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ORIGINAL ARTICLE

Constriction of the levator hiatus during instruction of pelvic floor or transversus abdominis contraction: a 4D ultrasound study

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Abstract A new theory claims that the pelvic floor muscles (PFM) can be trained via the transversus abdominis (TrA). The aim of the present study was to compare the effect of instruction of PFM and TrA contraction on constriction of the levator hiatus, using 4D perineal ultrasonography. Thirteen women with pelvic organ prolapse participated in the study. Perineal ultrasound in standing position was used to assess constriction of the levator hiatus. Analyses were conducted off-line with measurements in the axial plane of minimal hiatal dimensions. The reduction of all the hiatal dimensions was significantly greater during PFM than TrA contraction. All patients had a reduction of the levator hiatus area during PFM contraction (mean reduction 24.0%; range 6.1–49.2%). In two patients, there was an increase of the levator hiatus area during TrA contraction. Instruction of PFM contraction is more effective than TrA contraction.

Keywords Levator hiatus · Pelvic floor muscles · Transversus abdominis · Ultrasound

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Introduction

Today, there is level A evidence that pelvic floor muscle training (PFMT) can effectively treat stress urinary incontinence (SUI) and mixed urinary incontinence, and it is recommended as first-line treatment for these conditions [1]. Cure rates, measured as <2 g of leakage on pad testing, varies between 44% and 70% [2]. In addition, there is evidence from three randomized controlled trials (RCT) that PFMT may also be effective in the treatment of pelvic organ prolapse (POP) [3–5].

Recently, a theoretical model involving training of the deep abdominal muscles, in particular the transversus abdominis (TrA), to initiate tonic PFM activity has been introduced to restore pelvic floor dysfunction [6]. This approach is based on the understanding that synergistic activity of the PFM and TrA occurs in normal trunk activities in healthy continent women. It has also been suggested that if women are not able to contract the PFM, contracting the TrA may be used to stimulate PFM contraction [7]. Today, anecdotally, there seems to be an increasing number of physical therapists skipping vaginal palpation and teaching TrA contraction instead of PFM contraction to women with pelvic floor disorders.

The PFM surround the pelvic openings, and during a voluntary contraction, they close the urethra and increase urethral closure pressure, lift the pelvic organs inside the pelvis, stabilize and prevent descent during rise in intra-abdominal pressure [8], and constrict the levator hiatus (LH) [9]. Because of its position in the bottom of the pelvic canister, the PFM are supposed to contract unconsciously during any increase in intra-abdominal pressure and as a response to impact from ground reaction forces, e.g., during running and jumping. Hence, an increasing tone and co-contraction of the PFM is expected in continent women during increased impact from physical activity, coughing, and sneezing [10]. The TrA, due to its anatomical location, can have no such direct effect on the continence mechanism, as it is not surrounding the urethra and does not form a structural base to counteract gravidity in the standing position. A possible contribution must go via a co-contraction of the PFM during the TrA contraction.

Recently, the dimensions of the LH have achieved increasing interest in understanding the pathophysiology and mechanism of incontinence and pelvic organ prolapse in women [8]. Reduction of the LH opening can be used to measure the effectiveness of a single PFM contraction as this has to be due to shortening of the muscle fibers [9]. The aim of the present study was to compare the effect of instruction of PFM and TrA contraction on constriction of the levator hiatus, using 4D perineal ultrasonography.

Materials and methods

Consecutive women, at their first consultation when participating in an ongoing randomized controlled trial on PFMT to reduce pelvic organ prolapse, took part in the present study. None of the participants had started to train the PFM. Exclusion criterion for participation in the RCT was inability to understand instructions given in the Norwegian language, inability to contract the PFM, being nulliparous, being less than 1 year post-partum, having had previous pelvic surgery, having chronic lung disease, or stage 0 and 4 POP measured by the pelvic organ prolapse quantified (POP-Q) [11]. All participants were interviewed about their age, weight, height, education, physical activity level, pelvic floor symptoms, and birth history. The pelvic organ prolapse questionnaire was used to assess symptoms of POP [12].

The data examined for this project were obtained in the context of a randomized controlled trial of PFMT on POP approved by the Regional Medical Ethics Committee and the Norwegian Social Science Data Services. All subjects gave written informed consent to participate.

Sample size calculation

So far, we have data on LH reduction during PFM contraction from 17 volunteers for a reliability study [13]. We used these data showing that there was a mean of 25% (95% CI 18–32) reduction of the LH area during PFM contraction for the power calculation. We suggest that 50% less constriction of the LH during TrA contraction compared to each woman's PFM contraction may be a clinically relevant co-contraction. Using alpha 0.05 and power of detecting differences of 0.80, the minimum sample size was 13 women.

Instruction of PFM and TrA contraction

Correct PFM contraction was defined as an inward lift and squeeze around the pelvic openings and assured with vaginal palpation in crook-lying position [14]. Correct TrA contraction was taught according to Urquhart et al. [15]. The participants were first taught to breathe in and out and then gently and slowly draw in the lower abdomen below the navel without moving the upper stomach, back, or pelvis [15]. Correct contraction was assured with palpation medial to the anterior superior iliac spines.

Apparatus

A GE E8 ultrasound system (GE Healthcare, Oslo, Norway) with 4–8 MHz curved array 3D/4D ultrasound transducer (RAB 4–8 l/obstetric) was used. The volume acquisition angle was set to its maximum of 70° in the sagittal plane and 85° in the coronal plane (frame rate was approximate 3 Hz).

Procedure

Participants were instructed to void before the examination. After instruction of PFM and TrA contractions in a crook-lying position by a trained physiotherapist (PT), one gynecologist (MM) performed the ultrasound examinations. The PT (IHB) gave instructions to the participants and supervised the test procedure. The PFM and TrA contractions were performed in the standing position. It took approximately 16 s to perform each maneuver and recording was with 4D real-time ultrasound. The ultrasound transducer was covered with a condom and directed cranially on the perineum [16]. Only a minor part of the PB was scanned in order to include the back sling of the puborectal muscle. All participants first performed PFM contractions followed by TrA contractions.

Ultrasound analyses

Analyses of 4D real-time volumes were conducted off-line on a laptop by one investigator (IHB), using the software "4D View v 6.2" (GE Healthcare, Oslo, Norway). All volumes were previewed and excluded from the analysis unless a significant portion of the pubovisceral muscle was visible. Measurements were performed in the axial plane of minimal hiatal dimensions (Fig. 1). The plane of minimal hiatal dimensions was identified as the minimal distance between the hyperechogenic posterior aspect of the PB and the hyperechogenic anterior border of the puborectal muscle at the anorectal angle [9]. The back sling of the puborectal muscle forms a "bump" posterior to the rectum in the mid-sagittal plane [17], which forms the anorectal junction. In order to ensure that the minimal hiatal dimensions were found, the axial and sagittal plane was

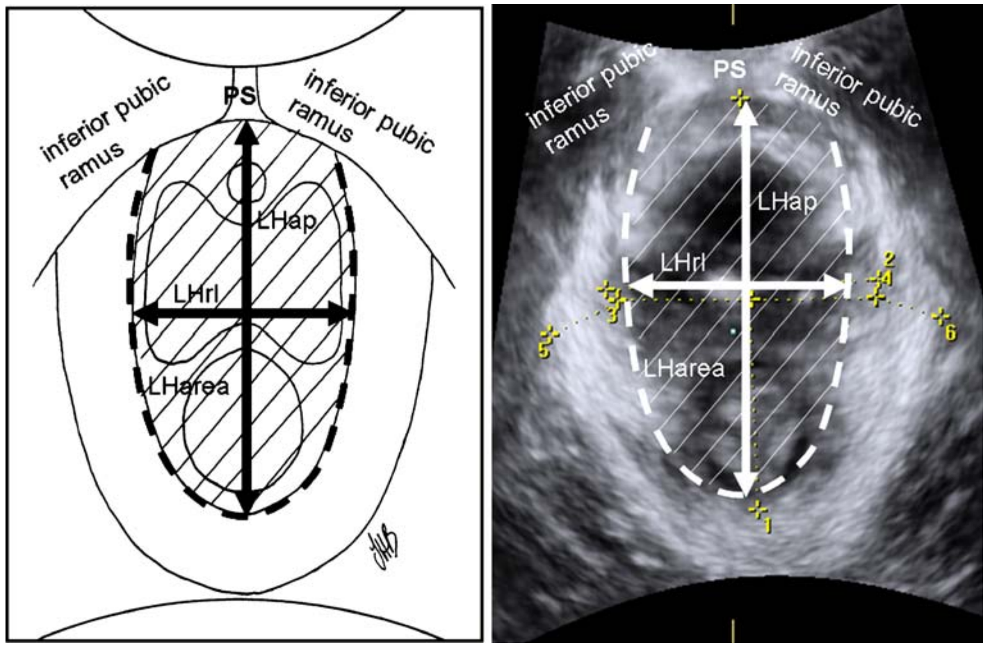

Fig. 1 Drawing and ultrasound image of measurements in the axial plane of minimal hiatal dimensions. Levator hiatus area (*LH area*) is marked with *lines*. *LHap* Levator hiatus antero-posterior diameter, *LHrl* levator hiatus transverse diameter right–left, *PS* pubic symphysis. *Left figure* with permission from Hoff Brækken et al. [30], Copyright© (2008) Wiley-Liss, Inc

carefully observed [13]. The area of the levator hiatus was measured as the area bordered by the pubovisceral muscle, symphysis pubis, and inferior pubic ramus (Fig. 1). In addition, hiatal dimension from the right to the left side (LHrl) and antero-posterior distance (LHap) were quantified. Intra-tester reliability of constriction of the LH area and antero-posterior dimension during PFM contraction has been found to be very good to good [13]. Muscle length of the PFM (pubovisceral muscle) was calculated as the circumference of the LH minus the suprapubic arch [18]. Measurements of the muscle length demonstrated good reliability at rest and fair reliability during contraction [13].

Statistical analysis

Background variables are reported as frequencies or means with standard deviation (SD). All data were normally distributed. Reductions in levator hiatus dimensions during contraction of PFM and TrA are given as means with SD and as percentages. Differences in reduction levator hiatus area, anterior–posterior dimension, transverse dimension, and muscle length between PFM contraction and TrA (effect sizes) are reported as means with 95% confidence intervals (CI). Wilcoxon-paired samples test is used to test differences between the two maneuvers. *P* value is set to <0.05.

Results

Background variables of the study group are shown in Table 1. All participants were of Scandinavian origin. Six women reported mechanical symptoms from their POP (heaviness, bulging), five SUI, two urge urinary incontinence, and eight defecatory problems.

Changes in LH area, transverse and AP dimensions, and PFM length during PFM and TrA contractions are given in Table 2. There was a statistically significant difference in reduction of all the hiatus dimensions in favor of the PFM contraction.

The constriction of the LH area for each individual for both instructions is shown in Table 3. All participants had a reduction of the levator hiatus area during PFM contraction with a mean percentage of reduction of 24.0% (range 6.1–49.2%). The corresponding percentage of reduction during TrA contraction was 9.5% (range −9.8–28.7%). In two patients, there was an increase of the levator hiatus area (opening of the hiatus) with 0.4% and 9.8% during TrA contraction, respectively.

Table 1 Background variables of the participants (*N*=13)

Variables	Values
Age (years)	46.5 (7.2)
BMI (kg/m^2)	24.7 (3.6)
Parity	2.6 (0.8)
POP-Q stage (*N*)	
1	3
2	9
3	1

Mean with standard deviation (SD)

Table 2 Changes in levator hiatus opening dimensions and muscle length shortening during pelvic floor muscle (PFM) and transversus abdominis (TrA) contraction measured by 4D ultrasound (N=13)

	PFM contraction	TrA contraction	Mean difference with 95% CI	p value
Change in levator hiatus area (cm^2)	5.16 (3.20)	1.86 (2.23)	3.30 (1.35–5.25)	0.003
Change in transverse dimension (cm)	0.20 (0.31)	−0.02 (0.30)	0.23 (0.05–0.40)	0.016
Change in anterior–posterior dimension (cm)	1.24 (0.70)	0.70 (0.56)	0.54 (0.23–0.86)	0.003
Muscle length shortening (cm)	2.46 (1.39)	1.39 (1.19)	1.07 (0.20–1.95)	0.022

Mean values with SD and mean difference between PFM and TrA contraction with 95% confidence intervals (CI)

Discussion

This study showed that instruction to contract the PFM was significantly more effective than instruction to contract the TrA in constriction of the levator hiatus and shortening of the PFM length in a group of women diagnosed with POP and other symptoms of pelvic floor disorders. During PFM contraction, all women had a reduction in all levator hiatus dimensions, while two women had an opening of the hiatus during TrA contraction.

To date, only few research groups have quantified the constriction of the LH area during PFM contraction [13, 18–19]. Thyer et al. [18] and Braekken et al. [13] have both demonstrated that the 4D ultrasound method used is reliable in measuring LH dimensions. Weinstein et al. [19] found that there was a constriction of 1.5 cm^2 of the LH area and a reduction of muscle length from 8.7 to 7.9 cm in nulliparous asymptomatic women. Thyer et al. [18] showed a reduction in LH area from 18.9 to 15.4 cm^2 in women consulting a gynecology clinic. Our results on the degree of LH constriction during PFM contraction are somewhat greater than what was found in the above mentioned studies. This may be due to differences in populations and pelvic floor function, but also the actual instruction and verbal motivation to reach maximal voluntary contraction may influence the maximum muscle force and may differ between studies.

Table 3 Constriction of levator hiatus (LH) area during instruction of pelvic floor muscle (PFM) contraction and instruction of transversus abdominis (TrA) contraction in individual participants (N=13)

	PFM instruction (cm^2)	TrA instruction (cm^2)
1	9.10	6.68
2	1.69	1.46
3	3.86	−0.11
4	2.95	0.83
5	4.08	2.73
6	9.77	2.29
7	5.34	4.49
8	2.35	0.14
9	1.75	0.20
10	6.69	−2.03
11	11.56	1.77
12	4.66	3.39
13	3.30	2.38

We have not been able to find other studies investigating a possible closure of the hiatus during TrA contraction. However, other research groups have investigated a possible co-contraction of the PFM during TrA contraction using other measurement methods. Bø and Stien [20], Sapsford and Hodges [21], and Neumann and Gill [22] found a co-contraction of the PFM during TrA contraction measured with different EMG methods. These studies were all investigating healthy women, where such co-contraction is expected and a factor that may explain that they are continent. The sample sizes of the trials were all small (N= 6, 4, 6), and given the small study groups, the results cannot be generalized to the healthy population. Furthermore, they cannot be extrapolated to be valid in women with different types of pelvic floor disorders where the pelvic floor muscles, peripheral nerves, and fascias may be injured and not functioning. The present study also had a small sample size, but it was based on a power calculation, and our results showed that a co-contraction of the PFM during TrA contraction cannot be expected in all women with POP or other pelvic floor disorders.

The results of the present study support the results of a former study [23]. Using suprapubic ultrasound, we found that in 30% of healthy volunteers, there was a downward movement of the pelvic floor during a TrA contraction. Furthermore, in two participants, a voluntary contraction of the PFM on top of the TrA contraction could not counteract the downward movement from the TrA. Contrary to this, Jones et al. [7] found that there was a co-contraction of the TrA in a group of nine SUI women and in 22 healthy volunteers. However, they only reported their results as mean values for the two groups, and we do not know if all the SUI women had a co-contraction.

Previous studies have shown that the lift created by a co-contraction of the PFM during TrA contraction is significantly weaker than what can be utilized with PFM contraction [23, 24]. Bø et al. [23] found that the lift during PFM contraction was almost three times than that occurring during TrA contraction. Dumoulin [24] used MRI to compare bladder neck elevation during contractions of the PFM, TrA, and external rotators of the hip and found that instruction of PFM contraction was 31.4% and 50.8% more effective than instruction to contract TrA and external rotators, respectively. Thompson et al. [25] found that incontinent women displayed greater bladder neck descent than continent women during abdominal curls. In general muscle training, the training needs to be specific both towards the aimed muscle group and muscle action in order to increase muscle volume and strength [26]. Danneels et al. [27] compared low load stabilization training with targeted resistance training of the lumbar muscles and found that only the latter increased the cross-sectional area. They concluded that intensive resistance training of the targeted muscle group seemed to be necessary to restore the size of the muscles in patients with atrophy. The main aims of PFMT is to increase muscle volume, close the levator hiatus, strengthen both the muscle fibers and the connective tissue in and around the musculature to make it stiffer, and to lift the PFM into a higher position inside the pelvis [28]. By changing the morphology, a timed and adequately strong, automatic co-contraction of the PFM may occur during increase in intra-abdominal pressure. Hence, PFMT needs to be specific and target the muscle group that can act on preventing POP and incontinence.

In clinical physical therapy practices, ultrasound or MRI is seldom available, and it is difficult for the physical therapist to observe PFM function during instruction of TrA contraction in a valid way from the outside [14]. The results of the present study do not support the suggestion that there is always a reflex co-contraction of the PFM during TrA contraction. Hence, we do not find a general “justification for facilitation of the PFM via the TrA if the patients are unable to voluntarily contract the PFM” [7]. On the contrary, if a co-contraction is not verified, contraction of the TrA may open up the levator hiatus and push the PFM downwards, thus stretching and weakening the pelvic floor.

Limits of the present study are small sample size to generalize to a larger population and that we were not able to use a second ultrasound at the TrA simultaneously with the perineal ultrasound. However, we followed written recommendations on how to instruct and assess an effective TrA contraction using abdominal palpation [15], and used ultrasound on the TrA on some of the patients in standing to verify correct contraction. Hence, we have made sure that all the participants were able to perform a correct PFM and TrA contraction. Due to practical reasons following our protocol for the RCT investigation, the order of the two instructions in the present study was not randomized. Based on clinical experience and several clinical trials of PFM training and basic studies on PFM contraction, we have, however, no reason to believe that there will be significant fatigue of the PFM after only three contractions, especially when all women were able to perform a correct and coordinated contraction. We made the investigation in standing position as this is where the PFM and TrA muscle should act to resist gravidity. We consider the upright position as a more functional way of assessing PFM function as this is where symptoms of pelvic floor dysfunction such as SUI and POP are experienced. One of the benefits of using 4D perineal ultrasound to measure PFM function is that the assessment can be done in standing position.

So far, there has been only one RCT investigating whether TrA training has an additional effect on PFMT in the treatment of SUI in women [29]. The results did not show any additional effect of adding TrA training to PFMT. The present study showed that there was a co-contraction of the PFM with TrA contraction constricting the levator hiatus in 11 out of 13 women, but to a variable degree ranging from −9.8% to 28.7%. This constriction was significantly less than during a PFM contraction. Whether this is enough to improve PFM function and reduce SUI or POP needs to be evaluated in a RCT.

Conclusions

Instruction of PFM contraction is significantly more effective in reducing the levator hiatus than instruction of TrA contraction in women with POP. In some women with symptoms of pelvic floor dysfunction, contraction of the TrA may open up the hiatus instead of closing it. A significant co-contraction of the PFM cannot be expected during TrA contraction in all women with pelvic floor dysfunction. In clinical practice, indirect training via TrA without confirming that there is a simultaneous and efficient co-contraction of the PFM is therefore not recommended.

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Conflicts of interest None.

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