LITERATURE REVIEW

Is pelvic floor muscle training enhanced by supplementary transversus abdominis recruitment in the treatment of female urinary incontinence? A review of the evidence and reflection on current practices

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Abstract
This literature review evaluates whether the treatment of female urinary incontinence (UI) with conventional pelvic floor muscle training (PFMT) is enhanced by the addition of transversus abdominis (TrA) recruitment. The main databases were searched for randomized controlled trials and controlled trials published between 2008 and 2018 (inclusive). Additionally, the National Institute for Health and Care Excellence guidelines, the ResearchGate website and the *Journal of Pelvic, Obstetric and Gynaecological Physiotherapy* were reviewed, and hand-searches of references and grey literature were also performed. Six articles were identified and selected for full critical review. Heterogeneity in dosage, exercise selection, supervision, setting and outcome measures was highlighted. Articles were critically reviewed with a view to understanding the effect of the addition of TrA recruitment to PFMT, and the possibility of identifying the most effective approach when treating women with UI. Five out of six trials reported positive outcomes after adding TrA recruitment to PFMT; however, the superiority of this method over PFMT alone is weakened by the heterogeneity and limitations of the studies evaluated in this literature review.

Keywords: abdominal canister, coactivation approach, pelvic floor muscle training, transversus abdominis, urinary incontinence.

Introduction

Defined as the unintentional release of urine, urinary incontinence (UI) is a condition that affects 25–45% of women worldwide (Hay-Smith *et al.* 2011; Abrams *et al.* 2017). In many cases, it has a significant impact on quality of life (QoL) (Abrams *et al.* 2015). Affecting 35–49% of young and perimenopausal women (Bø *et al.* 2015), stress urinary incontinence (SUI) is the most common form of this condition. It is defined as involuntary leaking during physical stress scenarios such as sneezing or coughing, or while undertaking sporting or impact activities (Haylen *et al.* 2010). Urge urinary incontinence (UUI) is defined as the unintended loss of urine associated with urgency, while mixed UI (MUI) is a combination of the other two conditions (Haylen *et al.* 2010). The higher prevalence of SUI means that this is the condition that patients most commonly present with at the pelvic physiotherapy clinics.

The pathophysiology of SUI is still not fully understood. It is accepted that SUI is the result of urethral sphincter muscle weakness and anatomical shortcomings in urethral support. These issues result in insufficient urethral closure during a rise in intra-abdominal pressure (IAP). The causes of SUI are multifactorial, the most common being pregnancy, vaginal delivery, pelvic surgery, lifestyle features including high-impact activities, obesity, ageing and neurological

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disorders (Chaitow *et al.* 2012), all of which affect the function of the pelvic floor muscle (PFM) complex.

The PFMs constitute a neuromyofascial unit that forms a sling around the urethra, vagina and anus, and also extends to the ischial tuberosity, linking the pelvis with the lower limbs and spine. Thus, the function of the PFMs can be directly and indirectly affected by surrounding and connective structures. Made up of mixed muscle types (i.e. fast- and slow-twitch fibres) that are difficult to differentiate, the PFMs work as a single unit in all anatomical and functional planes. The complexity of the pelvic floor also arises from its ability to contract voluntarily and involuntarily. Its effective voluntary contraction increases urethral pressure and elevates the bladder neck (DeLancey *et al.* 2008), and such activity is used in physiotherapy rehabilitation that aims to restore its automatic activity. The involuntary (automatic) activity of the PFMs occurs during breathing, coughing, laughing and postural perturbations. As such, this requires fast, reflexive PFM contractions (Deffieux *et al.* 2008) that effectively regulate urethral and bladder pressure in order to maintain continence. Precontraction of the PFMs as a preventative mechanism to counteract a sudden increase in IAP (e.g. as a result of coughing) is known as "the Knack", a technique that was introduced and described by Miller *et al.* (1998). This protective, preparatory activation of the PFMs is widely used in the management of UI.

The function of the perineal muscles is multifactorial, and these play a role in:

- the mechanism of continence (DeLancey *et al.* 2008);
- supporting the viscera (Ashton-Miller & DeLancey 2007);
- sexual function;
- the stability of the lumbopelvic region (Hodges & Gandevia 2000; Hodges *et al.* 2007);
- supporting the mechanism of respiration (Hodges & Gandevia 2000; Hodges *et al.* 2007; Talasz *et al.* 2011; Bordoni & Zanier 2013; Park & Han 2015);
- preparatory activity and stability during postural perturbations (Hodges *et al.* 2002, 2007; Lee & Hodges 2016);
- the impact of postural alignment (Sapsford *et al.* 2008; Capson *et al.* 2011; Lee & Hodges 2016); and
- acting as a pressure mediator during activities that increase IAP (Hodges *et al.* 2007; Junginger *et al.* 2010).

The function of the PFMs depends on the coordinated interaction of these tissues with other muscles. In asymptomatic subjects, PFM activity is synchronized with the core muscles of the trunk, transversus abdominis (TrA), multifidus and diaphragm (Sapsford 2004; Hodges *et al.* 2007; Lee *et al.* 2008; Vleeming 2012). The latter form the abdominal cylinder, and the coordinated and balanced activity of these four muscles counteracts elevated IAP, maintaining continence.

In a study employing electromyography, Junginger *et al.* (2010) concluded that the most effective form of bladder neck elevation occurs when a submaximal contraction of the PFMs and TrA is performed. In turn, this provides sufficient counteractive force against an increase in IAP, and contributes to successful closure of the urethra (Sapsford *et al.* 2013). The latter two findings suggest that urethral realignment and closure may be achieved more effectively when TrA (TrA) recruitment is added to PFM training (PFMT), and coactivation is integrated into function.

The synergistic activity of the TrA and PFMs has been well researched and documented in healthy subjects. However, Sapsford *et al.* (2013) reported that this interaction enhanced urethral closure in asymptomatic women, and thus, contributed to the mechanism of urinary continence. In addition, two observational studies by Junginger *et al.* (2014, 2018) also demonstrated positive outcomes of TrA recruitment and PFMT as part of a coordinated rehabilitation approach that was individually prescribed for women with different types of UI over 6 weeks. However, without any controls or randomization being employed, it is difficult to know whether these findings demonstrate the superiority of a synchronized TrA recruitment and PFMT strategy over PFMT alone.

With the recent integration of modified Pilates (Key 2013; Byrnes *et al.* 2018) into physiotherapy, many clinicians apply the principles of coactivation to their rehabilitation programmes and use the modified Pilates method in neuromuscular training (Contreras 2018). The use of "the Knack" manoeuvre has also been integrated into rehabilitation programmes in which TrA recruitment is added to PFMT (Junginger *et al.* 2010, 2014, 2018).

Rationale for the literature review

The International Consultation on Incontinence (Abrams *et al.* 2017) and National Institute for

Health and Care Excellence (NICE 2019) guidelines recommend PFMT as the primary treatment in the management of UI. Other treatment options that are currently employed by patients and clinicians include an integrative approach involving PFMT in combination with TrA recruitment. The rehabilitation of one muscle in isolation may be less effective than addressing several as a single, synchronized unit. Nevertheless, the effectiveness of PFMT in isolation has been well researched and validated (Abrams *et al.* 2017; Dumoulin *et al.* 2018), and it is questionable if its success would be augmented by the inclusion of TrA recruitment (Bø *et al.* 2009).

According to Kari Bø *et al.* (2009), unlike PFMT, there is a lack of empirical evidence for the addition of TrA recruitment. However, in a systematic review that included five studies published between 1990 and 2007 (Bø *et al.* 2009), the authors' investigation was focused on validating the effect of TrA alone and in co-contraction with PFMT in the treatment of women with SUI and mixed UI. Transversus abdominis exercise alone is not the recommended first-line treatment for UI (NICE 2019; Abrams *et al.* 2017), and therefore, the results of this study do not reflect current evidence-based practice (Bø *et al.* 2009).

Therefore, the aim of the present literature review is to compare the effectiveness of PFMT with and without the addition of TrA recruitment in women with different types of UI through the analysis of the best available trials in the academic literature. The present authors sought to establish whether adding TrA recruitment to PFMT increases the latter's effectiveness, and provide insights and implications for wider clinical practice.

Materials and methods

An exhaustive search of the main databases [i.e. MEDLINE, CINAHL, AMED, the Cochrane Library and the Physiotherapy Evidence Database (PEDro)] and additional resources (i.e. NICE guidelines, the ResearchGate website and the *Journal of Pelvic, Obstetric and Gynaecological Physiotherapy*) for articles in English up to 10 years old was conducted. Handsearches of references and grey literature were also performed. Specifically designed search criteria defined the population, intervention, control, outcome, study type and time (PICOST; Guyatt *et al.* 2008), and these are presented in "Appendix 1" (see Tables 3 & 4).

The inclusion criteria were women of age 18 years and above with all types of UI (i.e. SUI, UUI and MUI). The studies were required to include at least one symptom-related outcome measure employing validated QoL questionnaire(s), and as a secondary outcome, to assess PFM function. Since the aim of the present literature review was to compare two different approaches (i.e. PFMT versus PFMT with TrA recruitment), randomized controlled trials (RCTs) and controlled trials of moderate to high methodological quality, as determined by a minimum PEDro score of 4 (PEDro 1999; Bø & Hilde 2013), were selected.

The exclusion criteria were studies including pregnancy, men, paediatrics, previous pelvic surgery, previous spinal surgery, ongoing low back pain, respiratory disorders, neurological disorders, and cognitive or psychological disorders.

Figure 1 is a Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart (Moher *et al.* 2009; PRISMA 2009) illustrating the search strategy, and the process of selecting and eliminating studies. The PEDro scale and Critical Appraisal Skills Programme (CASP 2018) tools were used in combination to critically appraise the selected studies.

Results

Six articles were identified: three RCTs (Hung *et al.* 2010; Sriboonreung *et al.* 2011; de Souza Abreu *et al.* 2017); one pilot RCT (Lausen *et al.* 2018); one controlled trial (Ptak *et al.* 2017); and one long-term follow-up study (Dumoulin *et al.* 2013). All women received oestrogen throughout the trial by Ptak *et al.* (2017), and those in Dumoulin *et al.*'s (2013) research underwent PFM electrostimulation (ES). Since the participants received the additional treatments for the duration of the research by Dumoulin *et al.* (2013) and Ptak *et al.* (2017), it is believed that this would not have skewed the outcomes, and therefore, both studies were included in the present analysis. Table 1 provides a summary of the characteristics of the studies selected.

Four studies out of six analysed (Hung *et al.* 2010; de Souza Abreu *et al.* 2017; Ptak *et al.* 2017; Lausen *et al.* 2018) used a two-armed intervention to compare PFMT alone with PFMT and TrA recruitment in combination, but took different approaches in incorporating the latter with PFMT. Despite differences in the types of exercise and dosage, these four studies reported greater improvement in the intervention group

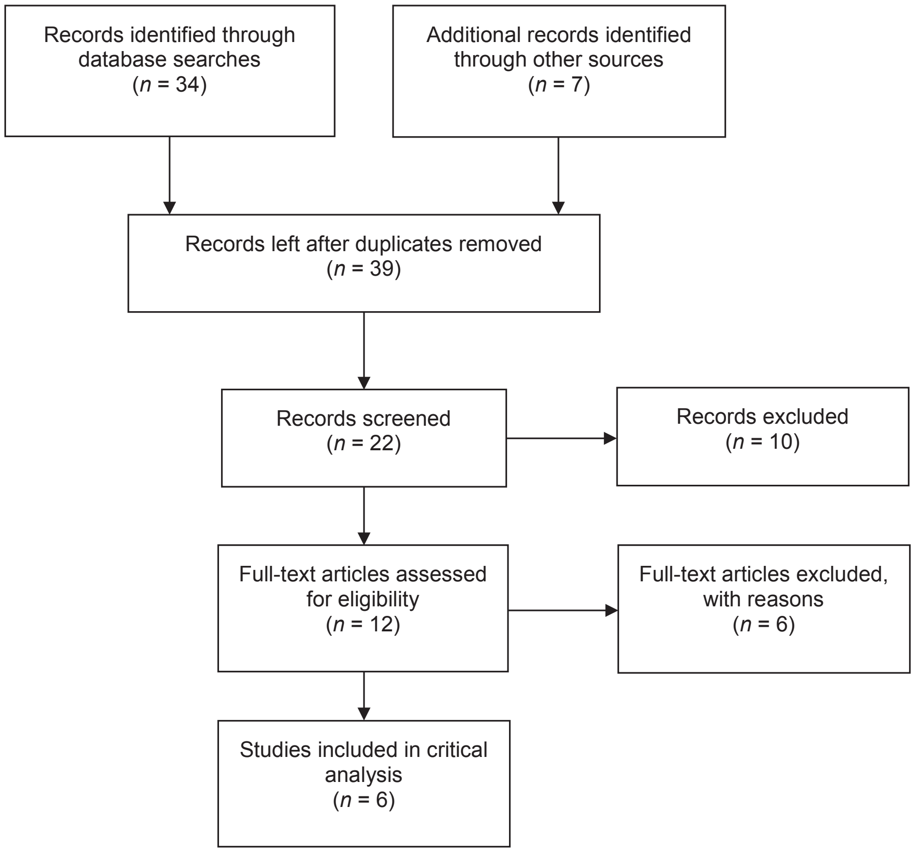

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart demonstrating the literature search strategy (Moher *et al.* 2009; PRISMA 2009).

when TrA recruitment was incorporated with PFMT. However, Dumoulin *et al.* (2013) described equal improvement across all groups, and concluded that positive outcomes were measured in the participants who continued to adhere to PFMT rather than the additional TrA recruitment. At the beginning of their study protocol, these authors included an additional control group in which participants received massage as an extra intervention. Consequently, those participants from the PFMT and massage control group were reallocated to one of the intervention groups: PFMT only, or PFMT and TrA recruitment. Sriboonreung *et al.* (2011) also had three group allocations: two performing different frequencies of PFMT and a third prescribed PFMT with TrA recruitment. Their conclusion was that two approaches produced the best results: combined PFMT and TrA recruitment, and more-intense, daily PFMT. Further appraisal of these six studies highlights the limitations of the research and further considerations for practice.

Study participants and selection

When the six studies under review were combined, a total of 441 participants from different regions (i.e. North and South America, Europe, and Asia) were included in the present analysis, which makes the pool of subjects more generalized and applicable.

All the studies that were critically reviewed included women with symptoms of SUI. Hung *et al.* (2010) also included participants with UUI and MUI, and their subjects presented with mild SUI symptoms measuring less than 2 g on a pad test, potentially decreasing the sensitivity of the test.

Moreover, the participants in the de Souza Abreu *et al.* (2017) study had body mass indices of between 28.2 and 29.9 (i.e. in the overweight category), and no comparison of their weight was made at the end of the intervention. If the women's motivation to exercise and lose weight had increased because of their participation in the study, then any weight variance might have confounded the outcomes of the interventions. The summary of the 5th International Consultation on Incontinence (ICI; Dumoulin *et al.* 2016) and the 6th ICI (Abrams *et al.* 2017) concluded that moderate loss of weight in combination with exercise is an effective method of decreasing UI (level 1 evidence according to the ICI).

Table 1. Summary of the studies included in the present literature review: (RCT) randomized controlled trial; (UI) urinary incontinence; (SUI) stress urinary incontinence; (UUI) urge urinary incontinence; (MUI) mixed urinary incontinence; (PFM) pelvic floor muscle; (PFMT) PFM training; (TrA) transversus abdominis; (SII) Symptom Impact Index; (QoL) quality of life; (Rx) treatment; (ES) electrostimulation; (UDI) Urogenital Distress Inventory; (IIQ) Incontinence Impact Questionnaire; (VAS) visual analogue scale; (DLS) dynamic lumbopelvic stabilization; (ISI) Incontinence Severity Index; (KHQ) King's Health Questionnaire; (PGI-I) Patient Global Impression of Improvement; (UDI) Urogenital Distress Inventory; (ICIQ-LUTS) International Consultation on Incontinence Questionnaire – Lower Urinary Tract Symptoms; (SSI) Symptom Severity Index; (I-QOL) Incontinence Quality of Life Questionnaire; and (RSES) Rosenberg Self-Esteem Scale

Study	Study design	Sample	Methodology	Outcome measures	Results	Conclusion
Hung *et al.* (2010)	Single-blinded RCT	Taiwan ($n=70$), SUI, UUI, MUI	Random allocation to: (1) PFMT + TrA recruitment (2) PFMT, bladder hygiene	Self-reported improvement, 20-min pad test, 3-day voiding diary, PFM function, SII	More subjects improved or cured in PFMT + TrA recruitment (cure rate > 90%) Amount and frequency of UI decreased after PFMT + TrA recruitment ($P<0.05$), but not PFMT group Maximum vaginal squeeze pressure decreased slightly in both groups	Coordinated training could improve symptoms and QoL in women with UI
Sriboonreung *et al.* (2011)	RCT	Thailand ($n=68$), SUI	Random allocation to: (1) PFMT three times a day (2) PFMT three times a week (3) PFMT + TrA recruitment	1-h pad test, PFM strength, Rx satisfaction	Increase in PFM strength in all groups, but significantly more in groups 1 and 3	All three protocols effective in increasing PFM strength and decreasing UI
Dumoulin *et al.* (2013)	7-year follow up of RCT, assessor-blinded	Canada ($n=57$), postpartum SUI	Random allocation (+ES) to: (1) PFMT (2) PFMT + TrA recruitment (3) control (massage)	20-min pad test, UDI, IIQ, VAS	At 7 years, no significant effect of group ($P<0.10$) Small to medium effect size ($r=0.11$)	Benefits noted in both groups in subjects who continued to adhere to PFMT
De Souza Abreu *et al.* (2017)	Controlled and randomized clinical trial	Brazil ($n=33$), SUI	Random allocation to: DLS + PFMT PFMT	ISI, voiding diary, KHQ, PGI-I	Improved ISI in both groups, but no statistical difference ($P=0.50$) At 3 months, greater improvement in ISI, voiding frequency, KHQ and PGI-I in the DLS + PFMT group	No statistical difference immediately pre- and post-intervention At 3 months, in favour of DLS + PFMT
Ptak *et al.* (2017)	Randomized trial	Poland ($n=140$), SUI	Random allocation (+ oestrogen) to: (1) PFMT + TrA recruitment (2) PFMT	ICIQ-LUTS	Significant improvement in QoL in both groups, but more favourable findings for PFMT + TrA	PFMT + TrA recruitment shown to be more effective
Lausen *et al.* (2018)	Pilot RCT	UK ($n=73$), SUI	Random allocation to: (1) PFMT and education session (2) modified Pilates (PFMT + TrA recruitment), and PFMT and education sessions	SSI, I-QOL, ICIQ-LUTS, RSES	Improved self-esteem, social embarrassment, impact on daily activities ($P<0.025$) and personal relationship in PFMT + TrA group	Modified Pilates + TrA recruitment may positively influence motivation and adherence

Outcome measures

The six studies reviewed employed a wide range of QoL questionnaires. The King's Health Questionnaire (KHQ) (Matza *et al.* 2004, 2006), one of the most popular and well-validated UI-specific, psychometrically comprehensive questionnaires, was used by de Souza Abreu *et al.* (2017). The KHQ and Incontinence Severity Index scores that they reported demonstrated an improvement in the combined PFMT with TrA recruitment group at a 3-month follow-up after 5 weeks of supervised training followed by self-directed rehabilitation. Two studies (Ptak *et al.* 2017; Lausen *et al.* 2018) used the same instrument, the International Consultation on Incontinence Questionnaire – Lower Urinary Tract Symptoms, and showed more improvement in QoL in the combined PFMT with TrA recruitment group. Similarly, in a study by Hung *et al.* (2010), the Symptom Impact Index indicated that the number of patient activities that were significantly affected was reduced in the combined PFMT with TrA recruitment group at 4 months.

Although the NICE (2019) clinical guidelines do not recommend its routine use, two studies (Hung *et al.* 2010; Dumoulin *et al.* 2013) used a 20-min pad test with slight differences. Hung *et al.* (2010) showed significant improvement in leakage volume in the combined PFMT and TrA recruitment group, and Dumoulin *et al.* (2013) found no significant effect between the groups. Similarly, Sriboonreung *et al.* (2011) demonstrated no statistical difference in improvement between groups using a 1-h pad test.

Three studies (Hung *et al.* 2010; Sriboonreung *et al.* 2011; Lausen *et al.* 2018) validated correct PFM activation prior to the interventions, but only Hung *et al.* (2010) and Sriboonreung *et al.* (2011) measured PFM strength afterwards. These authors reported conflicting results. While a significant increase in strength was associated with the intensity and frequency of the PFMT in Sriboonreung *et al.*'s (2011) study, Hung *et al.* (2010) reported a decrease in maximal vaginal squeeze pressure. The NICE (2019) clinical guidelines recommend digital assessment of PFM activation before individualized PFMT is prescribed. It is also questionable whether retraining of continence mechanism as we understand it is effective without confirmation of bladder neck elevation through PFM digital examination or diagnostic ultrasound.

Intervention groups, dosage and supervision

The PFMT interventions varied in terms of the type of exercise involved, the parameters used, the level of supervision and the number of contacts with the clinician. Table 2 describes the exercise protocols employed in each study, and the dosage applied in each group.

Only Ptak *et al.* (2017) instructed both groups of participants to perform "the Knack" manoeuvre. Following a previous study protocol (Zanetti *et al.* 2007), de Souza Abreu *et al.* (2017, p. 2161) reported training the PFMs "with cough". Both studies used a specific dosage and frequency, and the outcomes suggested that benefits were derived from additional TrA recruitment. Hung *et al.* (2010) and Lausen *et al.* (2018) did not specify the training parameters that they employed. In the latter study, all participants performed individual, physiotherapist-guided PFMT. In addition, some but not all women were treated with biofeedback. This multimodal, individualized PFMT approach reflects the clinical approach adopted by pelvic health physiotherapists, and therefore, it was not feasible for Lausen *et al.* (2018) to report the parameters of their study. However, in Hung *et al.*'s (2010) study, the PFMT group was only given verbal instructions, and had no additional contact with a physiotherapist, unlike the PFMT with TrA recruitment group. Unequal contacts between the groups in the same study might confound the findings that were in favour of the combined PFMT and TrA group (the reported "improved rate" in the training group was > 90%). Research shows that women who are supervised regularly by a clinician have an increased likelihood of reporting improvements (Hay-Smith *et al.* 2011). However, despite intense, supervised training, the PFMT group did not show superior QoL outcomes in the study by Ptak *et al.* (2017). Therefore, it is not clear whether the successful outcomes were a result of the frequency of supervision, the dosage or the method applied.

Four of the six studies used a coactivation approach when combining TrA recruitment with PFMT (Hung *et al.* 2010; de Souza Abreu *et al.* 2017; Ptak *et al.* 2017; Lausen *et al.* 2018), and all reported greater improvements in the combined training groups. It is unclear how TrA recruitment was incorporated in the training described in the Sriboonreung *et al.* (2011) study, and therefore, this made comparison and differentiation challenging. Only Dumoulin *et al.* (2013) taught participants to exercise the two muscles (i.e. the PFM and TrA) in isolation, but they did

Table 2. Analysis of the exercise protocol of the studies included in the literature review: (PFM) pelvic floor muscle; (PFMT) pelvic floor muscle training; (TrA) transversus abdominis; (VE) vaginal examination; (MVC) maximum voluntary contraction; (ES) electrostimulation; (DLS) dynamic lumbopelvic stabilization; and (APPI) Australian Physiotherapy and Pilates Institute

			Dosage			
Study	Initial PFM evaluation	Frequency of both interventions	PFMT	TrA recruitment + PFMT	TrA + PFM cueing	Follow-up period
Hung *et al.* (2010)	VE, taught correct PFM activation	Supervised twice a month for 4 months (only TrA recruitment group)	Parameters unknown Patients were given general information on PFMT and bladder hygiene	As per Sapsford (2004), a five-stage exercise programme was performed at home; subjects were seen twice a month for monitoring/progression	Coactivation	4 months
Sriboonreung *et al.* (2011)	VE, taught correct PFM activation	Unsupervised: home-based Group 1: three times a day Group 2: three times a day, three times a week To encourage motivation, patients had to come to hospital for log-in sheet	MVC, 6–8-s hold, then add six to eight fast contractions, rest for 6–8 s; eight to 12 repetitions	Three sets a day, three times a week; positions and movements unknown Dosage: 6–8-s hold, add six to eight fast contractions, rest for 6–8 s; eight to 12 repetitions in one session	Unknown	3 months
Dumoulin *et al.* (2013)	Unknown	Supervised once a week for 8 weeks, then continued unsupervised five times a week	ES = 15 min, PFMT = 25 min	ES = 15 min, PFMT = 25 min, TrA recruitment = 10 min	Taught in isolation, breathing not incorporated,	7 years
De Souza Abreu *et al.* (2017)	Unknown	One-to-one supervision twice a week for 5 weeks, advised to exercise daily for 5 weeks	As per Zanetti *et al.* (2007): 5-s hold, 5-s rest × 10; 2-s hold, 2-s rest × 20; 1-s hold, 1-s rest × 20; 10-s hold, 10-s rest × 5; five strong contractions with cough	DLS through four stages + PFMT From the correct movement, four to eight repetitions of each exercise performed Exercise repertoire resembles APPI modified Pilates.	Coactivation on exhalation	3 months
Ptak *et al.* (2017)	No VE, initial training aimed to promote correct PFM activation	Supervised four times a week for 3 months	MVC, three sets of 60–70 × 10; two sets of 1–2-s holds at 30–60% MVC × 10 on exhale “The Knack” Oestrogen	Supervised four times a week for 3 months MVC in supine crook lying, three sets of 60–70 × 10; two sets of 1–2-s holds at 30–60% MVC × 10 on exhale “The Knack” Oestrogen	Coactivation on exhalation	3 months
Lausen *et al.* (2018)	VE, verified correct PFM activation	Supervised once a week for 6 weeks	Between three and six individual sessions Parameters unknown because the treatment was individualized	Modified Pilates group classes once a week for 6 weeks Exercise repertoire resembles APPI method Additionally, received PFMT	Coactivation, but unclear if in synchronization with diaphragm	6 weeks

not specify the exact TrA recruitment protocol other than by providing a duration (10 min). It is questionable whether the time set for the protocol was sensitive enough for all participants who took part in the study, and as such, could reflect the true outcome of the treatment applied.

In the studies by Hung *et al.* (2010), de Souza Abreu *et al.* (2017) and Lausen *et al.* (2018), the duration of the sessions varied from 30 min two times a week (de Souza Abreu *et al.* 2017) to 1 h once a week (Lausen *et al.* 2018). However, the duration of the intervention in Hung *et al.* (2010) was unspecified: the participants were instructed to practise independently, and only received supervision bimonthly. Despite the heterogeneity of the exercise protocols, the latter three studies concluded that coordinated training may be more effective in improving symptoms and QoL in women with UI. On the other hand, Hung *et al.* (2010) reported a decrease in maximal vaginal squeeze pressure that may be attributable to a significantly lower number of contacts and no supervision.

A further disparity in training parameters was identified with regard to the intensity of the PFM contractions with or without TrA that were taught. Cuing maximal contraction of the PFMs and/or TrA is associated with activation of all the abdominal muscles, which increases IAP in turn (Sapsford *et al.* 2001), and prevents bladder neck elevation (Junginger *et al.* 2014). Therefore, Junginger *et al.* (2018) suggested that submaximal coactivation, where the bladder neck is elevated without increasing pressure on the bladder and urethra, might be more appropriate in symptomatic subjects. However, Bø *et al.* (2015) and Junginger *et al.* (2018) reported uncertainty about whether submaximal contractions could achieve hypertrophy and increase PFM strength. Ptak *et al.* (2017) and Lausen *et al.* (2018) were the only studies that used a submaximal approach. The latter study did not verify the correct PFM activation, as determined by Bø *et al.* (2015), but the outcomes of both supported combining PFMT with TrA recruitment. However, Sriboonreung *et al.* (2011) prescribed maximal contractions, and reported an increase in PFM strength in all groups, particularly if performing PFMT or PFMT with TrA recruitment three times a day, as opposed to three times a week. The remaining studies (Hung *et al.* 2010; Dumoulin *et al.* 2013; de Sousa *et al.* 2017) did not describe the intensity of the PFMT that was taught.

Lausen *et al.* (2018) ran their intervention group as a group class; however, the participants in the PFMT group received individual treatments from an experienced physiotherapist. While almost all the other studies (Hung *et al.* 2010; Dumoulin *et al.* 2013; de Souza Abreu *et al.* 2017; Ptak *et al.* 2017) involved individual sessions with different intensities and frequencies, Sriboonreung *et al.* (2011) looked at unsupervised, home-based training. These differences in the frequency of contacts with a clinician and the attention given (i.e. group versus individual training) further challenged the present review.

Discussion

There was considerable heterogeneity across the studies in terms of the types of intervention prescribed for both groups, i.e. PFMT alone and PFMT in conjunction with TrA recruitment.

The primary challenge in drawing a comparison between these two approaches comes from the potential for the participants across all groups to have improved equally with PFMT alone since all subjects in the selected research received PFMT. While all the authors except Dumoulin *et al.* (2013) showed a greater improvement in the experimental group (i.e. PFMT with TrA recruitment), the statistical validity of the studies reviewed is questionable.

Dumoulin *et al.* (2013) reported the highest dropout rate (40%), which meant that their findings were underpowered. This was the only long-term study included in the present analysis that also used ES with all participants and TrA recruitment in isolation. There is no evidence to suggest that ES improves PFM functionality, proprioception, neurological control and the activation strategy of the pelvic floor complex, and therefore, the extent to which it influenced the trial results is unclear. It is questionable why Dumoulin *et al.* (2013) taught TrA recruitment separately from training the muscles of the abdominal cylinder that are known to depend on its synchrony. Such an approach does not reflect either current scientific knowledge, or clinical modified Pilates, as practised in women's health physiotherapy clinics. The above authors' immediate post-intervention results also showed no statistically significant difference between the groups, which may imply that the wrong training approach was employed when TrA recruitment was added to PFMT for the management of UI in women.

Incorrect activation of the PFMs is a significant confounding factor in all studies of PFMT (Bø *et al.* 2015). Dumoulin *et al.* (2013), de

Souza Abreu *et al.* (2017) and Ptak *et al.* (2017) failed to evaluate PFM activation prior to their interventions, which further brings into question the validity of their findings. On the other hand, all the participants in Sriboonreung *et al.*'s (2011) study were taught correct activation prior to their intervention, and they all demonstrated an improvement in PFM strength and UI following intensive, home-based training. These positive outcomes might be explained by the initial PFM evaluation and the appropriate muscle activation education. This is an important factor to include in any future studies of PFMT in order to increase the specificity of the intervention given and the validity of the findings.

It was not possible to identify the most successful repetition of the parameters for PFMT with or without TrA recruitment because of heterogeneity across all studies. A similar conclusion was reported in a systematic review by Oliveira *et al.* (2017). Therefore, an individual approach to selecting the best possible PFMT parameters is recommended. Following the present literature review, it is reasonable to draw the same conclusion about optimally combining TrA recruitment with PFMT. However, the women allocated to the more-dynamic and functional approach to exercise for UI (i.e. PFMT with TrA recruitment) in the studies reviewed (Hung *et al.* 2010; de Souza Abreu *et al.* 2017; Lausen *et al.* 2018) might have been better motivated and more committed to their exercise programmes, which would suggest performance bias and call into question the improvement reported in the QoL outcomes in the combined PFMT and TrA recruitment groups in these three studies.

The exercise routines that most closely resembled a modified Pilates repertoire, as used by physiotherapists in the clinical setting, were prescribed by Hung *et al.* (2010), de Souza Abreu *et al.* (2017) and Lausen *et al.* (2018). All three studies involved coactivation of the PFMs and TrA, and the progression was divided into several stages. However, the various techniques employed differed in dosage, exercise repertoire and functional integration.

This may reflect disparities in the practitioner's background in teaching modified Pilates. Several schools of modified Pilates are basically similar, but involve variations in the exercise repertoire and the levels of difficulty involved. Furthermore, there are differences in the precision with which these selected modified Pilates exercises are taught. For example, the importance of posture, alignment and respiratory synchronization plays an integral role in balancing the activity of different muscle slings, and in particular, the primary sling known as the abdominal canister.

Studies by Sapsford *et al.* (2008) and Hodges *et al.* (2007) confirmed the variability in PFM activity in different sitting and standing postures. Sitting in an upright posture generates greater PFM activity than a supported, slumped position. These findings indicate that the starting position and postural alignment play a crucial part in PFM rehabilitation with or without TrA coactivation.

The importance of individual postural alignment and the positions in which the participants were asked to exercise were addressed by de Souza Abreu *et al.* (2017) and Hung *et al.* (2010), but not discussed in the other studies under review.

In addition, harmonizing breathing (diaphragmatic movement) in coordinated TrA recruitment and PFMT may further affect the normal mechanisms for regulating IAP (Sapsford 2004; Talasz *et al.* 2011), and may be an important consideration in the rehabilitation of women with UI. Only three studies (Hung *et al.* 2010; de Souza Abreu *et al.* 2017; Ptak *et al.* 2017) instructed patients to exhale on coactivation of the PFMs and TrA, mimicking the normal mechanics of the abdominal canister.

The lack of individual prescription across all the studies included, and the vagueness about how and why the chosen exercises were taught are just some of the barriers that were identified to evaluating these two different approaches.

Limitations

There are several limitations to this literature review. There is a considerable risk of bias across all the selected studies. Despite random sequence allocation in all trials, only three concealed the allocation (Hung *et al.* 2010; Sriboonreung *et al.* 2011; Ptak *et al.* 2017), meaning that there was a degree of selection bias in the pooled subjects. Performance bias was present in all studies because it was impossible to blind the participants and the therapists, and this bias must be considered when interpreting the results. Hung *et al.* (2010) and de Souza Abreu *et al.* (2017) were the only studies in which the outcome assessors were blinded, and therefore, one needs to be aware of the detection bias in the other four trials. While Sriboonreung *et al.* (2011) included the results from all lost-to-follow-up participants, it is unclear if the criteria were fully met, as these were in Hung *et al.*'s (2010), who carried forward all missing values by their baseline values. The other studies did not perform an intention-to-treat analysis, and therefore, involved attrition bias. There was also a lack of sample size calculation by Ptak *et al.* (2017) and Lausen *et al.* (2018), while Hung *et al.* (2010) used another four-armed study calculation for sizing that was not comparable with their two-armed study.

Lastly, the evaluation of the studies in this literature review was solely conducted by the first author (B.K.), and therefore, this may have included a degree of subjective bias.

Implications for clinical practice

Following the present literature review, the first author (B.K.) reflected on the modified Pilates method that she taught as a women's health master Pilates instructor. She subsequently updated the course material for physiotherapists, and outlined the strengths and weaknesses of group versus individual exercises for women with UI identified by this review.

The first author's (B.K.'s) clinical practice became more reflective, but remained unchanged. When appropriate, she incorporates TrA recruitment and diaphragmatic activity into PFMT. There is enough evidence to support the integration of TrA recruitment into PFMT for the management of women with UI when the treatment is individually prescribed. The specific cueing of the muscle contraction (maximal or submaximal) and dosage is difficult to incorporate in a group setting, and therefore, the first author (B.K.) questions whether a circuit-based group modified Pilates class with individually prescribed exercise modification and dosage could be more advantageous.

Following the present critical review and feedback from women attending a generalized PFM strengthening class in Switzerland, the first author (B.K.) will run updated circuit classes based on modified Pilates.

Conclusion

The aim of the present literature review was to identify whether adding TrA recruitment to PFMT would enhance outcomes in the management of female UI. Positive results associated with adding TrA recruitment to PFMT were reported in five out of six trials. However, there were certain limitations to the studies reviewed, and heterogeneity in the methodologies, interventions and outcome measures used made direct comparison challenging. It is important to distinguish between the effectiveness of different exercise protocols, settings (i.e. a group versus an individual approach), levels of supervision and dosages applied when adding TrA recruitment to PFMT. Individualized PFMT alone is the first-line treatment option for women with UI (Abrams *et al.* 2017; Dumoulin *et al.* 2018; NICE 2019), and there are indications that integrating the synergistic muscles of the abdominal canister may be of additional benefit in PFM rehabilitation. This needs to be investigated further in trials employing homogenous intervention protocols.

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Appendix 1

Table 3. Population, intervention, control, outcome, study type and time (PICOST) criteria and search strategy: (PEDro) Physiotherapy Evidence Database

Variable	Result
Population	Women with urinary incontinence
Intervention	Combined pelvic floor muscle training and transversus abdominis exercise
Comparison	Pelvic floor muscle training alone
Outcome measures:	
primary	quality of life
secondary	pelvic floor muscle function
Study type	Randomized controlled trials, trials
Keywords	Pelvic floor dysfunction OR pelvic floor weakness, pelvic floor disorder, voiding dysfunction, urinary incontinence, stress urinary incontinence, urodynamic stress urinary incontinence, urge urinary incontinence, urgency, mixed urinary incontinence, overactive bladder syndrome, overactive bladder, detrusor overactivity, physiotherapy, rehabilitation, re-education, training, exercise AND transversus abdominis OR abdominal training, lumbopelvic stabilization, Pilates training, modified Pilates, deep abdominal training, abdominal drawing-in manoeuvre, core training, core stability training, coordination training, co-activation training, dynamic lumbopelvic stabilization training, lumbar stabilization, stabilization training, trunk stabilization training AND pelvic floor muscle OR pelvic floor muscle exercise/training/rehabilitation/re-education, Kegels, levator ani, bladder neck mobility, bladder neck movement, urethral pressure, intra-abdominal pressure
Time	2007–2018
Inclusion criteria	Urinary incontinence, stress urinary incontinence, urge urinary incontinence, urgency, mixed urinary incontinence, overactive bladder syndrome
Exclusion criteria	Pregnancy, men, paediatrics, previous pelvic surgery, previous spinal surgery, ongoing low back pain, respiratory disorders, neurological disorders, cognitive or psychological disorders, PEDro score < 4/10

Table 4. Studies excluded from the literature review, and the reasons for doing so: (PEDro) Physiotherapy Evidence Database

Study	Reason
Culligan *et al.* (2010)	Inclusion criteria too wide: asymptomatic and symptomatic women involved
Kim *et al.* (2012)	Both groups followed the same exercise protocol, but in different settings
Kamel *et al.* (2013)	Included only obese women with stress urinary incontinence
Tajiri *et al.* (2014)	Comparison between participants performing pelvic floor muscle and transversus abdominis training, and an inactive control group
Lacombe *et al.* (2015)	Intervention not relevant (holistic gymnastics)
Augustina *et al.* (2016)	Low methodological quality (PEDro score = 3/10)