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Changes in pelvic floor morphometry and muscle function after multimodal physiotherapy for gynaecological cancer survivors suffering from dyspareunia: a prospective interventional study

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Abstract

Objective To investigate the changes in pelvic floor morphometry and muscle function after multimodal pelvic floor physiotherapy treatment in gynaecological cancer survivors suffering from painful intercourse (dyspareunia).

Design Prospective interventional study.

Setting Three university hospitals.

Participants Thirty-one gynaecological cancer survivors with dyspareunia.

Intervention The treatment consisted of 12 weekly sessions of physiotherapy combining education, pelvic floor muscle exercises with biofeedback, manual therapy and home exercises.

Main outcome measures Women were assessed at baseline and post-treatment. Pelvic floor morphometry was evaluated at rest and on maximal contraction by measuring bladder neck position, anorectal and levator plate angles as well as levator hiatal dimensions with three-dimensional/four-dimensional transperineal ultrasound imaging. Pelvic floor muscle function was evaluated by measuring passive forces (muscle tone measure), flexibility, stiffness, strength, coordination and endurance with an intra-vaginal dynamometric speculum.

Results Significant changes in pelvic floor morphometry and muscle function were found post-treatment. The parameters assessing the changes from rest to maximal contraction significantly improved (e.g., mean change of levator hiatal area narrowing 14%, 95% CI 11–18, Cohen's *d* effect size 1.48)), supporting the hypothesis of decreased muscle tone and improved muscle contractility following treatment. Women also presented with a significant decrease in tone (mean change -0.4 N, 95% CI −0.7 to −0.1, Cohen's *d* effect size 0.57) and stiffness

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(mean change −0.1 N/mm, 95% CI −0.2 to −0.1, Cohen's *d* effect size 0.59), as well as significant improvements in flexibility (mean change 9.0 mm, 95% CI 5.8–12.2, Cohen's *d* effect size 1.08), coordination (mean change 3 rapid contractions, 95% CI 2–4, Cohen's *d* effect size 0.85) and endurance (mean change 683%*s, 95% CI 388–978, Cohen's *d* effect size 0.90).

Conclusion Our findings suggest significant improvements in pelvic floor morphometry and muscle function after a multimodal physiotherapy treatment in gynaecological cancer survivors with dyspareunia. These effects may represent key treatment mechanisms to reduce dyspareunia, supporting the rationale for multimodal physiotherapy in this population.

Clinical trial registration number (ClinicalTrials.gov) NCT03935698.

Contribution of the Paper

- This is the first study to investigate the pelvic floor morphometry and muscle function changes following a multimodal pelvic floor physiotherapy treatment in gynaecological cancer survivors with dyspareunia.
- A significant reduction in pelvic floor muscle tone and stiffness as well as a significant increase in tissue flexibility, coordination and endurance were found post-treatment.
- Findings support the rationale for multimodal pelvic floor physiotherapy in gynaecological cancer survivors with dyspareunia as it targets pelvic floor muscle alterations.

Keywords: Cancer survivors; Dyspareunia; Pelvic floor; Physical therapy; Women's health

Introduction

Pain during sexual intercourse, also known as dyspareunia, is a common sexual complaint among gynaecological cancer survivors [1]. Even though it affects more than half of these women [2,3], dyspareunia in this population remains an understudied condition with a complex etiology. Surgery, radiation therapy and chemotherapy often impair hormonal, neurological, vascular and muscle function, contributing to pain during intercourse [4,5]. For instance, vaginal atrophy, which refers to stenosis, loss of tissue elasticity and dryness, may contribute to dyspareunia in this population [3,6]. Evidence extracted from a recent cross-sectional study is pointing toward a muscular etiological mechanism as alterations in pelvic floor morphometry and muscle function were found [7]. Gynaecological cancer survivors affected by dyspareunia presented with smaller levator hiatal dimensions at rest and lower changes from rest to maximal contraction using three-dimensional/four-dimensional transperineal ultrasound imaging, suggesting elevated pelvic floor muscle tone and altered contractile properties in comparison with asymptomatic women [7]. Assessed with an intravaginal dynamometric speculum, women with dyspareunia also showed an elevated muscle tone with greater stiffness as well as lower flexibility, coordination and endurance [7].

Given the involvement of altered pelvic floor morphometry and muscle function in dyspareunia in women who had been treated for gynaecological malignancies [7], a multimodal pelvic floor physiotherapy treatment could be effective for this population. Through education, exercises and manual therapy, this treatment may prove helpful in restoring muscle properties and, hence, reducing dyspareunia [8]. Data from young women with no history of cancer suggest that a physiotherapy treatment targeting pelvic floor muscle alterations effectively reduces pain during intercourse [9]. However, the effects of a physiotherapy treatment on these muscles may differ in gynaecological cancer survivors as they may present with more significant impairments [7]. A systematic review showed indeed that oncological treatments significantly alter the pelvic floor musculature [10]. To date, it is unknown whether a multimodal physiotherapy treatment can improve pelvic floor morphometry and muscle function in women with a history of gynaecological cancer. Therefore, the objective of this prospective interventional study was to investigate the potential changes in pelvic floor morphometry and muscle function after multimodal pelvic floor physiotherapy in gynaecological cancer survivors suffering from dyspareunia.

Method

Design

This is a multicenter prospective interventional study investigating the effects of a multimodal pelvic floor physiotherapy treatment in 31 gynaecological cancer survivors with dyspareunia. The data on feasibility, acceptability, pain, sexual function, pelvic floor dysfunction symptoms and their impact on the quality of life [11] and psychosexual outcomes [12] have been published elsewhere. This study focuses on the treatment effects on the pelvic floor muscles. The study took place in Sherbrooke and Montreal (Canada) and was approved by the institutional ethics committee and was registered at ClinicalTrials.gov (NCT03935698).

Participants

Women were included if they had been treated for endometrial or cervical cancer (stages I to IV) and had completed their oncological treatments for at least three months. They had to

experience vulvovaginal pain at a minimal intensity of five on a Numerical Rating Scale (ranging from 0 to 10) in more than 80% of sexual intercourse attempts, for at least three months. One of the gynaecologic oncologists of the research team performed a standardized gynaecological examination to rule out painful conditions (e.g., vaginitis, cystitis or dermatitis) that could be treated by standard medical care. Other eligibility criteria are presented in detail elsewhere [11].

Intervention

The multimodal pelvic floor physiotherapy treatment consisted of 12 weekly one-hour sessions [11]. All sessions, delivered individually and face to face, were conducted by an experienced and certified physiotherapist in pelvic health. The treatment combined education, pelvic floor muscle exercises with electromyography biofeedback (Evadri, Hollister, Biomation, Canada) using a small intra-vaginal probe, manual therapy and home exercises to reflect clinical practice. The pelvic floor muscle exercises aimed to promote relaxation, contraction, coordination and endurance. A relaxation period preceded and followed the exercises that included maximal contractions (100%), podium contractions (100%/50% of maximal voluntary contractions/100%) or reversed podium contractions (50%/100%/50%), rapid contractions and one-minute sustained maximal contraction. Women performed these exercises in a lying position (week 1 to week 8) followed by a sitting (week 9 and week 10) and a standing position (week 11 and week 12). The number of repetitions and the duration of the contraction were increased from session to session (e.g., up to 10 repetitions of 10-second maximal contractions, two times). Manual therapy comprised stretching, myofascial release, trigger/tender point pressure and massage. These techniques were applied externally and intravaginally to the pelvic floor muscles to increase flexibility, release muscle tension and trigger points. The home exercises were similar to those performed using biofeedback under supervision and were prescribed five times/week. In addition, participants were asked to use their finger or graded vaginal dilators for insertion and vulvar vestibule desensitization exercises, which were performed three times/week. Modalities were adapted to each participant (e.g., amount of pressure applied) and progressed throughout the 12 sessions (e.g., one to two fingers, more pressure or stretching applied). The treatment protocol is available elsewhere [11].

Outcome measures

Women were assessed at baseline and after treatment by an experienced physiotherapist not involved in the participant's treatment. A structured interview was undertaken to gather sociodemographic and medical data. Prior to conducting the assessment of pelvic floor morphometry and muscle function, women were asked to empty their bladder. Subsequently, the physiotherapist used instructions and digital palpation to teach the participant how to perform contraction and relaxation correctly. Measurements were taken in a supine position, with hips and knees flexed at a 90° angle, and feet flat on a conventional examining table.

Pelvic floor morphometry was evaluated with three-dimensional/four-dimensional transperineal ultrasound imaging using a Voluson E8 Expert BT10 device (GE Healthcare) equipped with a RM6C convex probe. Images were taken at rest and on maximal pelvic floor muscle contraction. Each condition was recorded twice and the recording presenting the smallest hiatal dimensions was considered for analysis. Ultrasound data were analyzed offline with software (4D View, Version 10.2; GE Healthcare) and parameters were acquired in the mid-sagittal and axial planes (Fig. 1) [13–17]. In the mid-sagittal plane, the bladder neck position was measured on the horizontal axis (x-axis) and the vertical axis (y-axis) in cm using the inferior and posterior margins of the pubic symphysis as the reference point. The anorectal angle (°) was measured as the angle between the longitudinal axis of the anal canal and the posterior rectal wall. The levator plate angle (°) was assessed as the angle formed by a horizontal line relative to the reference point of the pubic symphysis and a line drawn from this reference point to the crux of the anorectal angle. In the axial plane, minimal levator hiatal dimensions delimited laterally and posteriorly by the puborectalis muscle and anteriorly by the pubic symphysis margin were measured. Levator hiatal dimensions included levator hiatal area (cm^2), levator hiatal anterior-posterior diameter (cm), and the levator hiatal left-right diameter (cm). The excursion (i.e., magnitude of change in position) of every parameter was computed by subtracting the value at rest from the value at maximal contraction to assess the pelvic floor morphometry changes from rest to maximal contraction. Bladder neck cranial displacement ($y\text{-axis}_{contraction} - y\text{-axis}_{rest}$), ventral displacement ($x\text{-axis}_{contraction} - x\text{-axis}_{rest}$) and ventrocranial displacement ($\sqrt{[\text{cranial displacement}^2 + \text{ventral displacement}^2]}$), excursion of anorectal and levator plate angles ($\text{angle}_{rest} - \text{angle}_{contraction}$), levator hiatal area narrowing, levator hiatal anterior-posterior diameter and left-right diameter reduction ($[\text{measurement}_{rest} - \text{measurement}_{contraction}]/\text{measurement}_{rest} \times 100$) were calculated. All these pelvic floor morphometry parameters were shown to be valid, reliable and sensitive to change in previous studies [14,15,17–22]. In addition, the total vaginal length (cm) was taken at rest following the methodology of the Pelvic Organ Prolapse — Quantification system [23]. Vaginal atrophy was assessed with the Vaginal Atrophy Index, which comprises subscales to evaluate skin elasticity and turgor, pubic hair, labia, introitus, vaginal mucosa thickness and rugosity as well as vaginal depth [24]. The total score ranges from 6 to 15, with lower scores suggesting greater signs of vaginal atrophy (clinical cut-off score characterizing severe vaginal atrophy ≤ 11) [24].

Pelvic floor muscle function was assessed by measuring several parameters using an intra-vaginal dynamometric speculum (Fig. 2) [25–29]. This instrument consists of two parallel branches; the upper branch is fixed; the lower branch

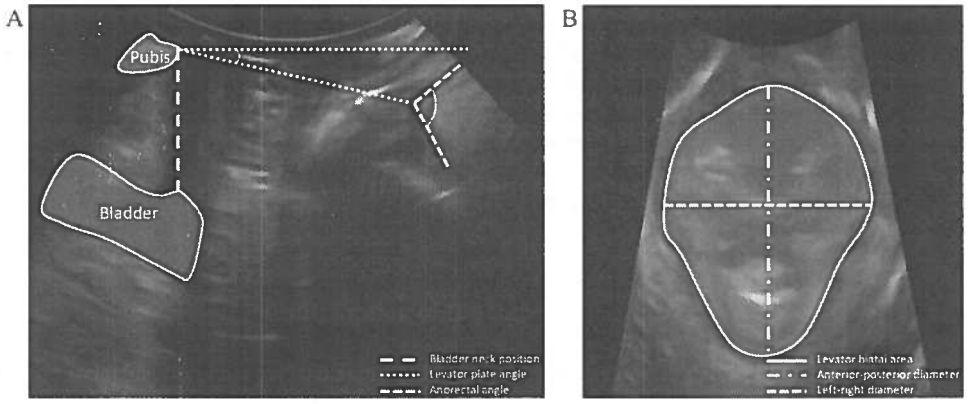

Fig. 1. Pelvic floor morphometry parameters as assessed with transperineal ultrasound imaging. A: Mid-sagittal plane. B: Axial plane.

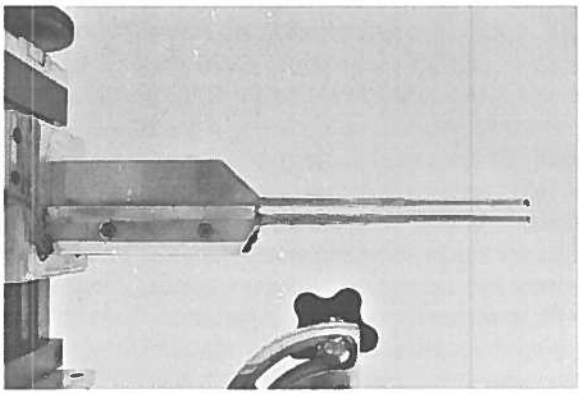

Fig. 2. Intra-vaginal dynamometric speculum set to minimal aperture.

is adjustable, which allows for measurements at different vaginal apertures. The branches were covered with nitrile and lubricated prior to insertion in the vaginal cavity. Women were then asked to perform three unrecorded pelvic floor muscle contractions for familiarization with the instrument. Passive forces (i.e., muscle tone) (N) were measured at minimal aperture (i.e., 11-mm anterior–posterior diameter) and at maximal aperture. The latter was determined by the participant's tolerance and served as a measure of tissue flexibility (mm). Five stretch-relax cycles were performed by separating the branches up to maximal aperture (i.e., lengthening phase) and then, closing back to minimal aperture (i.e., shortening phase) at a constant speed of 5 mm/s. This allowed the measurement of the passive forces (N) and the passive elastic stiffness at an aperture of 15 mm (change in forces/change in vaginal aperture; N/mm). The aperture corresponding to 2 N passive forces (mm) and the hysteresis (N × mm), which represents the loss of energy between the lengthening and shortening phases, were also measured. Pelvic floor muscle contractile properties were assessed during 3 different tests: (i) 10-second maximal contraction to measure maximal strength (N); (ii) 15-second rapid-repeated maximal contractions to measure coordination, described as the number of rapid contractions and speed of contraction (N/s); and (iii) 90-second sustained maximal contraction to measure endurance, defined as the normalized area (N*s) under the force curve (N) ([area/maximal force] × 100) (%*s). These parameters were shown to be valid, reliable and sensitive to change [25–29].

Data analysis

A study sample size of 27 participants [11] allowed a power of at least 99% to detect changes from baseline to post-treatment (for muscle function parameters) at a significance level of $\alpha = 0.05$, with the minimal detectable differences corresponding with the findings of reliability studies [25,27–29] and variance based on the effects of a multimodal physiotherapy treatment for women with dyspareunia but without a history of cancer [30].

Version 25.0 of IBM SPSS Statistics software (IBM Corp., Armonk, N.Y., USA) was used to perform the statistical tests. The normality of data distribution was verified by visual inspection and the Shapiro–Wilk test. Continuous variables were expressed as mean (standard deviation SD) or median (first quartile Q1; third quartile Q3), and categorical variables as the number (n) of participants (% of the total group). Paired t-tests or Wilcoxon signed-rank tests for the continuous variables and McNemar's or McNemar–Bowker's tests for the categorical variables (i.e., vaginal atrophy) were carried out to evaluate the changes from baseline to post-treatment in pelvic floor morphometry and muscle function. The 95% confidence interval (CI) of the changes is also presented. Effect sizes were calculated as $Cohen's\ d = \frac{mean\ of\ the\ differences}{standard\ deviation\ of\ the\ differences}$ (0.2 = small effect, 0.5 = medium effect, 0.8 = large effect) [31]. A p-value of <0.05 was interpreted as indicating a statistically significant change.

Results

Participants

Of the 31 women recruited, 28 completed the post-treatment assessment, one withdrew from the study (illness in the family) and two were lost at follow-up. The participants

Table 1
Pelvic floor morphometry changes from baseline to post-treatment (three-dimensional/four-dimensional transperineal ultrasound imaging).

	Baseline ($n=31$)	Post-treatment ($n=28$)	Changes from baseline ($n=28$)		P	Effect size (d)
	Mean (SD)	Mean (SD)	Mean (SD)	95% CI		
Rest						
Bladder neck position – x-axis (cm)	−0.2 (0.4)	−0.1 (0.5)	0.1 (0.5)	−0.1 to 0.3	0.50	0.13
Bladder neck position – y-axis (cm)	3.0 (0.5)	3.0 (0.5)	0 (0.2)	−0.1 to 0.1	0.70	0.07
Anorectal angle (°)	106.8 (9.8)	112.6 (8.9)	7.5 (6.3)	5.0 to 9.9	**<0.001**	1.19
Levator plate angle (°)	23.6 (6.6)	20.0 (6.6)	−3.9 (4.7)	−5.7 to −2.1	**< 0.001**	0.83
Levator hiatal area (cm^2)	13.4 (3.0)	15.4 (3.4)	2.0 (2.5)	1.0 to 2.9	**< 0.001**	0.80
Levator hiatal anterior-posterior diameter (cm)	5.2 (0.8)	5.5 (0.8)	0.3 (0.4)	0.1 to 0.5	**<0.001**	0.70
Levator hiatal left-right diameter (cm)	3.5 (0.4)	3.8 (0.5)	0.3 (0.3)	0.2 to 0.4	**<0.001**	0.96
Maximal contraction						
Bladder neck position – x-axis (cm)	−0.7 (0.4)	−0.9 (0.6) ($n=27$)[a]	−0.2 (0.5) ($n=27$)[a]	−0.4 to −0.1	**0.032**	0.44
Bladder neck position – y-axis (cm)	3.2 (0.5)	3.3 (0.5) ($n=27$)[a]	0.1 (0.3) ($n=27$)[a]	0.1 to 0.3	**0.029**	0.44
Anorectal angle (°)	101.9 (8.7)	98.7 (5.9) ($n=27$)[a]	−2.6 (7.8) ($n=27$)[a]	−5.7 to 0.5	0.10	0.33
Levator plate angle (°)	32.2 (6.6)	32.5 (8.4) ($n=27$)[a]	0.6 (4.7) ($n=27$)[a]	−1.3 to 2.5	0.51	0.13
Levator hiatal area (cm^2)	10.7 (2.1) ($n=30$)[a]	10.2 (2.2) ($n=27$)[a]	−0.6 (1.3) ($n=27$)[b]	−1.1 to −0.1	**0.032**	0.44
Levator hiatal anterior-posterior diameter (cm)	4.3 (0.7)	4.2 (0.6) ($n=27$)[a]	−0.1 (0.3) ($n=27$)[a]	−0.2 to −0.1	**0.022**	0.47
Levator hiatal left-right diameter (cm)	3.3 (0.4) ($n=30$)[a]	3.3 (0.4) ($n=27$)[a]	0 (0.3) ($n=27$)[a]	−0.2 to 0.1	0.46	0.14
Excursion						
Ventral displacement – x-axis (cm)	−0.6 (0.4)	−0.8 (0.4) ($n=27$)[a]	−0.3 (0.3) ($n=27$)[a]	−0.4 to −0.1	**<0.001**	0.74
Cranial displacement – y-axis (cm)	0.2 (0.2)	0.3 (0.3) ($n=27$)[a]	0.1 (0.2) ($n=27$)[a]	0.1 to 0.2	**0.011**	0.52
Ventrocranial displacement (cm)	0.6 (0.4)	0.9 (0.4) ($n=27$)[a]	0.3 (0.3) ($n=27$)[a]	0.1 to 0.4	**<0.001**	0.79
Anorectal angle excursion (°)	4.9 (5.8)	14.0 (8.3) ($n=27$)[a]	10.2 (10.0) ($n=27$)[a]	6.3 to 14.2	**<0.001**	1.02
Levator plate angle excursion (°)	8.6 (5.9)	13.5 (8.3) ($n=27$)[a]	5.5 (7.4) ($n=27$)[a]	2.6 to 8.4	**<0.001**	0.74
Levator hiatal area narrowing (%)	18.9 (9.2) ($n=30$)[a]	32.9 (10.1) ($n=27$)[a]	14.4 (9.8) ($n=27$)[a]	10.6 to 18.3	**<0.001**	1.48
Levator hiatal anterior–posterior diameter reduction (%)	15.9 (9.5)	22.4 (9.6) ($n=27$)[a]	7.2 (6.5) ($n=27$)[a]	4.7 to 9.8	**<0.001**	1.12
Levator hiatal left-right diameter reduction (%)	3.7 (4.7) ($n=30$)[a]	12.9 (7.8) ($n=27$)[a]	9.0 (7.9) ($n=27$)[a]	5.9 to 12.2	**<0.001**	1.15

CI: confidence interval, SD: standard deviation.
Note: Statistically significant values are in bold.
[a] Data of one participant was not recorded.

who did not complete the post-treatment assessment were not different from those who did complete the assessment. The mean age of the participants was 55.9 (SD = 10.8) years. The body mass index was 28.5 (SD = 5.3) kg/m^2. Regarding their medical history, 58% had given birth while 13% were using postmenopausal hormone therapy that remained unchanged throughout the study. The endometrium (65%) and cervix (36%) were the primary cancer sites. Stages of cancer were diagnosed as either I (61%), II (19%), III (16%), or IV (3%). Among the 31 women, nine women (29%) had only surgery, six (19%) had surgery + external beam radiation therapy or brachytherapy, seven (23%) had surgery + external beam radiation therapy + brachytherapy + chemotherapy, two (6%) had surgery + chemotherapy, and there were seven women (23%) who had external beam radiation therapy + brachytherapy + chemotherapy. It should be noted that 15 (48%) and 19 (61%) participants received external beam radiation therapy and brachytherapy, respectively. The median time since the last oncological treatment was 38 (Q1 = 9; Q3 = 70) months. The attendance rate (i.e., average proportion of completed treatment sessions) was 93% (SD = 21), and 29/31 (94%) women attended ≥10 sessions. The adherence rate to home exercises (i.e., average proportion of completed exercises according to a diary filled out by participants) was 88% (SD = 10). Further details on participant characteristics or adherence are described and discussed elsewhere [11].

Outcome measures

Table 1 summarizes the changes in pelvic floor morphometry using ultrasound imaging from baseline to post-treatment. At rest, the anorectal angle and the levator hiatal dimensions increased while the levator plate angle decreased ($P < 0.001$, effect size $d \geq 0.70$), suggesting a reduction in muscle tone. On maximal contraction, the bladder neck was positioned more cranially and ventrally after treatment ($P \leq 0.032$, $d \geq 0.44$). Moreover, a reduction in levator hiatal area and levator hiatal anterior-posterior diameter was found from baseline to post-treatment on maximal contraction ($P \leq 0.032$, $d \geq 0.44$), which is suggestive of improved pelvic floor muscle contractility. The excursion from rest to maximal contraction significantly increased following treatment ($P \leq 0.011$, $d \geq 0.52$), supporting the hypothesis of a decrease in pelvic floor muscle tone and an improvement in the contractility of the muscles. In addition, an increase in vaginal length was found (baseline: 7.5 (Q1 = 6.5; Q3 = 8.5) cm and post-treatment: 8.5 (Q1 = 7.0; Q3 = 9.0) cm) ($P < 0.001$). Based on the Vaginal Atrophy Index, fewer women presented significant signs

Table 2
Pelvic floor muscle function changes from baseline to post-treatment (intra-vaginal dynamometric speculum).

	Baseline ($n=30$)[a]	Post-treatment ($n=28$)	Changes from baseline ($n=28$)		P	Effect size (d)
	Mean (SD)	Mean (SD)	Mean (SD)	95% CI		
Initial passive resistance at minimal vaginal aperture (11-mm aperture)						
Passive forces (N)	1.5 (0.6)	1.2 (0.6)	−0.4 (0.7)	−0.7 to -0.1	**0.006**	0.57
Passive resistance at maximal vaginal aperture						
Passive forces (N)	9.4 (4.4)	13.5 (5.8)	3.8 (5.4)	1.7 to 5.9	**<0.001**	0.71
Maximal aperture (mm)	22.6 (8.1)	31.7 (8.0)	9.0 (8.3)	5.8 to 12.2	**<0.001**	1.08
Dynamic stretches during lengthening and shortening cycles						
Passive forces at 15-mm aperture (N)	2.0 (1.3)	1.4 (0.7) ($n=26$)[b]	−0.6 (1.2) ($n=26$)[b]	−1.1 to −0.1	**0.017**	0.50
Passive elastic stiffness at 15-mm aperture (N/mm)	0.4 (0.2)	0.3 (0.2) ($n=26$)[b]	−0.1 (0.2) ($n=26$)[b]	−0.2 to −0.1	**0.006**	0.59
Vaginal aperture at a common force of 2 N (mm)	16.2 (2.7)	18.8 (4.0) ($n=26$)[b]	2.5 (4.1) ($n=26$)[b]	0.8 to 4.1	**0.005**	0.61
Hysteresis (N × mm)	59.3 (57.1)	126.3 (83.4) ($n=26$)[b]	62.7 (72.8) ($n=26$)[b]	33.3 to 92.1	**<0.001**	0.86
10-second maximal contraction						
Maximal strength at 15-mm aperture (N)	4.4 (2.3)	5.1 (2.4)	0.7 (2.6)	−0.2 to 1.7	0.13	0.36
15-second rapid-repeated maximal contractions						
Number of contractions	7 (2)	10 (4)	3 (4)	2 to 4	**<0.001**	0.85
Ascending slope	6.5 (6.4)	9.1 (6.8)	3.1 (6.2)	0.7 to 5.6	**0.012**	0.51
Descending slope	−6.2 (5.0)	−8.5 (6.5)	−2.4 (5.4)	−4.5 to −0.3	**0.027**	0.44
90-second sustained maximal contraction						
Endurance on 50 seconds (%*s)	1771 (761)	2404 (707)	683 (760)	388 to 978	**<0.001**	0.90

CI: confidence interval, SD: standard deviation.
Note: Statistically significant values are in bold.
[a] One participant was not able to complete the assessment due to pain.
[b] Two recordings were not saved appropriately and resulted in outliers misleading the interpretation.

of vaginal atrophy after treatment according to the total score ($P=0.002$). More specifically, significant changes were observed in the subscales evaluating skin elasticity and turgor, vaginal mucosa thickness and rugosity as well as vaginal depth ($P \leq 0.029$).

Table 2 depicts the changes in pelvic floor muscle function as assessed with the intra-vaginal dynamometric speculum from baseline to post-treatment. Participants showed a decrease in pelvic floor muscle passive forces at minimal aperture ($P=0.006$, $d=0.57$), suggesting a reduction in muscle tone. According to the maximal aperture obtained, an increase in tissue flexibility ($P<0.001$, $d=1.08$) was found. This was observed in conjunction with increased passive forces ($P<0.001$, $d=0.71$), which is in line with the force-muscle length relationship [29]. Regarding the parameters recorded during the five stretch-relax cycles, there was a significant reduction in forces and stiffness measured at 15-mm aperture as well as a significant increase in the aperture to reach 2 N of forces and hysteresis ($P \leq 0.017$, $d \geq 0.50$). Coordination and endurance also improved significantly after treatment ($P \leq 0.027$, $d \geq 0.44$). However, there was no statistically significant change in pelvic floor muscle strength.

Discussion

This is the first study that has investigated the effects of a multimodal pelvic floor physiotherapy treatment on pelvic floor morphometry and muscle function in gynaecological cancer survivors with dyspareunia. Although the study design does not allow for comments on causation, results suggest significant improvements inpelvic floor morphometry and muscle function as women showed substantial changes from baseline to post-treatment. Data related to ultrasound imaging suggested a reduction in muscle tone and improvements in pelvic floor muscle contractile properties after treatment. In line with these results, measurements of the intra-vaginal dynamometric speculum demonstrated a decrease in muscle tone and stiffness as well as improvements in tissue flexibility, coordination and endurance. An increase in vaginal length and fewer signs of vaginal atrophy following treatment were also discerned.

Pelvic floor muscle tone was greatly reduced after treatment with medium to large effect sizes, which underscores the significance of this change. Tissue flexibility, as evaluated from the maximal tolerated aperture between the two speculum branches, also increased substantially with a large-effect size. A significant reduction in stiffness, with medium effect size, and improvement in pelvic floor muscle response to stretching (i.e., hysteresis), with large effect size, were also observed. Our data could not be compared to other interventional studies in gynaecological cancer survivors given that no work to date has examined treatment effects on muscle outcomes. The results are in accordance with those of a prospective study investigating an eight-session multimodal physiotherapy intervention in younger women suffering from

dyspareunia with no history of cancer [32]. Nonetheless, the authors used digital palpation to assess pelvic floor muscle tone, which has been criticized for its subjectivity and lack of reliability [33]. The instruments for the current study were therefore selected to enable robust evidence by overcoming the limitations related to palpation. Moreover, an increase in vaginal length and fewer signs of vaginal atrophy were noticed after treatment as compared to baseline. Similar effects were reported in a narrative review investigating dilation programs in women who underwent radiation therapy [34]. However, the assessment tools used in the previous studies were not described or were non-validated measures as opposed to the objective measurements taken in the present study [34–36]. Previous research was also conducted in women almost immediately after radiation therapy who did not necessarily suffer from dyspareunia [34–36]. Overall, our findings suggest that the passive properties of the pelvic floor muscles and vaginal dimensions improved while vaginal atrophy decreased after treatment. These changes may contribute to successful (i.e., unpainful and complete) vaginal intercourse [37]. It could be hypothesized that these changes may result from the cumulative and combined effects of the multiple modalities used, including exercises with and without biofeedback emphasizing muscle relaxation and motor control, dilator use and manual therapy techniques [38].

Additionally, improvements in pelvic floor muscle contractile properties, including coordination and endurance, with small to large effect sizes were observed. Although coordination and endurance have never been assessed in gynaecological cancer survivors after a physiotherapy treatment, our results are in line with a study evaluating an intervention that comprised pelvic floor muscle exercises to reduce urinary incontinence in women with no history of cancer [39]. The authors also found an increase in number of contractions, speed of contraction and endurance following treatment, as assessed with the intra-vaginal dynamometric speculum [39]. In contrast to Cacciari *et al.* [39], no significant change in pelvic floor muscle maximal strength was observed in the current study. This was expected as our treatment protocol emphasized muscle relaxation and motor control rather than strength training. The type of exercises may therefore explain the changes obtained in muscle function. Furthermore, Gentilcore-Saulnier *et al.* [32] showed no change in pelvic floor muscle activity at maximal contraction, as measured with electromyography, but increased maximal strength, as assessed with digital palpation, after a physiotherapy intervention in younger women with dyspareunia and no history of cancer. As electromyography measures can be influenced by confounding factors such as vaginal dimensions [40,41] and palpation has been criticized [33], this stresses the importance in selecting valid measures and in using more than one instrument to comprehensively evaluate muscle properties.

A major strength of this study was the use of an objective and comprehensive assessment of pelvic floor morphometry and muscle function using robust instruments. The main limitation of the study is the absence of a control group, which restricts causal inference. It is worth mentioning that the treatment was specifically designed to target the muscle alterations found in gynaecological cancer survivors [7]. As these impairments improved following treatment, this suggests that multimodal physiotherapy could have led to the effects obtained. Nevertheless, a randomized controlled trial is needed to confirm our findings. This study should include an appropriate sample size with sufficient representation of the different oncological treatments, as each appears to have distinct effects on the tissues which could influence treatment efficacy. It should be underlined that there is currently no minimal clinically important difference or normative data available to compare our measures to determine whether the treatment was meaningful in modifying pelvic floor morphometry and muscle function. However, the average change in passive forces at minimal vaginal aperture, tissue flexibility, number of rapid contractions, speed of contraction and endurance exceeded the error measure (i.e., standard error of measurement) [25,27–29].

Conclusion

Our findings suggest significant improvements in pelvic floor morphometry and muscle function after a multimodal pelvic floor physiotherapy treatment in gynaecological cancer survivors with dyspareunia. These changes may represent key treatment mechanisms to reduce dyspareunia as they relate to the etiology of dyspareunia after gynaecological cancer. This study supports the rationale for physiotherapy in this population. A future randomized controlled trial is necessary to confirm our conclusions.

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