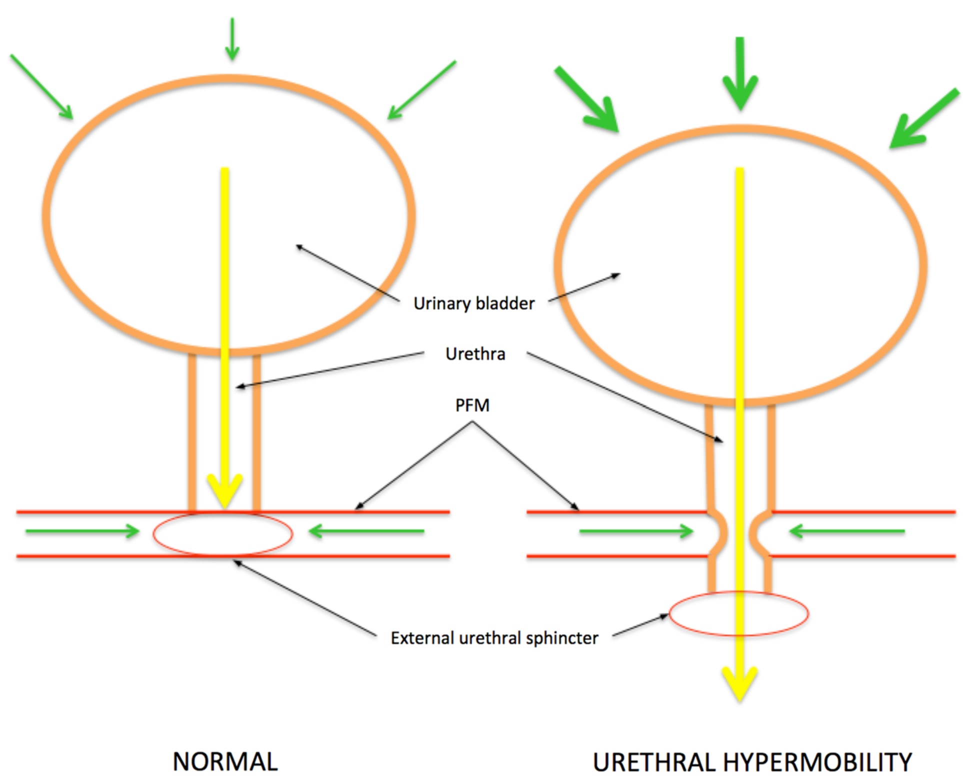

Fig. 1 Urethral hypermobility refers to a condition that causes the urethra to drop below the pelvic floor muscles (PFM). When the support provided by the PFM is lost (e.g., after childbirth due to PFM damage), the bladder neck and the urethra may shift into a lower position, increasing the pressure on the bladder neck. If the pressure on the bladder exceeds the pressure on/in the urethra, leakage occurs

size and to enlarge from 15–25 cm^2 to 60–80 cm^2, allowing the levator hiatus to widen during crowning [15].

A recent study conducted on animal models aimed to identify and quantify any architectural adaptations of PFM during pregnancy and to determine whether these changes occur also outside the pelvic floor. After harvesting pelvic muscles and tibialis anterior samples from mid- and late-pregnant rats and from 4- and 12-week postpartum rats, authors analyzed fiber length, physiologic cross-sectional area (typically used to determine the contraction properties of a muscle), sarcomere length and hydroxyproline content (for the evaluation of intramuscular collagen content). Changes in architectural design and an increase in collagen content were reported only in pelvic floor muscles. In particular, sarcomeres were added in series increasing fiber length. Hence, given the fact that muscle injury is generally related to excessive sarcomere strain, increased fiber length may represent a protective measure since the mechanical deformations that occur during parturition are distributed across a greater number of sarcomeres [16].

Although possible muscle adaptation, vaginal delivery represents a potential major risk factor for the onset of SUI and women who have had a vaginal delivery have a 2.5-fold increased risk when compared to those who had a cesarean section [17]. Several mechanisms may facilitate urine leakage (Fig. 2):

(i) perineal/pelvic injuries associated with vaginal delivery and prolonged abdominal pulling during fetal expulsion may be responsible for stretching and compression of the pelvic nerves, leading to ischemia, neurapraxia or compromised nerve function (pudendal nerve injury) [18];
(ii) childbirth may weaken both the fascial structure and the connective tissue supporting the bladder neck and the urethra, promoting urethral hypermobility [19–21];
(iii) any injuries of the levator ani during delivery may result in fibrosis and subsequentially may lead to a weakened pelvic floor [22].

Vacuum extraction, forceps delivery and perineal lacerations are all associated with pelvic floor disorders (including UI) up to 10 years after first delivery [23]. The effect of episiotomy in the prevention of postnatal UI, however, is still controversial [24]. In some countries, episiotomy represents a routine procedure, but in the majority of the cases, it is performed under obstetrical indication, such as fetal hypoxia and operative vaginal delivery (restricted approach). In a meta-analysis published in 2009, it was found that restricted episiotomy was associated with less perineal lacerations when compared to routine episiotomy, but no difference was found in the incidence of UI after delivery [25]. Similar results have been reported in other studies, which found no difference in UI and pelvic floor disorders incidence 3 months after delivery in primiparous women, suggesting that routine episiotomy does not protect against UI [26, 27]. On the other hand, Chang et al. [28] in a prospective study published in 2011 reported that the incidence of UI was significantly higher in women who had a vaginal delivery with episiotomy when compared to those who had a vaginal delivery without it. At the present time, there is no consensus on the possible protective role of

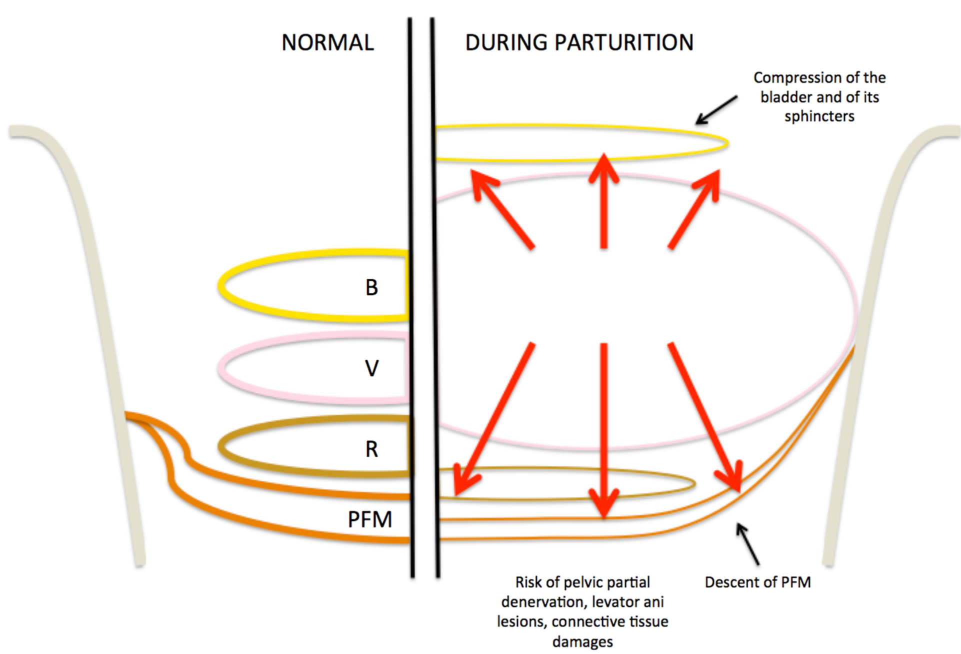

Fig. 2 Effects of parturition on pelvic and urinary structures (*B* urinary bladder; *V* vagina, *R* rectum; *PFM* pelvic floor muscles)

elective/intrapartum cesarean delivery on long-term pelvic floor dysfunction. A recent systematic review on the impact of delivery route on pelvic floor disorders (including genital prolapse and UI) found that vaginal delivery is more likely to be associated with PFM injuries, increased bladder neck mobility and "ballooning" of the levator hiatus when compared to cesarean section [29].

Objective measurement techniques

Several authors tried to investigate the physiological changes of the bladder and the pelvic supportive structure during pregnancy through objective measurement techniques, but results are contradictory.

Urodynamic testing is not clinically useful during pregnancy because urinary symptoms generally begin early in pregnancy and do not correspond to urodynamic findings, but it may be helpful in identifying women who are more susceptible to postpartum pelvic floor disorders. Different investigators reported an increased bladder compliance (up to 1300 cc in the 8 month) and an increased bladder pressure at maximum capacity (ascribed to the enlarged uterus) in pregnant women studied with single- and multi-channel cystometry [30–33]. Pregnant women with SUI were found to have a reduced urethral length with lower closure pressure and diminished sphincter function at rest/stress when compared to continent pregnant women [32–34].

Perineal ultrasound (US) represents a simple, non-invasive, readily available and reproducible tool to evaluate bladder neck position and mobility, and it allows the evaluation of pelvic organs at rest and during straining. SUI is usually associated with post rotational descent of the proximal urethra and bladder neck hypermobility [35–37]. However, bladder neck mobility is also common in asymptomatic nonpregnant nulliparous women, with variable extent (from 4 to 32 mm during coughing and from 2 to 31 mm during Valsalva) [38]. The lack of an internationally accepted US definition for bladder neck hypermobility and the overlap between continent and incontinent US measurements represent major limitations in the use of perineal US in the diagnostic process. Several studies report that during pregnancy, the bladder neck is more caudal with increased mobility during Valsalva [34, 36, 39, 40]. King and Freeman reported that patients with postpartum SUI were more likely to have an increased mobility already antenatally when compared to continent postpartum women [35]. The same results were found by Dietz and Bennet, but no correlation with UI symptoms and US parameters was found [36]. In the study published by Desschers and colleagues, both bladder neck position and mobility returned to antenatal values in most women at 6–10 weeks postpartum [39]. A widened resting angle of the bladder neck is another US feature that could be found during pregnancy. In the study published by Wijma et al. [41], the resting angle of the urethrovesical junction was already significantly increased at 12–16 weeks of pregnancy when compared to nonpregnant values (51.5° vs 44.5°) with further widening during pregnancy (up to 62°), indicating that the dynamic quality of the pelvic supportive structures is already weakened early in pregnancy. Notwithstanding, no correlation with UI was found.

2D and 3/4D translabial/transperineal US represents a highly valuable tool in evaluating levator ani function and morphology with good correlation with MRI in detecting major defects. Although it is a non-invasive, reproducible technique, carrying out the procedure requires a substantial learning curve. Increased hiatal area at rest and on Valsalva along with increased urethral mobility have been observed already in the third trimester of pregnancy by Sheck et al. [42].

Electrophysiologic tests Different studies used electromyography (EMG) and pudendal nerve terminal motor latency (PNTML) to evaluate possible neurogenic damages of PFM after delivery. EMG is generally used to asses the electrical activity of a striated muscle and PNTML measures the nerve conduction and allows the identification of pudendal nerve damage. It is well known that labor and vaginal delivery may cause partial denervation of the pelvic floor, especially in women delivering their first baby [43]. Different studies have observed an increased PNTML after childbirth, which was significantly associated with increased duration of the second stage of labor and high birth weight (> 4 kg), but not with forceps or vacuum delivery [44]. In the study published by Tetzschner et al., PNTML measurements were significantly increased in women with UI and a significant association with vacuum extraction was observed. No association was found with duration of the second stage of labor, birth weight, head circumference and epidural analgesia [45].

Pelvic floor muscle training (PFMT)

Pelvic floor muscle training (PFMT) consists in the repetition of one or more sets of voluntary contractions of the pelvic muscles. Frequency, intensity and progression of the exercises vary, depending on the protocol. At the present time, no standardized PFMT protocol exists. Generally, in a typical PFMT program, more sets of exercises are performed on different days of the week, for at least 6–8 weeks and after this initial phase, a maintenance program should be recommended to ensure long-term effects [46, 47]. The rationale of PFMT in the prevention/treatment of UI lay on several reasons. By building muscles volume, PFMT elevates the PFM and the pelvic organs, closes the levator hiatus, reduces pubovisceral length and elevates the resting position of the bladder. All this morphological changes contribute to improve the structural support of the pelvic floor and, during pregnancy, help in counteracting the increased intra-abdominal pressure caused by the developing fetus. In addition, a trained muscle besides being less prone to injury, has generally a greater reserve of strength so that injury to the muscle itself, or its nerve supply, does not cause sufficient loss of muscle function to reach the threshold where reduced urethral closure pressure results in leakage. Moreover, when damaged, it might be easier to retrain as the neural adaptation and the motor learning have already been assimilated [46]. PFMT may be delivered to women for both prevention and treatment of UI and may be started both during pregnancy and after childbirth.

Materials and methods

The largest medical information databases (Medline–Pubmed, EMBASE, Lilacs, Cochrane Library and Physiotherapy Evidence Database) were searched using the Medical Subject Heading (MeSH) terms "pelvic floor muscle training", "prevention", "urinary incontinence", "urinary stress incontinence", "objective measurement techniques", "pregnancy, "exercise", "postpartum" and "childbirth" in different combinations. The searches were updated regularly (date of last search: August 2018). Both meeting abstracts and full-length papers were included and the relative reference lists were systematically searched. After duplicates removal, the database searches resulted in 839 references. 124 articles were assessed for eligibility after the exclusion of some studies based on title, abstract and inclusion criteria and 41 papers were included in the study (Fig. 3). Recently, a Cochrane review on PFMT for prevention and treatment of urinary and fecal incontinence has been published [10]. Consequently, no meta-analysis was performed and only a narrative summary of results concerning antenatal and postnatal PFMT for prevention and treatment of UI is provided.

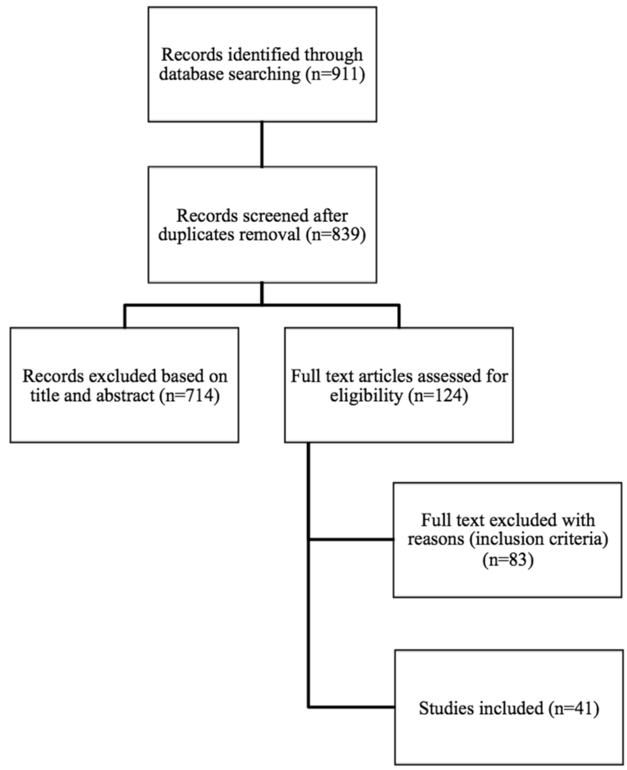

Fig. 3 Flowchart of the search strategy

Results

PFMT during pregnancy

Twenty-five studies on PFMT started during pregnancy were identified. Ten trials were focused on the role of PFMT in the prevention of UI [48–57], four on the role of PFMT in the treatment of UI [58–61] and 11 both in the prevention and in the treatment of UI [48, 51, 62–70].

Concerning the first group of studies, continent pregnant women (both nulliparous and multiparous) were enrolled and PFMT was started at different weeks of gestation, ranging from 14 to 30 weeks of gestation. Different PFMT programs were followed with a significant heterogeneity in length, intensity and frequency of the training period (Table 1). Patients randomized to PFMT group were 62% less likely to experience UI in late pregnancy and in the early postpartum period, and were less likely to report UI 3–6 months after delivery [10]. Seven studies evaluated the severity of UI (episodes of UI, amount of urine leakage) and, although the high variability in the choice of measure, a general trend of a positive effect of PFMT was found [48–50, 52, 54, 56, 57]. In three studies, authors evaluated the continence of patients in late pregnancy and in the early postpartum period through a stress test (positive cough or pad test) and women randomized to PFMT were more likely to be continent when compared to the control group [50, 52, 55]. Concerning the long-term effect of PFMT, two studies evaluated continence at > 5 years and no difference was found in UI prevalence rate [50, 51], suggesting that PFMT is probably not effective at long term. However, these data could also be explained by subsequent pregnancies, stop in the exercises or, as shown in the study published by Morkved, women were performing similar PFMT protocols regardless of which group they had initially been randomized [51]. Only one study reported a general improvement in quality of life in the PFMT group [56].

The role of PFMT in the treatment of UI was evaluated in four studies [58–61]. In all studies, pregnant incontinent women were included (primiparous [60], multiparous [59], not stated [58, 61]). Also in this group of patients, PFMT protocols and follow-up intervals varied (Table 2).

Table 1 Antenatal PFMT protocols for prevention of urinary incontinence

Study	Subjects	Training protocol
Sampselle et al. [48]	$N=72$ primigravid women enrolled at 20-week pregnancy	*PFMT group* 30 contractions at max or near-max intensity from 20-week *Control group* routine care
Stothers [49]	$N=86$ pregnant women	*PFMT group* 2 appointments/months during pregnancy and every 3 months in the postpartum period for 1 year *Control group* no PFMT
Reilly et al. [50]	$N=268$ primigravid continent women enrolled at 20-week pregnancy	*PFMT group* individual PFMT program (between 20 weeks and delivery) with physiotherapist at monthly intervals + additional home exercises (three sets of eight contractions held for 6 s, twice/day). Patients were instructed to contract the PFM when coughing or sneezing *Control group* routine care
Mørkved et al. [51]	$N=301$ primigravid women enrolled at 20-week pregnancy	*PFMT group* 12 weeks of intensive PFMT with physiotherapist + additional home exercises (ten max contractions held for 6 s and, to the last 4, 3–4 fast contractions were added, twice/day) *Control group* general information from general practitioner/midwife. Patients were not discouraged from PFMT
Gorbea et al. [52]	$N=75$ pregnant nulliparous continent women enrolled at 20-week pregnancy	*PFMT group* PFMT program with physiotherapist (ten contractions held for 8 s each followed by 3 fast 1 s contraction with 6 s interval rest) + weekly appointments at the clinic for 8 weeks, then weekly phone calls up to 20 weeks *Control group* patients were requested not to perform PFMT
Gaier et al. [53]	$N=127$ pregnant nulliparous continent women	*PFMT group* 12-week PFMT program during pregnancy (supervised by a physiotherapist and a midwife) *Control group* routine care and general information about pelvic floor muscle exercises
Barakat et al. [54]	$N=80$ pregnant continent women	*PFMT group* 35- to 45-min sessions of moderate physical activity, 3 days/week from 6–9 weeks to 38–39 weeks *Control group* standard care
Kocaoz et al. [55]	$N=102$ pregnant continent women recruited between the 14th and the 20th week of gestation	*PFMT group* three sets of ten contractions at max intensity, held for 10 s, three times/day, from enrollment to postpartum periods *Control group* standard care
Pelaez et al. [56]	$N=169$ pregnant nulliparous continent women recruited between the 10th and the14th week of gestation	*PFMT group* 55- to 60-min group sessions of moderate physical activity (8 min warm-up, 30 min of low impact aerobics, 10 min of PFMT, 7 min of cool down), three times/week. PFMT followed a progression (increasing the number of total contractions to from 8 to 100, with sets of slow and fast contractions) *Control group* usual care (follow up by midwifes + general information about PFMT)
Sangsawang et al. [57]	$N=70$ primigravid continent women recruited between the 20th and the 30th week of gestation	*PFMT group* supervised 6-week PFMT program with verbal instruction and a handbook (1 slow strong contraction held for 10 s followed by one fast contraction for a total of ten times, once/day) + 3 training 45 min session with a midwife during the 6 weeks *Control group* regular prenatal care

PFMT pelvic floor muscle training

Table 2 Antenatal PFMT protocols for treatment of urinary incontinence

Study	Subjects	Training protocol
Skelly et al. [58]	$N=705$ pregnant women with UI	*PFMT group* pelvic floor exercises (not specified) *Control group* conventional care
Woldringh et al. [59]	$N=264$ women with UI enrolled at 22-week pregnancy	*PFMT group* 3 sessions of individual PFMT between week 23 and 30 (aimed to raise patients' awareness of pelvic floor muscles) + 1 session 6 weeks after delivery + written information *Control group* routine care. Two-third of patients received some instruction on PFMT
Dinc et al. [60]	$N=92$ primiparous and multiparous pregnant women with UI enrolled between the 20th and the 34th week o pregnancy	*PFMT group* 3–16 weeks of intensive PFMT program + home exercises between the 20th and the 36th week of pregnancy (3 sets of 10–15 of fast and slow contractions, 2–3 times/day) *Control group* standard care
Cruz et al. [61]	$N=41$ pregnant women with UI enrolled between the 21st and the 26th week of gestation	*PFMT group* PFMT program with physiotherapist (5 or 6 biweekly sessions) *Control group* patients were instructed to perform a similar unsupervised PFMT program at home

PFMT pelvic floor muscle training, *UI* urinary incontinence

No difference was found in the prevalence of UI both in the early and in the late postnatal period [10]. Concerning the quality of life, only Cruz el al. [61] found an improvement in the PFMT group in late pregnancy.

Eleven trials reported PFMT for both prevention and treatment of UI during pregnancy [48, 51, 62–70]. Pregnant women with and without UI were recruited at different weeks of gestation (from 18 to 42 weeks of pregnancy). Different PFMT protocols were followed (Table 3). Overall, patients randomized to the PFMT group had a 26% lower risk to report UI in late pregnancy [10]. In the early and mid-postpartum periods, a significant difference in UI prevalence was found, favoring the PFMT group when compared to the control group. No difference was found in the late postnatal period [10]. Ko et al. [65] reported a statistically significant improvement in quality of life in the PFMT group at different time points (late pregnancy, mid- and late-postpartum). On the other hand, two other studies found no difference [63, 70]. Only one trial used the pad test to evaluate continence after PFMT and no difference was found between the two groups [70]. In addition, the PFMT group was shown not to be superior to the usual care group in terms of symptoms improvement: no differences were found at 3 and 12 months postpartum in frequency and amount of urine leakage [48, 62].

PFMT after childbirth

Fifteen studies on PFMT begun after childbirth were identified: five on the role of PFMT in the treatment of UI [71–75] and ten on the possible effect of PFMT on both prevention and treatment of UI in the postpartum period [76–85].

Concerning the role of PFMT in the treatment of UI in the postnatal period, the training was started 3 months or more after childbirth in all studies. Only incontinent women at 3 months or more after delivery were enrolled. Both primiparous and multiparous women were included. Different PFMT protocols were followed (Table 4). Postnatal PFMT was compared to standard discharge recommendations (including or not general information about PFMT) in all studies, except for two: Dumoulin et al. [73] introduced eight sessions of weekly relaxation massage in the control group and Kim et al. [74] allowed an 8-week unsupervised training. Patients randomized to PFMT group were less likely (about 22%) to experience UI symptoms in the late postnatal period (up to 12 months after delivery) [10]. A general reduction in severity of symptoms and episodes of UI was found, but given the different methods used to evaluate and report these, a solid statement can not be made [10]. Glazener et al. [72] reported a significant improvement in UI-related anxiety, but found no difference in the incidence of UI at 6-year follow-up. Regarding the quality of life, Dumoulin et al. [73] reported a significant improvement in the PFMT group, whereas Kim et al. [74] found no difference between the two groups.

Ten trials on the role of PFMT in both prevention and treatment of UI in the postnatal period were identified. In all studies, continent and incontinent women after spontaneous vaginal delivery were recruited. Chiarelli and Cockburn included only women who had an operative delivery (forceps or ventouse), or with fetal macrosomia (≥ 4000 g) (high-risk population for postpartum UI) [78]. Different PFMT protocols were followed (Table 5), but in three studies, no details were given concerning the training program [76, 77, 79]. In all studies, the control group received conventional discharge

Table 3 Antenatal PFMT protocols for mixed prevention and treatment of urinary incontinence

Study	Subjects	Training protocol
Sampselle et al. [48]	*N* = 72 primigravid women enrolled at 20-week pregnancy	*PFMT group* 30 contractions at max or near-max intensity from 20-weeks *Control group* routine antenatal care
Hughes et al. [62]	*N* = 1169 pregnant nulliparous women enrolled at 20-week pregnancy	*PFMT group* 1 PFMT individual session + 1 PFMT group session with physiotherapist between the 22nd and the 25th week of pregnancy + home training once/day for up to 11 months *Control group* routine antenatal care
Mørkved et al. [51]	*N* = 301 primigravid women enrolled at 20-week pregnancy	PFMT group 12 weeks of intensive PFMT with physiotherapist + additional home exercises (10 max contractions, held for 6 s with 6-s rest + 4 fast contractions Control group general information from general practitioner/midwife. Patients were not discouraged from PFMT
Dokmeci et al. [63]	*N* = 24 pregnant women	*PFMT group* PFMT program during pregnancy (not specified) *Control group* routine antenatal care
Bø et al. [64]	*N* = 105 nulliparous women enrolled at 24-week pregnancy	*PFMT group* 12–16 weeks of aerobic exercises, ×2/week + intensive PFMT + additional home exercises ×3/day (10 contractions at max intensity, held for 6 s with 6 s rest + 4 fast contractions) *Control group* routine antenatal care
Ko et al. [65]	*N* = 300 nulliparous women enrolled between the 16th and the 24th week of pregnancy	*PFMT group* individual supervised PFMT program (1 session/week between the 20th and the 36th week of pregnancy) + additional home exercises (3 sets of 8 contractions held for 6 s, twice/day). Patients were instructed to contract the PFM when coughing or sneezing *Control group* routine antenatal care
Frumenzio et al. [66]	*N* = 100 pregnant women enrolled between the 38th and the 42th week of pregnancy	*PFMT group* 8 week PFMT program (2 weekly supervised sessions of Kegel exercises, repeated daily at home + stretching exercises) *Control group* routine antenatal care
Stafne et al. [67]	*N* = 855 pregnant women enrolled at 20-week pregnancy	*PFMT group* 12 weeks of aerobic exercises, twice/week + additional home exercises 3 times/day (10 contractions at max intensity, held for 6 s with 6-s rest + 4 fast contractions) between the 20th and the 36th week of pregnancy *Control group* general information from general practitioner/midwife and written information. Patients were not discouraged from PFMT
Miquelutti et al. [68]	*N* = 197 pregnant women recruited at ≥ 18 weeks of pregnancy	*PFMT group* regular meetings with physical exercise + general information (once/month up to 30 weeks, twice/month up to 36 weeks, once/week till delivery Control group routine antenatal care
Assis et al. [69]	*N* = 87 pregnant women recruited at 18 weeks of pregnancy	*PFMT group* home exercises, 3 times/day (10 contractions at max intensity, held for 6 s with 6 s rest + 4 fast contractions) evaluated 6 times during pregnancy. Divided into 2 groups: (a) Supervised by a physiotherapist (b) Unsupervised *Control group* routine antenatal care
Fritel et al. [70]	*N* = 282 nulliparous women enrolled between the 20th and the 28th week of pregnancy	*PFMT group* 8 20- to 30-minute supervised PFMT sessions (1 session/week) between the 24th and the 36th week of pregnancy + written information on pelvic floor anatomy and pelvic floor contraction exercises. Patients were encouraged to perform daily muscle exercises *Control group* written information on pelvic floor anatomy and pelvic floor contraction exercises

PFMT pelvic floor muscle training

Table 4 Postnatal PFMT protocols for treatment of urinary incontinence

Study	Subjects	Training Protocol
Wilson and Herbison [71]	$N=230$ patients recruited at 3-months postpartum	*PFMT group* 80-100 fast/slow contractions a day (8–10 sessions/day), followed up at 3, 4, 6 and 9 months after delivery. Instructions were given by a physiotherapist and a perineometer was used to teach awareness of voluntary pelvic floor muscle contraction. Patients were divided into 3 groups: (a) only PFMT (b) trained with vaginal cones 15 min/day, (c) both a and b *Control group* standard postnatal exercises
Glazener et al. [72]	$N=747$ patients recruited at 3 months postpartum	*PFMT group* 80–100 fast/slow contractions a day (8–10 sessions/day), followed up at 5, 7 and 9 months after delivery. If necessary bladder training at 7 and 9 months *Control group* no intervention
Dumoulin et al. [73]	$N=64$ patients recruited at 3 months or more after their last delivery	*PFMT group* divided into 2 groups: (a) multimodal pelvic floor rehabilitation (8 weekly sessions of 15-min electrical stimulation of the pelvic floor muscle + 25 min PFMT with biofeedback + home exercise program 5 days/week), (b) multimodal pelvic floor rehabilitation with abdominal muscle training (8 weekly sessions of 15-min electrical stimulation of the pelvic floor muscle + 30 min of deep abdominal muscle training) *Control group* 8 weekly sessions of relaxation massage
Kim et al. [74]	$N=20$ postpartum women recruited at less than 6 weeks after vaginal delivery	*PFMT group* 8-week supervised PFMT (verbal instructions by a physiotherapist) *Control group* 8-week unsupervised PFMT
Ahlund et al. [75]	$N=100$ primiparous women recruited at 10-16 weeks after vaginal delivery	*PFMT group* 3 fast contractions followed by 3 times 8–12 slow contractions at max intensity, held for 6 s, 7 days/week for 6 months + short lecture of basic anatomy + written information + follow up visit by a midwife every 6 weeks *Control group* written information and general recommendations about PFMT

PFMT pelvic floor muscle training, *UI* urinary incontinence

recommendations (including or not general information about PFMT), except in the study of Meyer et al. [77] where controls were specifically asked not to perform PFMT. No difference was found in UI prevalence up to 6 and 12 months after delivery [10]. Regarding frequency and amount of urine leakage, Sleep et al. [76] found no difference at 3 months postpartum between the two groups, whereas Liu et al. [81] reported less severe UI symptoms in the PFMT group. To evaluate continence during follow-up, some studies used the pad test: Hilde et al. [82] found no difference between the two groups at 6-month follow-up, whereas Wen et al. [80] reported that women randomized to PFMT group were less likely to be incontinent at 12-month follow-up.

Effect of PFMT on the urinary tract and on the pelvic supportive structure assessed by objective measurement techniques

Only few studies have investigated the effect of PFMT on the urinary tract and on the pelvic supportive structure by using objective measurement techniques.

In the study published by King and Freeman [35], 106 healthy nulliparous women were recruited antenatally for the evaluation of bladder neck mobility during pregnancy and in the postpartum period. A frequent US finding in the postnatal period is an increased mobility of the bladder neck with an increased angle of rotation at Valsalva.

Table 5 Postnatal PFMT protocols for mixed prevention and treatment of urinary incontinence

Study	Subjects	Training protocol
Sleep and Grant [76]	*N* = 1800 postpartum women recruited within 24 h after vaginal delivery	*PFMT group* conventional antenatal care + individual PFMT session with midwifery coordinator during hospital stay after delivery + health diary recommending a specific PFMT task every week *Control group* conventional antenatal and postnatal care + PFMT recommended as often as remembered + health diary
Meyer et al. [77]	*N* = 107 primiparous women recruited between the 12th and the 39th week of pregnancy	*PFMT group* 12 PFMT supervised sessions with physiotherapist followed by 20 min of biofeedback and 15 min of electrostimulation (started at 2-month postpartum) *Control group* conventional care, no PFMT recommended
Chiarelli and Cockburn [78]	*N* = 720 postnatal women following operative delivery (forceps or ventouse), or with fetal macrosomia (≥ 4000 g). Recruited at postnatal ward	*PFMT group* individual PFMT + contact with physiotherapist during postnatal ward and 8-week postpartum + techniques to minimize perineal descent + postpartum wound management + use of transversus abdominus contraction + written/verbal information about PFMT *Control group* conventional care
Ewings et al. [79]	*N* = 234 women recruited at postnatal wards	*PFMT group* individual PFMT session with physiotherapist during hospital stay after delivery + 2 PFMT group sessions at 2 and 4 months after delivery *Control group* conventional care + verbal and written information about PFMT
Wen et al. [80]	*N* = 148 women recruited after vaginal delivery	*PFMT group* 6–8 weeks of PFMT *Control group* conventional care
Liu [81]	*N* = 192 primiparous women recruited after vaginal delivery	*PFMT group:* individual PFMT session with experienced midwife + 10 weeks of daily PFMT (15–30-min sets, ×2–3/day) *Control group* conventional care
Hilde et al. [82]	*N* = 175 primiparous women recruited 6 weeks after vaginal delivery	*PFMT group:* individual instructions for pelvic floor muscle contraction + daily PFMT at home (three sets of 8–12 contractions close to maximum) + supervised PFMT group session once a week (starting 6–8 weeks after delivery) *Control group* conventional care + individual instructions for pelvic floor muscle contraction
Kou et al. [83]	*N* = 150 women recruited 6 weeks after vaginal delivery	*PFMT group* 6 weeks of PFMT *Control group* conventional care
Peirce et al. [84]	*N* = 145 postpartum women recruited within 24 h after vaginal delivery with primary third degree tear	*PFMT group:* 3-month period of home biofeedback physiotherapy (the machine was set to 10 contractions, each of 5-s duration, with a 10-s rest between each contraction) *Control group* PFMT general information (standard Kegel exercises for a 5-minute period) provided by senior postpartum midwives or physiotherapists. PFMT was recommended for a 3-month period
Frost et al. [85]	*N* = 72 primiparous women recruited after vaginal delivery	*PFMT group* conventional care + written/verbal information about PFMT *Control group* conventional care

PFMT pelvic floor muscle training, *UI* urinary incontinence

From the first visit at approximately 15–17 weeks, patients were regularly seen every 10 weeks during pregnancy with the last visit at 10–14 weeks postpartum. At each appointment, a perineal US was performed, to measure bladder volume and to evaluate bladder neck movement and rotation at rest and at Valsalva (which was standardized by using a modified sphygmomanometer). During the last visit, data on performance and frequency of postnatal pelvic floor exercises (PFEs) were recorded ("daily PFEs" = > 10 PFEs/day; "sometimes PFEs" = > 10 PFEs 2–3 times/week; "no PFEs" = less frequent than the previous). Persistent occasional SUI after delivery was reported in 18.4% of patients and de novo postpartum SUI in 3.9%, where women who performed postnatal PFEs were less likely to be incontinent ($p = 0.02$). The positive effect of postnatal PFEs on continence was even stronger in patients with antenatal bladder rotation > 10° at Valsalva ($p = 0.003$).

Another study which evaluated the effect of PFMT on bladder neck was recently published by Lekskulchai et al. [86]. In this case, PFMT was performed during pregnancy. 219 pregnant nulliparous women were enrolled and divided into two groups: 108 were randomized for antenatal PFMT (15 contractions, held for 5 s, performed three times after each meal) and 111 received routine antenatal care (control group). Patients were seen two times during pregnancy (second and third trimester) and two times in the postpartum period (at 3 and 6 months postpartum). At each visit, a transperineal US was performed to evaluate bladder neck position at rest and at Valsalva. Although, no significant difference between the two groups was found concerning urinary symptoms both during pregnancy and in the last postpartum visit, at 6 months postpartum the control group showed a greater bladder neck descent when compared to the intervention group ($p = 0.003$). In addition, in the subgroup of patients who had a vaginal delivery, the bladder neck descent was even greater in the control group when compared to women who regularly performed PFMT ($p = 0.006$).

In the study conducted by Dornowski et al. [87], 113 healthy pregnant women with and without SUI were recruited. Patients were divided into three groups: symptomatic women who underwent PFMT (group 1), asymptomatic women who underwent PFMT (group 2) and asymptomatic women without training (group 3). Group-supervised exercise sessions were held three times/week for 6 weeks and included a warm-up phase, an aerobic part with music, strength conditioning exercises and isolated PFM exercises. A surface EMG was performed before and after the 6-week training program. Three EMG measurements were taken: quick flicks (*Q*), static contractions (STA) and BASE/REST baselines before measurement and after 10-s contractions. Group 1 registered in most of the measured parameters the lowest values of PFM electrical activity but, during *Q*, group 1 showed the highest increase after training. If we consider that the electrical activity registered during *Q* reflects the ability of holding urine and/or stopping urine in case of increased intra-abdominal pressure (e.g., sneezing, coughing, running, heavy lifting, etc.), we can assume that PFMT improved the efficiency of PFM contraction.

Discussion

The use of PFMT in the treatment of UI in symptomatic women was first described by Kegel in 1948 [88]. PFMT protocols generally include five stages, all of them being essential and consequential: (i) information, (ii) posture correction, (iii) awareness stage and proprioceptive neuromuscular facilitation, (iv) strengthening programs and (v) perineal blockage before stress [89]. When to start it, how to perform it and by whom PFMT should be given represent three major variables that increase the heterogeneity of the findings and strongly impact the quality of the evidence.

PFMT could be recommended for primary, secondary or tertiary prevention. Primary prevention is done by preventing exposure to hazards and by increasing resistance to diseases or injuries before they occur. Secondary prevention aims to reduce the impact of a disease or injury that has already occurred, by detecting and treating it as soon as possible. Tertiary prevention consists of the treatment of symptoms of an on-going illness or injury that has lasting effects [90]. In the case of UI, given its multifactorial aetiology (compromised neural function, weakened PFM, decreased fascial support), it may be impractical to screen all patients to establish if the disease process is either absent or present, but still asymptomatic and in addition to that, at the present time, some clinical tests have still limited validity. Hence, especially in asymptomatic patients, the obtained results may be a combination of primary and secondary prevention effects. When to start a training protocol and to whom should offer it, still remain two highly debated topics. The 2017 Cochrane review concluded that antenatal PFMT in continent women may help in preventing the onset of UI in late pregnancy and postpartum. The efficacy of PFMT (both antenatal and postnatal) in treating UI remains uncertain [10].

Another specific problem when analyzing the effect of PFMT on UI is the high variability in training protocols, which are also often poorly described. In addition, the lack of a standardized PFMT protocol represents a major limitation to the transferability of study results. Indeed, intensity, frequency and type of exercise are the main factors which will set the effect size [91]. Several trials [50–52, 60, 65, 67, 73] follow the same PFMT protocol proposed by Bo et al. [92]. The authors suggest an "intensive training" that consists in the repetition of three sets of ten contractions at maximum intensity, held for 6 s, 3–4 times/week, which follows the general recommendations for strength training to increase the cross-sectional area of a muscle [93]. This type of protocol has been proven to be effective in reducing genital organs prolapse, too. Indeed, it builds muscle volume and thickness, reduces muscle length, closes the levator hiatus and elevates the resting position of the bladder and consequently also lifts the position of the bladder neck [94]. In different studies on PFMT effects, protocols with 1 weekly supervised session were considered intensive. However, if we consider that athletes who suffered major sport injuries are offered at least 2–3 physiotherapy sessions/week, the attention that is paid to PFM training appears suboptimal. In addition, low-dosage training may be a major reason for dropouts especially in patients who did not achieve satisfactory results and consequently are not motivated for new training periods at optimal dosage. Behavioral support is another aspect that should be taken into account when starting PFMT to ensure adherence, especially if the training protocol implies home exercises. Different adherence support strategies were mentioned in different studies (worksheets and exercise booklets, phone calls, individual tailoring and supervision, group setting), but only nine studies provided data about exercise behavior among patients included in both PFMT and control group [50, 51, 59, 64, 67, 70, 76, 78, 82]. Event if the collection of adherence data in both intervention and control groups could attenuate the difference between the two by changing the exercise behavior, it may also reduce the dropout rates in both groups.

A great heterogeneity was also found in the professional figure that provided the information about PMFT and supervised the training. Physiotherapists, nurses, midwives, obstetricians and general practitioners were generally involved, but no comparison was made between the effects of interventions given by different professionals.

Another topic of debate when discussing the benefits of PMFT is a possible lack of long-term effects. Few studies investigated the effect of PMFT over the years and all failed to demonstrate any benefit of PFMT when compared to the control group [48, 50, 51]. As any training program, it is plausible that its effect will decrease in time if not continued or if not followed by a maintenance program. Generally, muscle strength diminishes at a slower rate than that at which strength is gained through exercise. In a study published in 2004, it was shown that after cessation of exercising, muscle strength decreases by about 5–10% per week and this rate strictly depends on intensity and length of the training period [95]. An effective maintenance training protocol to slow down strength loss usually reduces frequency and volume of the exercises, but preserves the intensity of the previous training [96]. To date, no studies have investigated the minimum training that is necessary to maintain PFM strength after childbirth.

The paucity of studies which assessed the efficacy of PFMT through objective measurement techniques represents also another great limitation. As stated before, several tests still have reduced validity especially when performed during pregnancy, making the evaluation of PFMT effectiveness even harder.

Conclusions

Overall, the quality of the studies was low, mostly owing to poor reporting measurements, different training protocols and dosage in both interventional and control groups (in many cases usual care included also general information about PFMT) and small sample size (which may cause type two error). At the present time, there is insufficient evidence to state that PFMT is effective in preventing and treating UI in late pregnancy and in the postpartum. However, based on the evidence provided by studies with large sample size, well-defined training protocols, high adherence rates and close follow-up, a PFMT program following general strength-training principle like the one proposed by Bo et al. [92] can be recommended both during pregnancy and in the postnatal period. In addition, given the detrimental effect of PFM dysfunction on quality of life, more high-quality randomized controlled trials on the topic are needed and should represent a high priority in the field of urogynecology.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

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