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ORIGINAL ARTICLE

Pelvic floor muscle training: mechanisms of action for the improvement of genitourinary syndrome of menopause

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ABSTRACT

Objective: This study aims to investigate the mechanism of action of pelvic floor muscle training (PFMT) for the improvement of the signs and symptoms of genitourinary syndrome of menopause (GSM) in postmenopausal women with GSM and urinary incontinence (UI).
Methods: Twenty-nine women were included in the secondary analysis of a single-arm feasibility study. Using color Doppler ultrasound, the peak systolic velocity, time-averaged maximum velocity, and pulsatility index of the internal pudendal and dorsal clitoral arteries were measured at rest and after a pelvic floor muscle (PFM) contraction task. PFM function was assessed by dynamometry, and vulvovaginal tissue elasticity was measured using the Vaginal Atrophy Index.
Results: PFMT significantly improved blood flow parameters in both arteries ($p < 0.05$) and significantly increased the speed of PFM relaxation after a contraction ($p = 0.003$). After the intervention, a marginally significant decrease in PFM tone was observed, as well as an increase in PFM strength ($p = 0.060$ and $p = 0.051$, respectively). Finally, improvements in skin elasticity and introitus width were observed as measured by the Vaginal Atrophy Index ($p < 0.007$).
Conclusion: Our findings suggest that PFMT improves blood flow in vulvovaginal tissues, PFM relaxation capacity, and vulvovaginal tissue elasticity in postmenopausal women with GSM and UI.

Introduction

Genitourinary syndrome of menopause (GSM) is a highly prevalent condition affecting up to 50% of postmenopausal women[1–3]. It is characterized by a collection of genital and urinary signs and symptoms associated with a decrease in estrogen and other sex hormones[4]. The most common GSM symptoms are vaginal dryness, pruritus, dyspareunia, and urinary incontinence (UI)[4]. In a recent single-arm feasibility study, a 12-week pelvic floor muscle training (PFMT) program significantly reduced GSM signs and symptoms in postmenopausal women with UI[5]. After the intervention, 76% of participants reported an improvement of their most bothersome symptom of GSM. Increased secretions on vaginal walls, thicker vaginal epithelial surface, and improved vaginal color were observed through a perineal and vaginal examination and the Vaginal Health Assessment scale.

PFMT refers to exercises that improve pelvic floor muscle (PFM) strength, endurance, power, and/or relaxation[6]. PFMT is taught and monitored by healthcare professionals such as physiotherapists. Mechanisms of action related to the positive effects of PFMT on stress UI have been previously proposed in the literature. First, an intentional, effective PFM contraction (lifting the PFM in a cranial and forward direction), prior to and during effort or exertion, clamps the urethra and increases the urethral pressure, preventing urine leakage[7]. Second, the bladder neck receives support from strong, toned PFMs (resistant to stretching), thereby limiting its downward movement during effort and exertion, thus preventing urine leakage[8]. Although PFMT has been shown to improve symptoms of GSM (vaginal dryness, dyspareunia, and vulvovaginal itching/irritation), the mechanisms of action have never been investigated. This article proposes three hypotheses to explain how PFMT improves GSM signs and symptoms: increased vulvovaginal blood flow; improved PFM function; and increased vulvovaginal elasticity.

Hypothesis 1: increase in vulvovaginal blood flow

Postmenopausal women experience atrophy of blood vessels located in the lamina propria of the vaginal epithelium,

which leads to a reduction of blood flow[9]. It is well recognized that 4–12 weeks of skeletal muscle training increases blood flow in the arteries of trained muscles both at rest and after activation[10]. Since PFM arteries also supply blood to the vulvovaginal tissues[11], PFMT could therefore improve blood flow in these tissues and decrease symptoms of vaginal dryness, dyspareunia, and vulvovaginal itching/irritation in postmenopausal women.

Hypothesis 2: improvement of PFM function

Similarly to premenopausal women with vulvovaginal pain disorders, postmenopausal women with GSM are hypothesized to have increased PFM tone, and reduced PFM strength and coordination[12–14]. Therefore, PFMT could help improve PFM function in postmenopausal women, leading to decreased symptoms of dyspareunia.

Hypothesis 3: increase in vulvovaginal tissue elasticity

Breakdown of collagen and elastin fibers in vulvovaginal tissues occurs with chronic estrogen deprivation in postmenopausal women, leading to loss of vulvovaginal elasticity[15]. PFMT consists of repeated PFM contractions mobilizing different layers of tissues in the pelviperineal structures. PFMT could therefore improve skin or tissue elasticity and increase the introitus opening. These changes could reduce dyspareunia in postmenopausal women with GSM.

This study aims to investigate the mechanisms of action related to the improvement of GSM signs and symptoms after PFMT in postmenopausal women with GSM and UI by testing the three hypotheses. This study will assess the effects of PFMT on vulvovaginal blood flow, PFM function, and vulvovaginal tissue elasticity.

Methods

Study design

This is the secondary analysis of a single-arm feasibility study on the impact of PFMT in women with GSM and UI[5]. Recruitment took place from June 2015 to July 2017 through community advertisements, newspaper adverts, and professional referrals. Participants included women age 55 years and over, who were postmenopausal (with their last menstrual period >12 months ago), reporting GSM symptoms (vaginal dryness, dyspareunia, vulvovaginal itching/irritation, and/or dysuria) in the last 2 weeks, and having symptoms of stress or mixed UI at least three times per week. Participants were assessed by a gynecologist, who confirmed that the participant displayed at least two of the following GSM signs as per Greendale's criteria: petechiae, absent rugae, decreased elasticity, and friability of the vaginal wall[16]. Participants were excluded if they had vulvar dermatological diseases, radiation for gynecological cancer, or a vaginal or urinary infection within the previous 3 months or were taking antiestrogenic medication. Participants were also excluded if they had cognitive impairments, were obese (body mass index $\geq 35\,kg/m^2$),

or had reduced mobility, chronic constipation, or important organ prolapses (Pelvic Organ Prolapse Quantification System >2). Participants using hormonal therapy or vaginal moisturizer were required to have stable dosages for at least 6 months prior to participation in this study to ensure stability of signs and symptoms.

This study received ethical approval from the Institutional Review Board of the Institut universitaire de gériatrie de Montréal (Montreal, Canada) (approval number CER IUGM 12-13-002) and women provided their written consent prior to their participation.

For this study, each participant completed two pre-intervention evaluations (PRE1 and PRE2), a 12-week PFMT program, and a post-intervention evaluation (POST). As psychometric properties have never been investigated in a population of postmenopausal women with GSM, PRE2 was conducted 2 weeks after PRE1 to ensure the stability of the measurement of vulvovaginal blood flow with color Doppler ultrasound. Using vaginal digital palpation, a trained physiotherapist taught participants how to perform a maximal PFM contraction without compensation (gluteal, adductor, and abdominal muscle contraction) at the end of PRE2 to ensure adequate PFM activation during the PFMT program. POST was performed at the end of the 12-week intervention.

Outcome measurements

The following outcome measurements were used to test the three hypotheses before and after the intervention.

Vulvovaginal blood flow

Vulvovaginal blood flow was assessed using color Doppler ultrasound of the main vessel irrigating both the vulvovaginal tissues and the PFM, the internal pudendal artery, and one of its terminal branches, the dorsal clitoral artery. Using a clinical ultrasound system (Voluson E8; GE Healthcare), blood flow measurements of the internal pudendal artery were taken with a 2–7-MHz curved-array probe placed on the participant's right gluteal area, according to Kovacs' procedure[17,18]. For the dorsal clitoral artery, blood flow was measured by placing a 4–13-MHz linear probe latero-laterally on the pubis, according to Khalifé's procedure[19,20]. Doppler measurements of both arteries were taken: three times at rest; and three times after a PFM contraction task[18,20]. For each repetition, the peak systolic velocity, time-averaged maximum velocity, and pulsatility index were collected. Details on the blood flow assessment of the internal pudendal artery and the dorsal clitoral artery have been previously published, and good test–retest reliability has been demonstrated in asymptomatic premenopausal women[18,20].

PFM function

PFM function was assessed with an intravaginal dynamometric speculum (10 mm anteroposterior diameter). The women adopted a supine position with hips and knees flexed, and the lubricated branches of the speculum were inserted into the vaginal cavity. Women were asked to relax their PFMs as

much possible (passive force or tone measurement). Mean resting forces were recorded over 15 s with the speculum branches opened by 1 mm (equivalent to an 11-mm vaginal aperture). The mean of two trials was considered for analysis. PFM maximal strength and speed of relaxation after a rapid PFM contraction were measured at a 20-mm vaginal aperture (equivalent to adding 10 mm of distance between the branches). For the maximal strength measurement, women were instructed to contract their PFM maximally for 10 s. The peak force value minus the baseline value (rest) was considered. For speed of relaxation after a rapid PFM contraction, women were asked to contract maximally and then relax as fast as possible for 15 s. The mean slope of the descending curve of the first contraction was considered. The psychometric properties of this instrument, including its reliability, validity, and responsiveness of its measurements, have been widely investigated in similar populations[21,22].

Vulvovaginal tissue elasticity and global GSM signs

The Vaginal Atrophy Index is a physical examination tool, which assesses the severity of the following six GSM signs: skin elasticity and turgor; pubic hair; labia minora and majora atrophy; introitus width; vaginal mucosa thickness; and vaginal depth[23]. Each of the items is rated with descriptive scales from 1 to 3, or from 1 to 2, with a total score ranging from 6 to 15[23]. Lower scores represent higher severity of GSM signs. Scores for 'skin elasticity and turgor' and 'introitus width' were specially used to investigate the elasticity of vulvovaginal tissues. Good inter-rater reliability has been found with this tool in this population[23].

Intervention protocol

The 12-week PFMT program was composed of weekly 1-h PFMT sessions, supervised by an experienced physiotherapist, and daily home-based PFM exercises (15–20 min). The program included PFM strength, endurance, and coordination exercises as well as functional training. The intervention protocol was divided into three phases, allowing for a gradual progression. The full exercise protocol was published previously[5].

Statistical analysis

Statistical analyses were performed using SPSS software, version 20. For the color Doppler ultrasound results, paired-sample t-tests were first used to assess measurement stability between PRE1 and PRE2. As there was no significant difference between PRE1 and PRE2, a second paired-sample t-test was then used to assess differences between means of measurements for pre-intervention evaluations and measurements for POST. For the results obtained by dynamometry and with the Vaginal Atrophy Index, paired-sample t-tests were computed to assess measurement differences between PRE1 and POST. The statistical significance level of all analyses was $p < 0.05$.

Table 1. Baseline characteristics ($n = 29$).

Parameter	Value
Age (years), mean ± SD	68.0 ± 6.6
Parity, mean ± SD	1.8 ± 1.1
Body mass index, mean ± SD	26.0 ± 4.5
Sexual status, n (%)	
Having intercourse	20 (69%)
No intercourse	9 (31%)
Continence status, n (%)	
Stress urinary incontinence	5 (17%)
Mixed urinary incontinence	24 (83%)
Treatment for GSM, n (%)	
None	19 (66%)
Following treatment[a]	10 (34%)

SD, standard deviation.
[a]Vaginal hormonal therapy (HT), $n = 8$; systemic HT, $n = 2$; non-hormonal vaginal moisturizer, $n = 2$; vaginal and systemic HT, $n = 1$; vaginal HT and non-hormonal vaginal moisturizer, $n = 1$.

Results

Participant demographics are detailed in Table 1. A total of 32 women with a mean age of 68.0 ± 6.6 years were recruited. Three women withdrew from the study for personal reasons (time constraints) but their baseline data did not differ from the other participants. Among the participants having completed the study, 20 (69%) were having sexual intercourse, five (17%) had stress UI, and 24 (83%) had mixed UI. Ten participants (34%) were on stable doses of hormonal therapy for GSM for the full duration of the study, as well as 6 months prior.

Vulvovaginal blood flow

As no significant difference was found between PRE1 and PRE2 for all parameters assessed with color Doppler ultrasound ($p > 0.05$), the mean of the two pre-intervention evaluations was compared with the post-intervention results (POST) (Table 2). Among the data set, 28 out of 29 images (97%) were adequately visualized for analysis of both arteries. After the intervention, peak systolic velocity increased significantly for both arteries at rest (internal pudendal artery, $p = 0.031$; dorsal clitoral artery, $p = 0.040$). A significant increase was also found for the peak systolic velocity parameter of the internal pudendal artery ($p < 0.001$) and for the timed-average maximum velocity of both arteries after the PFM contraction task (internal pudendal artery, $p = 0.010$; dorsal clitoral artery, $p = 0.038$). No significant change was found in the pulsatility index in both conditions.

PFM function

Data from 28 out of 29 women (97%) were available for analysis. After the intervention, dynamometric results showed a significant improvement in the speed of relaxation after a PFM contraction ($p = 0.003$). Furthermore, a marginally significant decrease in passive forces (PFM tone) and an increase in PFM strength were found ($p = 0.060$ and $p = 0.051$, respectively) (Table 3).

Table 2. Change in blood flow at rest and after a PFM contraction task from baseline to week 12 ($n = 28$).

Blood flow parameter	At rest			After a PFM contraction task[a]		
	Mean of pre-intervention evaluations	Post-intervention evaluation	p-Value	Mean of pre-intervention evaluations	Post-intervention evaluation	p-Value
Internal pudendal artery blood flow						
Peak systolic velocity (cm/s)	43.2 ± 8.9	48.6 ± 11.8	0.031[b]	45.8 ± 9.3	56.4 ± 11.0	<0.001[b]
Timed-average maximum velocity (cm/s)	8.1 ± 3.1	8.6 ± 4.3	0.528	9.0 ± 3.9	11.3 ± 4.2	0.010[b]
Pulsatility index	5.8 ± 1.5	6.5 ± 2.1	0.142	5.9 ± 1.5	5.5 ± 1.7	0.401
Dorsal clitoral artery blood flow						
Peak systolic velocity (cm/s)	5.22 ± 0.96	5.97 ± 2.09	0.040[b]	5.51 ± 1.07	6.20 ± 1.90	0.128
Timed-average maximum velocity (cm/s)	1.46 ± 0.77	1.60 ± 1.01	0.418	1.48 ± 0.62	1.82 ± 0.99	0.038[b]
Pulsatility index	4.30 ± 1.28	4.23 ± 1.72	0.840	4.24 ± 1.41	3.95 ± 1.79	0.356

Data presented as mean ± standard deviation. PFM, pelvic floor muscle.
[a]Five 10-s maximal contractions followed by ten 1-s maximal contractions.
[b]Statistically significant ($p < 0.05$).

Table 3. Change in PFM dynamometry and Vaginal Atrophy Index from baseline to week 12.

Parameter	Pre-intervention evaluation	Post-intervention evaluation	p-Value
PFM dynamometry ($n = 28$)			
Passive forces (N)	1.31 ± 0.90	1.07 ± 0.62	0.060
Strength (N)	3.70 ± 2.66	4.20 ± 2.65	0.051
Speed of relaxation (N/s)	−5.26 ± 4.29	−6.78 ± 4.61	0.003[a]
Vaginal Atrophy Index ($n = 29$)			
Total score (/15)	9.93 ± 1.44	11.14 ± 1.48	<0.001[a]
Skin elasticity and turgor (/3)	1.31 ± 0.43	1.90 ± 0.56	<0.001[a]
Pubic hair (/2)	1.39 ± 0.47	1.31 ± 0.47	0.305
Labia minora and majora (/2)	1.31 ± 0.47	1.41 ± 0.50	0.264
Introitus width (/3)	2.31 ± 0.54	2.66 ± 0.48	0.007[a]
Vaginal mucosa thickness (/3)	1.74 ± 0.49	2.03 ± 0.32	0.004[a]
Vaginal depth (/2)	1.85 ± 0.36	1.90 ± 0.31	0.415

Data presented as mean ± standard deviation. PFM, pelvic floor muscle.
[a]Statistically significant ($p < 0.05$).

Vulvovaginal tissue elasticity and global GSM signs

On the Vaginal Atrophy index, GSM signs improved globally after PFMT, as shown by higher total index scores ($p < 0.001$) (Table 3). Furthermore, PFMT generated significant improvements in vulvovaginal tissue elasticity (skin elasticity and turgor, $p < 0.001$; and introitus width, $p = 0.007$). There was also a significant increase in vaginal mucosa thickness ($p = 0.004$). No significant change was found for the other items of the Vaginal Atrophy index (pubic hair, labia minora and majora, and vaginal depth).

Discussion

To our knowledge, this study is the first to explore the potential mechanisms of action explaining the improvement of GSM signs and symptoms in postmenopausal women with UI, after completing a 12-week PFMT program. According to our results, the improvement of GSM signs and symptoms may be related to improved blood flow in the arteries supplying vulvovaginal tissues, improved PFM relaxation capacity, and increased vulvovaginal tissue elasticity.

As hypothesized, blood flow in the internal pudendal artery and the dorsal clitoral artery improved at rest. This implies that more blood goes through the internal pudendal artery and its terminal branches at each cardiac cycle. Training other skeletal muscles has been previously shown to increase blood flow in both the main artery and their terminal branches in postmenopausal women. Nyberg et al. observed increased blood flow velocity at rest in the femoral artery of postmenopausal women after leg muscle training[24].

Gavin et al. found an increased capillary density in the trained muscle (the quadriceps) in the same population[25]. Blood flow of the internal pudendal artery and the dorsal clitoral artery also improved after the maximal PFM contraction task. This implies that those vessels enhanced their capacity of adaptation to meet the muscle's needs after PFM activation. The internal pudendal artery provides blood to the PFM, the vagina, the vulva, the clitoris, and the perineum. Therefore, an increase in blood flow at rest and after PFM activation in this artery should provide more blood to these structures and impact them. This hypothesis is supported by the significant increase in vaginal secretions and improved color of the vaginal epithelium after a PFMT program[5], as well as increased thickness of vaginal mucosa using the Vaginal Atrophy Index. These changes may be related to a reduction in GSM symptoms, such as vaginal dryness and vaginal pruritus.

No change was found for the pulsatility index, although increased peak systolic velocity and timed-average maximum velocity were found for both arteries. The pulsatility index is defined as the difference between the peak systolic and minimum diastolic velocities divided by the timed-average maximum velocity ([peak systolic velocity – end-diastolic velocity] / timed-average maximum velocity). Previous studies found that end-diastolic velocity was often equal to or close to zero[18,20]. Therefore, the increased values of both the numerator and the denominator of the pulsatility index explain why no change in the ratio was found.

Participants demonstrated an improved PFM relaxation capacity after completing the PFMT program. This indicates

that the participants benefitted from increased muscle control after completing the PFMT program. Contraction and relaxation exercises included in the PFMT program may have helped reduce vulvovaginal tissue friction and dyspareunia during intercourse. A reduction in PFM tone and an increase in PFM strength were found at the post-treatment dynamometric assessment. However, these results were non-significant. In previous studies evaluating the impact of PFMT on UI in postmenopausal women, a significant increase in PFM strength was found after 6–12 weeks of training[26–28]. Maximum PFM strength was measured by dynamometric assessment in this study, using maximum PFM force during a contraction minus the baseline value at rest (PFM tone). Postmenopausal women with UI often have lower PFM tone[29], while women with vulvovaginal pain disorders, such as provoked vestibulodynia, have heightened PFM tone[12]. Therefore, the increased variability in the dynamometric assessment and non-significant results in this study may have been caused by participants having either lower or higher PFM tone at baseline. The study's limited sample size may also explain the non-significant results in PFM tone and PFM strength for the dynamometric assessment.

As expected, the PFMT program increased vulvovaginal tissue elasticity and introitus width in postmenopausal women with GSM and UI after the intervention. As shown by Madill et al. with anatomical magnetic resonance imaging, a maximum voluntary PFM contraction lifts the urethrovesical junction by approximately 7 mm[27]. The daily activation of these tissues during a 12-week PFMT program could explain the increased skin elasticity and introitus flexibility after the intervention. These positive effects could lead to a decreased feeling of vaginal tightness in women with GSM.

Strengths, limitations, and further studies

Strengths of this study include the use of reliable and valid outcome measures to explore the three mechanistic hypotheses. Participants were included in the single-arm feasibility study based on medical diagnoses, and PFM contractions were taught individually using vaginal palpation by an experienced physiotherapist. Moreover, the study's evaluator and physiotherapists involved in the intervention were independent to reduce assessment bias.

Limitations of this study included the participation of older women with GSM and UI. Results may therefore not be applicable to women with other symptoms of GSM. Our exclusion criteria could also limit the generalizability of our results, as participants may not be fully representative of postmenopausal women with higher BMI and other comorbidities. Furthermore, our study's limited sample size could have caused the non-significant results for PFM strength and tone in the dynamometric assessment. Further studies should include, to generalize the results to the global population of women with GSM, women of all ages with natural postmenopausal status, regardless of their UI status.

Conclusion

In this study, PFMT was shown to increase blood flow in the arteries supplying vulvovaginal tissues, to improve PFM relaxation capacity, and to increase vulvovaginal tissue elasticity. These changes are observed with the improvement of GSM signs and symptoms in postmenopausal women with GSM and UI. Further studies are needed to better understand their relationship.

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