Pelvic-Floor Properties in Women Reporting Urinary Incontinence After Surgery and Radiotherapy for Endometrial Cancer

Stéphanie Bernard, Hélène Moffet, Marie Plante, Marie-Pier Ouellet, Jean Leblond, Chantale Dumoulin

S. Bernard, PT, MSc, Department of Rehabilitation, Faculty of Medicine, Université Laval, Québec, Québec, Canada, and Center for Interdisciplinary Research in Rehabilitation and Social Integration, Québec, Québec, Canada.

H. Moffet, PT, PhD, Department of Rehabilitation, Faculty of Medicine, Université Laval, and Center for Interdisciplinary Research in Rehabilitation and Social Integration. Address all correspondence to Dr Moffet at: Helene.Moffet@rea.ulaval.ca.

M. Plante, MD, Department of Gynecologic Oncology, University Hospital of Québec City, Québec, Québec, Canada.

M.-P. Ouellet, MD, Faculty of Medicine, Université Laval, and University Hospital of Québec City.

J. Leblond, PhD, Center for Interdisciplinary Research in Rehabilitation and Social Integration.

C. Dumoulin, PT, PhD, School of Rehabilitation, Faculty of Medicine, Université de Montréal, Montréal, Québec, Canada, and Research Centre of Institut Universitaire de Gériatrie de Montréal, Montréal, Québec, Canada.

[Bernard S, Moffet H, Plante M, et al. Pelvic-floor properties in women reporting urinary incontinence after surgery and radiotherapy for endometrial cancer. *Phys Ther*. 2017;97:438–448.]

Published Ahead of Print: February 15, 2017
Accepted: December 11, 2017
Submitted: February 25, 2016

Background. Endometrial cancer is the fourth most prevalent cancer in Canadian women. Radiotherapy (RT) is frequently recommended as an adjuvant treatment. There is a high prevalence (>80%) of urinary incontinence (UI) after RT. It is plausible that UI is associated, at least in part, with alterations of the pelvic-floor muscles (PFM).

Objective. The aim of this exploratory study was to compare the PFM functional properties of women reporting UI after hysterectomy and RT for endometrial cancer with those of women with a history of hysterectomy but without UI.

Design. A descriptive cross-sectional study was conducted. Eleven women were recruited for the affected group, and 18 were recruited for the comparison group.

Methods. Urogenital and bowel functions were assessed using International Consultation on Incontinence Questionnaires, and PFM properties were evaluated using a Montreal dynamometer. Nonparametric tests were used for comparison of personal characteristics, functional status, and muscle properties. A correspondence analysis detailed the association between UI severity and PFM properties.

Results. Maximal opening of dynamometer branches, maximal vaginal length, PFM maximum force and rate of force development in a strength test, and number of rapid contractions during a speed test were reduced in the affected group. No significant difference was found for the endurance test. The severity of UI was found to correspond to the rate of force development and the number of rapid contractions in a speed test, endurance, age, and vaginal length.

Limitations. The results are limited to the population studied. The small sample size limited the strength of the conclusions.

Conclusions. Some evidence of alterations in PFM properties were found in women with UI after hysterectomy and RT for endometrial cancer. These alterations appeared to be associated with UI, suggesting a possible role for rehabilitation.

Each year in Canada, more than 9,000 women receive a diagnosis of gynecological cancer, including uterine, cervical, and ovarian malignancies.[1] Accounting for 6.5% of all new cancer diagnoses, uterine cancer is now the fourth most prevalent cancer in Canadian women.[1] The prevalence rate for endometrial cancer has shown an increase of greater than 2% per year since 2004;[2] this cancer is now the third most important cancer responsible for the increase in the overall cancer incidence in women.[1] Treating endometrial cancer can involve many different modalities; surgery, radiotherapy (RT), and chemotherapy are the most frequently used treatments.[3–5] The choice of modality is determined by several factors, including staging and grading of the cancer itself, patient's age, and risk of recurrence. The primary intervention for endometrial cancer in the early stage[6] is surgery (hysterectomy), while RT and chemotherapy are most often reserved for more locally advanced cancers or for patients assessed as having a higher risk of recurrence on the basis of histopathological features.[4]

These interventions are not without consequences; soft-tissue lesions and urogenital dysfunctions have been frequently described in the literature, especially following RT.[7] Patients with gynecological cancer often demonstrate vaginal agglutination, vaginal stenosis, and vaginal length shortening after oncology treatments.[8–11] Dyspareunia especially has been associated with vaginal atrophy and dryness following RT.[12] Functionally, many Pelvic-floor dysfunctions have been observed: urinary incontinence (UI) and urgency, sexual dysfunctions, and fecal incontinence and urgency.[12–14] These dysfunctions bring much distress to women who have survived cancer: decreased participation in activities of daily living and in social activities and, consequently, a decrease in overall quality of life.[9,13,15–18] With the decreasing mortality rate, most patients live for several years with treatment-related morbidity.[15]

In women without cancer, such urogenital dysfunctions are often associated with changes in the function of the pelvic-floor muscles (PFM).[19] Radiation-induced alterations in the muscle tissue of the pelvic floor of patients treated for pelvic malignancies have been reported before, but only scarcely for gynecological cancers. Indeed, in a review of the effects of RT on the PFM, only 2 studies documented these effects in patients with cervical cancer.[20] The first of these 2 studies was by Yeoh et al,[21] who measured the maximal thickness of the anal sphincter by anorectal manometry and found no differences between patients and people who were healthy (controls). The other study retrieved by this review was by Noronha et al,[22] who found no difference in the digitally measured maximal strength of the PFM between the surgical group and the RT group. However, additional chi-square analyses of the results revealed an interesting higher proportion of low-grade values (0/5 and 1/5 according to the Oxford scale) for maximal PFM strength during the manual muscle testing in the group that had received radiation.[20] Nonetheless, it is likely that urogenital dysfunctions following RT are associated, at least in part, with a deterioration in PFM function.[18] Considering the high prevalence of pelvic-floor dysfunctions after gynecological cancers and the scarcity of assessment of the PFM in women with a history of gynecologic cancer in the literature, there is an urgent need to measure PFM function after RT.

The primary aim of this study was to describe the PFM functional properties of women reporting a new incidence of UI after hysterectomy and RT for endometrial cancer (ONCO group) and of women with a history of hysterectomy for benign disease but without UI (HT group). Moreover, we aimed at verifying if there is an association between the severity of urinary symptoms and PFM properties for all participants. We hypothesized that the PFM of women after RT would demonstrate higher resistance to passive stretch and lower maximal strength than the PFM of women in the HT group. Additionally, we hypothesized an association between PFM properties and the severity of UI symptoms.

Method

This exploratory study had a nonexperimental cross-sectional design. Following approval from the ethics committee of each participating institution, participants for this study were recruited by various announcements in medical clinics and facilities of the Centre Hospitalier Universitaire de Québec. Additionally, a retrospective review of the hospital database was conducted for simple hysterectomy procedures performed during the preceding 60 months for either endometrial cancer or benign diseases. Solicitations to participate were sent by the hospital archive department. This study was conducted primarily at the Center for Interdisciplinary Research in Rehabilitation and Social Integration.

For the ONCO group, women were eligible to participate if they were 55 years old or older, had been diagnosed with endometrial cancer stage I or II, had been disease and treatment free for at least 12 months but less than 60 months, and had reported de novo UI since the oncology treatments. All participants in this group had received a simple hysterectomy with bilateral salpingo-oophorectomy and adjuvant RT, consisting of brachytherapy with or without additional external-beam radiation therapy. The symptoms of UI were first screened by telephone using the 3 Incontinence Questions assessment of Brown et al[23]; this short, simple, 3-question assessment allows the detection and classification of symptoms of UI (stress, urge, or mixed incontinence). Exclusion criteria were a body mass index (BMI) higher than 40.0, major pelvic organ prolapse (greater than stage 2), use of medication known to interfere with continence or PFM functional properties, chronic constipation (according to Rome III criteria[24]), additional adjuvant therapies (such as chemotherapy), excessive vaginal scarring or stenosis preventing insertion of the PFM dynamometer, and any active cancers.

For the HT group, women were eligible if they had received a simple hysterectomy for the treatment of a nonmalignant condition and had been through menopause (≥55 years old or had received bilateral salpingo-oophorectomy). The exclusion criteria differed from those for the ONCO group only by the additional absence of any history of pelvic cancer and of symptoms of UI.

Every woman gave written informed consent to participate in this study.

Prior to the assessments, incontinence symptoms were confirmed using a 7-day bladder diary. This self-report diary included questions on beverage consumption, frequency and quantity of each micturition, and leakage episodes. A 7-day bladder diary has been demonstrated to be a reliable measure for the frequency of micturition and leakage.[25] During the single 90-minute assessment session, demographic, general medical, gynecologic, and anthropometric data were recorded. Furthermore, the nature and severity of urogenital symptoms were assessed using the International Consultation on Incontinence Questionnaires (ICIQ): the ICIQ-UI (short form) for UI symptoms, the ICIQ-VS for vaginal symptoms, and the ICIQ-B for bowel symptoms.[26–28] A French translation of the ICIQ-UI was readily available, but this was not the case for the other 2 questionnaires; therefore, forward translation and backward translation were conducted prior to questionnaire use to confirm adequate translation. All forms of the ICIQ were scored as described by Avery et al,[26] with lower scores indicating less bothersome symptoms and higher quality of life.

All participants emptied their bladders prior to the physical and dynamometric assessments. A clinical examination was conducted by an experienced therapist (S.B.). She was not unaware of the group affiliation since physical signs of RT were generally discernible and impossible to ignore. Participants were in a hook-lying position during this examination. The level of pain was assessed before and after each of the digital and dynamometric assessments to ensure participants' comfort and to avoid effects on muscle performance. Bidigital palpation was used to detect major muscle dysfunction and to ensure adequate contraction of the PFM. The tone of the PFM in the plane of the levator ani muscles was measured anteriorly-posteriorly and laterally in accordance with the 7-point scale of Reissing et al (very hypotonic: −3; very hypertonic: +3; normal tone: 0).[29] The contractile properties of the PFM were tested with the PERFECT scheme of Laycock and Jerwood.[30] Appropriate feedback was given by the evaluator to avoid synkinesis from the abdominal, gluteal, or adductor muscles during PFM contractions. Vaginal length, which was the distance in centimeters between the vaginal vault and the hymen, was measured using a hysterometer.

Following the clinical examination, the PFM functional properties were assessed with dynamometry. The Montreal dynamometer has been shown to provide valid and reliable measures of PFM function in women who are continent and women who are incontinent.[31–33] The instrument is composed of 2 pairs of strain gauges on movable speculum-shaped branches, allowing force measurements at different vaginal apertures in an anterior-posterior direction. The instrument was inserted 5 cm into the vagina with an anterior-posterior incline of 20 to 25 degrees, and PFM functional properties were assessed through various standardized tasks.[33,34] Passive properties were assessed first at a minimal aperture of 1 mm between the dynamometer branches (minimal opening passive resistance) and then at a maximal aperture between the branches, determined by the acceptable tolerance limit for the participant, for 5 seconds (maximal opening passive resistance). For both of these tests, participants were instructed to relax their PFM as much as possible.

The following tests were executed at a 10-mm aperture between the speculum branches, and the best performance from 2 trials for each test was used for analysis. For testing of the maximal voluntary contraction (MVC) of the PFM, participants were instructed to contract the PFM as strongly as they could at command and to hold the contraction for 10 seconds. The mean force at baseline, the maximum force in newtons, and the highest instantaneous rate of force development (N/s) were calculated and used for analysis. Coordination was then assessed during the speed test. Participants were asked to maximally contract and completely relax the PFM as many times as possible during a 10-second interval. The verbal instruction given to the participants was to "contract as fast and as strong as possible, and as many times as they could" during the test. The mean force at baseline, the maximum force in newtons of each completed cycle of contraction and relaxation, the highest rate of force development for each contraction, the number of completed contractions, and the time between the contractions were used to represent performance. The last task was the endurance test, and only 1 trial was recorded. Participants were instructed to maximally contract their PFM and sustain the contraction for 90 seconds; a standardized encouragement was given every 30 seconds. The mean force at baseline, and the mean force in newtons between 10 and 70 seconds from the onset of contraction were used for analysis. Performance during the endurance test was quantified as the area under the curve during a 60-second duration: mean force between 10 and 70 seconds multiplied by 60 seconds.

The interval between tests was 60 seconds. The dynamometer was connected to a laptop on which the Numeri program (Labview; National Instruments, Austin, Texas) converted voltage units into newton units and presented real-time data in written and graphical forms.

At the end of the assessments, a generic PFM training program containing various strength, endurance, and coordination exercises was given in a written form to all participants to promote PFM fitness.

Data Analysis

Custom software, Winvisio 2.2.4, was used for a posteriori graphical form visual analyses of PFM data. All dynamometric values during active tasks were first corrected according to the mean force at baseline by subtraction of the mean passive force recorded at rest for a 500-millisecond duration before initiation of the contraction. Automatic extraction of the mean, maximal, and minimal values of the different variables of interest was also carried out.

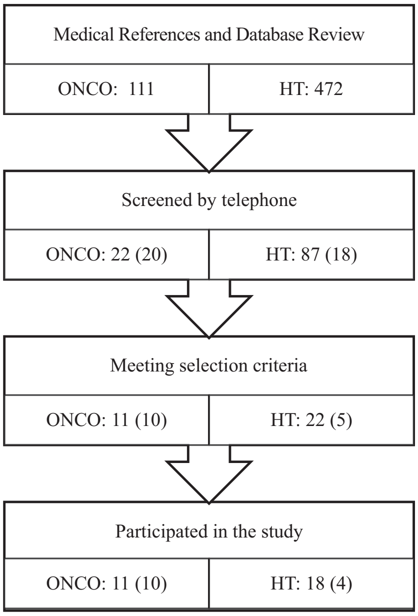

Figure 1.
Flow diagram of the study. Numbers in parentheses represent percentages of participants retained at each step of the study from the initial number of solicitations to participate. HT=group of women with a history of hysterectomy for benign disease but without urinary incontinence (UI), ONCO=group of women reporting a new incidence of UI after hysterectomy and radiotherapy for endometrial cancer.

Statistical Analysis

An α criterion of .05 was used for all statistical analyses. When available, exact significance *P* values were required. A descriptive analysis (mean, SD, and type of distribution) of each group was first conducted for each dependent variable. Nonparametric tests (Mann-Whitney *U*) were used for comparison of personal characteristics, functional status, and muscle properties between groups (the primary objective of this study). Effect sizes were derived from the delta (Δ) calculations of McGaw and Glass[35]; absolute values of greater than 1 are clinically interesting. Absolute values between 0.5 and 1.0 reveal either mild associations or stronger associations that need to be better measured, defined, or applied to a more selective population. Associations between UI and PFM functional property variables were described using correspondence analysis. For this analysis, continuous data were transformed into categorical data using quartiles of each included variable and then were summarized graphically. Additional Mann-Whitney tests were applied to corresponding factors on the graph to determine the significance of relationships. All statistical analyses were conducted using SPSS Statistics 23 for Windows (IBM Corp, Armonk, New York).

Role of the Funding Source

This project was funded by the Quebec Network for Research on Aging Incontinence and Sexuality Thematic Group. Ms Bernard received a grant from the Canadian Institutes of Health Research, the Ordre Professionnel en Physiothérapie du Québec, and the Center for Interdisciplinary Research in Rehabilitation and Social Integration. The sources of funding did not play a role in the investigation.

Results

A total of 583 announcement letters were distributed. Of the 583 women invited, 29 were found to be eligible and were recruited for the study (Fig. 1). From the 111 initial solicitations for participation in the ONCO group, 11 women were recruited; all reported a new incidence of UI after treatments for endometrial cancer. Eighteen women were recruited for the comparison group (HT group); none reported UI after hysterectomy for benign disease. A comparison of the characteristics of the participants in the groups is shown in Table 1.

The 2 groups were similar in parity but differed significantly in terms of age, BMI, and number of years since hysterectomy. As expected, the ONCO group had UI, which was confirmed by significantly higher total scores on the ICIQ-UI, but also had decreased bowel function, as represented by higher scores on the ICIQ-B for both bowel pattern and bowel control. Scores on the ICIQ-VS (either total scores or scores for individual sections) were not significantly different between the groups. However, 1 question was answered differently by women in the 2 groups. When asked "Do you avoid sexual activities because of your vaginal symptoms?" 36.4% of participants in the ONCO group answered "yes," while none of those in the HT group did.

The mean differences in PFM properties between the groups are summarized in Table 2. Most PFM properties were statistically different between the ONCO group and the HT group. The properties with the greatest effect sizes derived from the Δ calculations of McGaw and Glass[35] were vaginal length in centimeters (Δ: −1.80), maximal aperture of the dynamometer branches in millimeters (Δ: −1.68), and number of full rapid contractions during a 10-second interval (Δ: −1.47). In the MVC test, there were significant differences for maximum force in newtons (Δ: −0.56) and maximal rate of force development in N/s (Δ: −0.52); curves are shown in Figure 2. In the speed test, there was a significant difference between the highest peak and the lowest peak of force in newtons (Δ: 0.77), which represented the loss of force generated on the dynamometer with repetitive contractions. A similar tendency was observed for the difference between the highest peak and the lowest peak of rate of force development (slope), on the verge of reaching significance. Fewer completed contractions during the speed test, represented by a greater duration in seconds between force peaks (Δ: 1.56), were also found for the ONCO group.

Assessment of pain levels during the examinations revealed absent or low-level discomfort (0/10 or 1/10 on a visual analog scale) during active muscle performance tests for all participants. Pain reported during the maximal opening of the dynamometer branches (varying from 0/10 to 8/10 in both groups) rapidly resolved to 0/10 when the stretch was released.

The results for the secondary objective of this study, regarding the association between PFM properties and the severity of UI, are shown in Figure 3; to avoid clutter, only the significant associations are shown. The coordinates are the inertia (equivalent to loadings into factor analysis) for the first 2 dimensions of the

Table 1.
Sociodemographic and Functional Characteristics of Participants in Each Group[a]

Characteristic		HT Group (n=18)[b]	ONCO Group (n=11)[b]	P[c]
Age, y		64 (8.0)	69.4 (5.7)	.04
Body mass index, kg/m^2		25.8 (3.7)	30.4 (4.5)	.006
Time since hysterectomy, y		3.1 (4.2)	3.1 (1.2)	.04
Parity		2.1 (0.9)	1.4 (1.2)	.15
Familial status[e]				.26[d]
Married		9 (50.0)	3 (27.3)	
Single		4 (22.2)	1 (9.0)	
Common-law partner		3 (16.7)	3 (27.3)	
Widower		2 (11.1)	4 (36.4)	
Smoking[e]		0 (0.0)	1 (9.0)	.19[d]
Occupation[e]				.15[d]
	Paid worker	8 (44.4)	2 (18.2)	
	Retired	10 (55.6)	9 (81.8)	
ICIQ-UI[f] total score		1.1 (3.0)	11.6 (2.8)	<.00001
ICIQ-VS[f] scores				.09
	Vaginal symptoms	6.4 (6.5)	10.8 (8.7)	
	Sexuality	9.3 (12.4)	25.5 (12.0)	.11
	Avoiding sex because of vaginal symptoms[e]	0 (0.0)	4 (36.4)	.006[d]
	QOL	0.7 (1.2)	2.2 (2.7)	.03
ICIQ-B[f] scores				
	Bowel pattern	4.1 (9.9)	8.0 (8.2)	.008
	Bowel control	5.5 (9.7)	14.9 (15.4)	.009

[a] HT group = women with a history of hysterectomy for benign disease but without urinary incontinence (UI), ONCO group = women reporting a new incidence of UI after hysterectomy and radiotherapy for endometrial cancer, ICIQ = International Consultation on Incontinence Questionnaires, ICIQ-UI = ICIQ for UI symptoms, ICIQ-VS = ICIQ for vaginal symptoms, QOL = quality of life, ICIQ-B = ICIQ for bowel symptoms.
[b] Values are reported as means (standard deviations) unless otherwise indicated.
[c] *P* values were derived from Mann-Whitney *U* exact significance tests unless otherwise indicated.
[d] *P* value was derived from a chi-square test.
[e] Values are reported as numbers (percentages).
[f] Functional status and QOL measure.

correspondence analysis. The distribution of the severity of UI, characterized by scores on the ICIQ-UI, is represented on the graph by large black circles; UI− represents lower scores on the ICIQ-UI (less severe symptoms), and UI+ represents higher scores on the ICIQ-UI (more severe symptoms). As expected, the ONCO group was located close to the UI+ location, while the HT group was located close to the UI− location, along a continuum (dashed line) almost parallel to the x-axis.

The first dimension caught most of the associations, although the second dimension could not be completely ignored. With regard to PFM properties, a more or less linear relationship paralleled the continuum for 5 variables: endurance (End), number of rapid contractions (Number Peaks), rate of force development of a rapid contraction (Slope Speed), vaginal length, and age. For instance, participants with less endurance (End−) on a 4-category scale more likely belonged to the UI+ group and the ONCO group. In a correspondence analysis, high positive correlations exist between neighboring points. Mean rank differences between the UI− group and the UI+ group for these 5 variables were confirmed, and *P* values were determined (Fig. 3).

Discussion

The purpose of the present study was to compare the PFM functional properties of women reporting UI after treatment for endometrial cancer with those of women with a history of a comparable hysterectomy for a benign condition but without UI. To our knowledge, the present study is the first to show some evidence of alterations in PFM properties, as measured by dynamometry, after treatments for endometrial cancer. As initially hypothesized, the ONCO group demonstrated lower maximal strength during an MVC test than the HT group. Higher resistance to passive stretch was also supported by our results;

Table 2.
Analyses of Differences in PFM Functional Properties Between HT Group and ONCO Group[a]

Property	HT Group (n=18)		ONCO Group (n=11)		
	X̄(SD)	Range	X̄(SD)	Range	Effect Sizes[b] (P^c)
Passive force at 1-mm aperture of dynamometer (N)	0.7 (0.5)	0.0–1.7	1.1 (0.7)	0.5–2.3	**0.96 (.01)**
Maximal aperture of dynamometer (mm)	32.3 (5.3)	20.6–40.2	23.4 (6.0)	14.6–35.1	**−1.68 (<.001)**
Passive force at maximal aperture of dynamometer (N)	9.6 (3.3)	2.7–15.3	8.3 (4.0)	4.2–17.6	−0.39 (.06)
Maximum force during MVC (N)	8.9 (3.1)	2.2–14.8	7.2 (3.8)	3.7–16.7	**−0.56 (.03)**
Maximum slope during MVC (N/s)	9.4 (9.2)	1.2–43.3	4.7 (3.5)	0.5–11.4	**−0.52 (.02)**
Endurance in 60 s (N×s)	167.3 (114.2)	48.8–495.2	137.4 (119.4)	21.3–361.5	−0.26 (.18)
Maximum force during speed test (N)	4.9 (2.8)	1.0–12.1	3.9 (1.8)	1.7–7.8	−0.36 (.19)
Difference between highest peak and lowest peak of force (N) in speed test	2.2 (1.3)	0.2–5.6	1.1 (0.8)	0.2–3.0	**−0.77 (.01)**
Maximum slope in speed test (N/s)	11.0 (6.7)	1.9–28.4	7.9 (5.4)	1.2–17.5	−0.46 (.10)
Difference between highest peak and lowest peak for slope (N/s)	4.9 (3.2)	1.1–14.9	3.3 (2.5)	0.7–8.9	−0.49 (.06)
Mean interpeak duration (s) in speed test	1.4 (0.5)	0.9–3.0	2.2 (0.9)	1.4–4.4	**1.56 (<.001)**
No. of full contractions during 10-s interval in speed test	6.8 (2.2)	3–11	3.6 (1.6)	1–6	**−1.47 (<.001)**
Vaginal length (cm)	9.2 (1.0)	8–12	7.4 (1.4)	6–10	**−1.80 (<.001)**

[a] PFM = Pelvic-floor muscle, HT group = women with a history of hysterectomy for benign disease but without urinary incontinence (UI), ONCO group = women reporting a new incidence of UI after hysterectomy and radiotherapy for endometrial cancer, MVC = maximal voluntary contraction. Values in bold type were significant.
[b] Effect sizes were derived from the Δ calculations of McGaw and Glass.[35]
[c] *P* values were derived from nonparametric unilateral Mann-Whitney *U* tests.

this finding was observed through decreased maximal opening of the dynamometer branches but not through increased force at maximal opening. We found associations between the severity of UI and some PFM functional properties, such as endurance, rate of force development, and number of contractions in a speed test, as well as characteristics such as age and vaginal length.

Differences in urogenital and bowel functional status were found between the groups. It was not surprising to observe poorer urinary functional status in the ONCO group, as UI was a selection criterion. However, poorer bowel function was also found in this group, for both bowel pattern and bowel control domains of the ICIQ-B, but bowel function was not a selection criterion. This finding is in accordance with the prevalence of bowel dysfunctions, such as fecal urgency and fecal incontinence, after RT in other studies.[12,18] Although vaginal symptoms in the 2 groups did not differ significantly, both groups had relatively high scores in the sexuality section, meaning more bothersome symptoms related to sexuality. Sexual dysfunction after hysterectomy and pelvic surgeries has been reported before,[36,37] and the results for both groups in the present study seem to be consistent with those findings, although the reasons behind these findings are beyond the scope of the present investigation.

Our results showed differences in PFM functional properties between the ONCO group and the HT group. The ONCO group had a lower rate of force development of an MVC, suggesting that this group had a lower ability to recruit all motor units at a given time than the HT group. The ability to generate muscle strength rapidly may be essential to responding to rapidly increasing abdominal pressure.[38,39] Force production in a limited time is also important for responses to mechanical perturbation during tasks requiring less power, such as standing balance and locomotion.[40] Many factors have been found to influence the rate of force development in skeletal muscle.[41,42] For instance, changes in muscle composition or fiber types can affect the rate of force development.[43] Such changes were observed after RT in the study by Gervaz et al,[44] who reported that connective tissue growth factor was found in the muscle fibers of irradiated anal sphincter strips, and in the study by Coakley et al,[45] who reported that fibrosis was revealed by MRI in the urogenital diaphragm muscles after RT. Such explanations may be plausible for the participants in the ONCO group in the present study.

Muscle cross-sectional area and maximal strength are also known to influence the rate of force development of anMVC.[42,46] Participants in the ONCO group had lower maximal strength than those in the HT group; this lower maximal strength, in turn, could have affected their ability to generate that maximal strength rapidly. However, when specifically asked to generate a fast and strong contraction in a speed test, participants in the ONCO group were able to demonstrate a rate of force development comparable to that of participants in the HT group. However, participants in the ONCO group were not able to maintain a comparable force throughout all contractions of the test, as demonstrated by a large difference between the highest peak

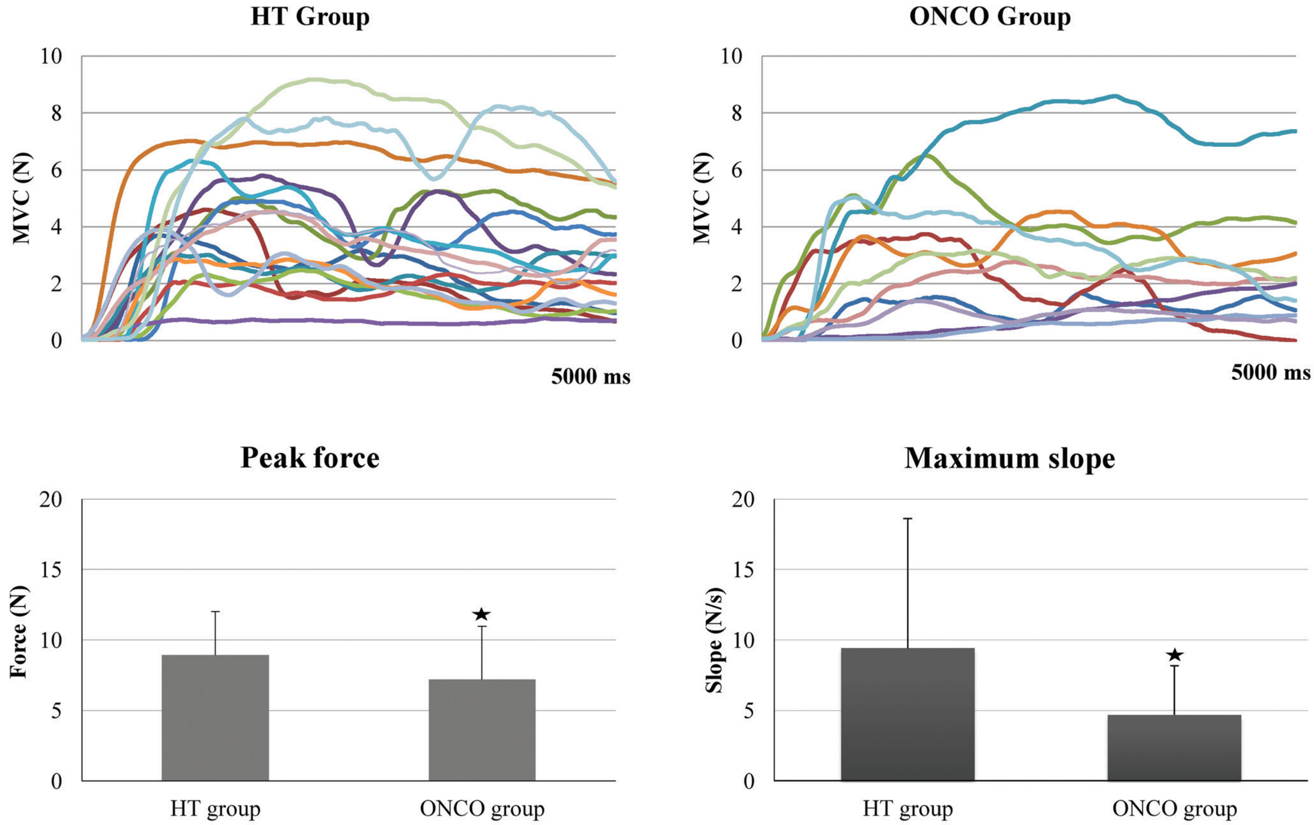

Figure 2.
Comparison of individual force profiles of the HT group (women with a history of hysterectomy for benign disease but without urinary incontinence [UI]; n = 17) and ONCO group (women reporting a new incidence of UI after hysterectomy and radiotherapy for endometrial cancer; n = 11) during a 5-s interval of the maximal voluntary contraction [MVC] tests beginning at initiation of contraction (left), and group means (and 1 SD) for peak force and maximum slope during the MVC tests (right). A curve for one participant in the HT group is not represented, as it impaired visual appreciation of the graph, but it was included in all statistics. Stars indicate values that were significantly different.

and the lowest peak of force. A loss of the rate of force development between the highest slope and the lowest slope measured for each peak showed a similar tendency, although it did not reach significance. Also, the greater interpeak duration and the smaller number of rapid contractions in the speed test were both indicators of altered coordination for the ONCO group. Neuromotor coordination is necessary for generating many full cycles of contraction-relaxation rapidly. The inability to generate many rapid contractions was previously found to be correlated with UI in other populations[19,47] and appeared to be related to the presence and severity of UI in the present study as well.

We also found signs of structural changes in the pelvic floor and tissues of the vagina, such as stenosis at the vaginal opening—as represented by a smaller maximal opening of the dynamometer branches—and a shorter vaginal length—as measured with the hysterometer. These findings support the presence of fibrosis and vaginal agglutination after RT, as previously reported in many other studies.[8,11,48–50] The relationship among fibrosis in the pelvic floor and vaginal soft tissues, altered PFM contractile properties, and the severity of UI has yet to be determined. Additionally, the small sample in the present study may have led to nonsignificant results because of the lack of statistical power for other variables. Larger studies are needed to draw conclusions about alterations in PFM functional properties. Finally, even though the findings of the present investigation seem to concur with those of previously mentioned studies regarding the effects of RT, we cannot exclude the possibility that any intergroup discrepancy found for PFM properties can also be explained by disparities between the surgical procedures received by the 2 groups—although our selection criteria were intended to reduce dissimilarities to a minimum.

Despite very specific selection criteria, there were still significant differences in age and BMI between the groups. It was not all too surprising to find a tendency for a greater age and a higher BMI in the ONCO group, considering that these 2 characteristics are important risk factors for endometrial cancer[2,51,52] and may be intrinsically linked to the development of UI in this population because these characteristics are also known risk factors for UI.[53,54] For instance, it is possible to

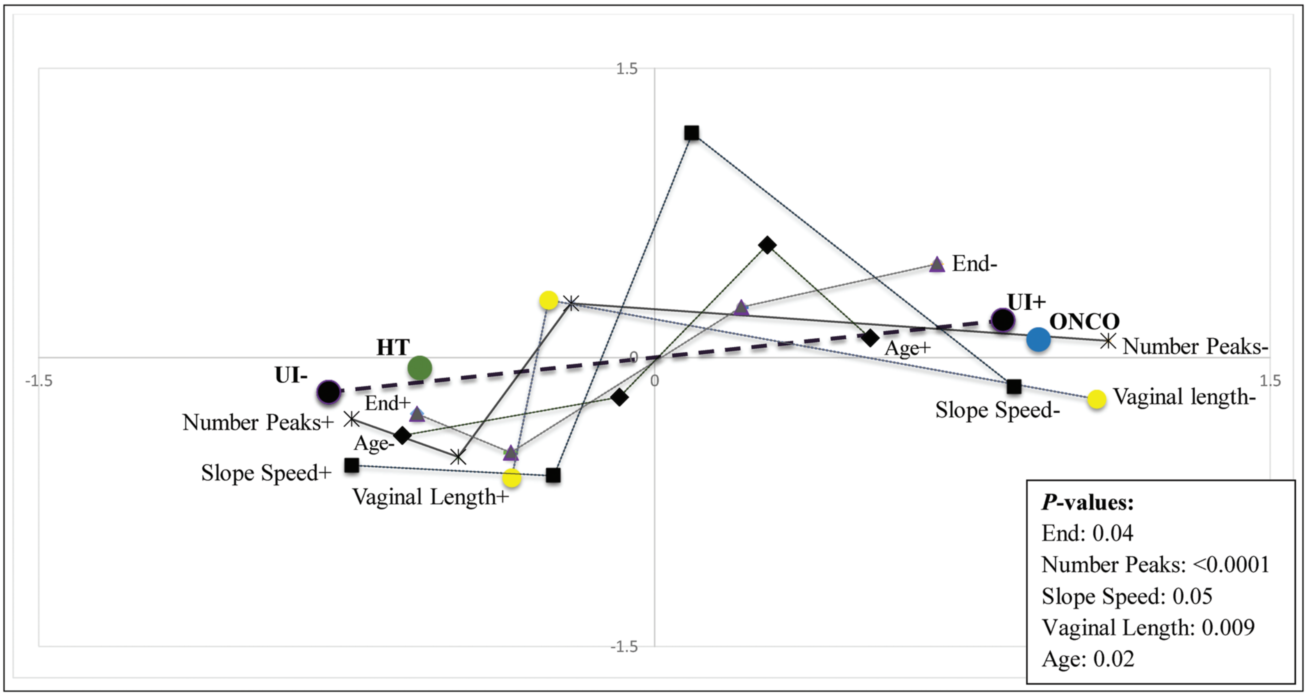

Figure 3.
Correspondence analysis between the presence and severity of urinary incontinence (UI), as represented by scores on the ICIQ-UI (International Consultation on Incontinence Questionnaires for UI symptoms), and personal characteristics and pelvic-floor muscle properties, as measured by dynamometry, in 29 participants. Only the variables that shared a distribution similar to that for UI scores ($P \leq .05$) are represented on the graph. UI- represents low scores on the ICIQ-UI, and UI+ represents higher scores. The distribution of scores obtained by the participants is represented by the dashed line between UI- and UI+. End+ represents higher performance on an endurance test, and End- represents a poorer performance. Age- represents a younger age, and Age+ represents a greater age. Vaginal Length+ represents a longer vaginal length, and Vaginal Length- represents a shorter length of the vagina. Slope Speed+ represents a steeper slope for a contraction during a speed test, and Slope Speed- represents a lesser slope during a speed test. HT represents the overall scores for the HT group on the ICIQ-UI, and ONCO represents the overall scores for the ONCO group. *P* values for these associations are presented in the box and were derived from nonparametric Mann-Whitney U exact significance tests.

identify physical changes in the lower urinary tract system with greater age, such as a smaller vesical maximal capacity and a lower density of the striated sphincter of the urethra, that can contribute to the development and worsening of UI symptoms.[54] Women more than 60 years old also show lower detrusor contractility and lower urethral pressure than younger women; these characteristics can also impair urinary continence.[55,56] Even though the mean age of participants in both groups in the present study was more than 60 years, such factors may have played a role in the severity of UI symptoms for some participants. This possibility applies, in particular, to participants experiencing more severe UI symptoms because such symptoms were found to correspond to greater age, even though these participants experienced de novo incontinence after oncology treatments.

An irrefutable relationship between BMI and UI was established before; more severe UI was associated with a higher BMI.[53] This was not the case in the present study, as BMI was not found to correspond to more severe UI symptoms. However, Hannestad et al[57] demonstrated, in a population-based study, an increased risk for all types of UI, with an odds ratio of 1.4 for BMIs from 25 to 29 (such as in the HT group in the present study) and an odds ratio of 1.9 for BMIs of 30 to 34 (as in the ONCO group); these results implied that the higher BMI in the ONCO group could have played a role in the experience of UI. We recommend that these 2 confounding variables be taken into consideration in future studies involving women with gynecological cancer. Furthermore, pain during examination could have had additional confounding effects on muscle performance; however, this possibility was not likely in the present study because pain remained low during assessments, except during a maximal stretch test at the opening of the vagina.

Small sample size was another limitation of the present study. The exploratory nature of the present study partly explains this limitation; however, in addition, our selection criteria were very specific to ensure as much homogeneity in our sample as possible. Therefore, only 111 potential participants with cancer could be retrieved from the medical database for the selected time period. Although the prevalence of UI after gynecological cancer appears to be quite high in the literature—up to 80% of patients with gynecological cancer[12,18,58]—the response rate of 20% in the present study could have occurred because the prevalence of UI was not as high in the population treated in our hospital setting or because some of the women had already sought treatment for the UI symptoms. Finally, the facts that our hospital is a tertiary oncology referral center covering a large geographical territory and that many treated participants lived in a rural area more than a 2-hour drive away from the center could have influenced the rate of response to our invitation.

In the population without cancer, PFM training has a grade 1A recommendation from a Cochrane collaboration for the treatment of UI and appears to be even more efficient when provided by a therapist specializing in the pelvic floor.[59] Coordination and timing exercises can be taught and have been shown to be beneficial for the population without cancer.[60,61] The benefits of such exercises for the population with gynecological cancer should be investigated. Whether PFM training can improve PFM functional properties, such as maximal strength, maximal rate of force development, and ability to generate fast, strong, and repetitive contractions, in the presence of fibrosis is unknown. Dilation therapy is often suggested during or after RT for the prevention of vaginal stenosis, but there is currently no strong evidence supporting its use.[62] Pelvic-floor muscle exercise programs and dilation therapy need to be further investigated so that they can be adapted to the particular needs of patients who have received RT.

In conclusion, this exploratory, cross-sectional study provides some evidence that PFM properties were altered after surgery and RT for the treatment of stage I and II endometrial cancer in women experiencing UI. Both passive and contractile properties of the PFM appeared to be affected; some of the affected properties seemed to be associated with the presence and severity of UI in this population. The relationships between muscle properties and UI suggest a possible role for pelvic-floor rehabilitation in the treatment of de novo UI after treatments for endometrial cancer.

Author Contributions and Acknowledgments

Concept/idea/research design: S. Bernard, H. Moffet, C. Dumoulin
Writing: S. Bernard, H. Moffet, M. Plante, M.-P. Ouellet, C. Dumoulin
Data collection: S. Bernard, M.-P. Ouellet
Data analysis: S. Bernard, H. Moffet, J. Leblond
Project management: S. Bernard, H. Moffet
Fund procurement: S. Bernard, H. Moffet, M. Plante, C. Dumoulin
Providing participants: M. Plante, M.-P. Ouellet
Providing facilities/equipment: H. Moffet, M. Plante, C. Dumoulin
Providing institutional liaisons: H. Moffet, M. Plante
Consultation (including review of manuscript before submitting): H. Moffet, M. Plante, J. Leblond, C. Dumoulin

The authors are grateful to the participants, gynecology surgeons, and research personnel for their contributions to this study.

Ethics Approval

Approval for the study was granted by the ethics committee of each participating institution.

Funding

This project was funded by the Quebec Network for Research on Aging Incontinence and Sexuality Thematic Group. Ms Bernard received a grant from the Canadian Institutes of Health Research, the Ordre Professionnel en Physiothérapie du Québec, and the Center for Interdisciplinary Research in Rehabilitation and Social Integration.

Disclosures

The authors declare no conflicts of interest.

DOI: 10.1093/ptj/pzx012

References

1 Canadian Cancer Society's Advisory Committee on Cancer Statistics. Canadian Cancer Statistics 2015. Toronto, Ontario, Canada: Canadian Cancer Society; 2015:16-22.

2 Canadian Cancer Society's Advisory Committee on Cancer Statistics. Canadian Cancer Statistics 2014. Toronto, Ontario, Canada: Canadian Cancer Society; 2014:16–22.

3 Greer BE, Koh WJ, Abu-Rustum N, et al. Uterine cancers. *J Natl Compr Canc Netw*. 2006;4:438–462.

4 Kupets R, Le T. Rôle du traitement adjuvant en matière de cancer de l'endomètre. *J Obstet Gynaecol Can*. 2016;38(12S):S208–S219.

5 Giede C, Le T, Power P. Rôle de la chirurgie en matière de cancer de l'endomètre. *J Obstet Gynaecol Can*. 2016;38(12S):S197–S207.

6 Creasman W. Revised FIGO staging for carcinoma of the endometrium. *Int J Gynecol Obstet*. 2009;105:109.

7 Creutzberg CL, van Putten WL, Koper PC, et al. The morbidity of treatment for patients with stage I endometrial cancer: results from a randomized trial. *Int J Radiat Oncol Biol Phys*. 2001;51:1246–1255.

8 Bergmark K, Avall-Lundqvist E, Dickman PW, et al. Vaginal changes and sexuality in women with a history of cervical cancer. *N Engl J Med*. 1999;340:1383–1389.

9 Bergmark K, Avall-Lundqvist E, Dickman PW, et al. Patient-rating of distressful symptoms after treatment for early cervical cancer. *Acta Obstet Gynecol Scand*. 2002;81:443–450.

10 Jensen PT, Groenvold M, Klee MC, et al. Early-stage cervical carcinoma, radical hysterectomy, and sexual function: a longitudinal study. *Cancer*. 2004;100:97–106.

11 Kirchheiner K, Fidarova E, Nout RA, et al. Radiation-induced morphological changes in the vagina. *Strahlenther Onkol*. 2012;188:1010–1017.

12 Donovan KA, Boyington AR, Judson PL, Wyman JF. Bladder and bowel symptoms in cervical and endometrial cancer survivors. *Psychooncology*. 2014;23:672–678.

13 Rutledge TL, Heckman SR, Qualls C, et al. Pelvic floor disorders and sexual function in gynecologic cancer survivors: a cohort study. *Am J Obstet Gynecol*. 2010;203:514.e1–514.e7.

14 Sadovsky R, Basson R, Krychman M, et al. Cancer and sexual problems. *J Sex Med*. 2010;7:349–373.

15 Le T, Menard C, Samant R, et al. Longitudinal assessments of quality of life in endometrial cancer patients: effect of surgical approach and adjuvant radiotherapy. *Int J Radiat Oncol Biol Phys*. 2009;75:795–802.

16 Nout RA, Putter H, Jürgenliemk-Schulz IM, et al. Five-year quality of life of endometrial cancer patients treated in the randomised Post Operative Radiation Therapy in Endometrial Cancer (PORTEC-2) trial and comparison with norm data. *Eur J Cancer*. 2012;48:1638–1648.

17 Joly F, McAlpine J, Nout R, et al. Quality of life and patient-reported outcomes in endometrial cancer clinical trials: a call for action! *Int J Gynecol Cancer*. 2014;24:1693–1699.

18 Nout RA, van de Poll-Franse LV, Lybeert ML, et al. Long-term outcome and quality of life of patients with endometrial carcinoma treated with or without pelvic radiotherapy in the post operative radiation therapy in endometrial carcinoma 1 (PORTEC-1) trial. *J Clin Oncol*. 2011;29:1692–1700.

19 Morin M, Bourbonnais D, Gravel D, et al. Pelvic floor muscle function in continent and stress urinary incontinent women using dynamometric measurements. *Neurourol Urodyn*. 2004;23:668–674.

20 Bernard S, Ouellet MP, Moffet H, et al. Effects of radiation therapy on the structure and function of the pelvic floor muscles of patients with cancer in the pelvic area: a systematic review. *J Cancer Surviv*. 2016;10:351–362.

21 Yeoh E, Sun WM, Russo A, et al. A retrospective study of the effects of pelvic irradiation for gynecological cancer on anorectal function. *Int J Radiat Oncol Biol Phys*. 1996;35:1003–1010.

22 Noronha AF, Mello de Figueiredo E, Rossi de Figueiredo Franco TM, et al. Treatments for invasive carcinoma of the cervix: what are their impacts on the pelvic floor functions? *Int Braz J Urol*. 2013;39:46–54.

23 Brown JS, Bradley CS, Subak LL, et al. The sensitivity and specificity of a simple test to distinguish between urge and stress urinary incontinence. *Ann Intern Med*. 2006;144:715–723.

24 Drossman DA, Dumitrascu DL. Rome III: new standard for functional gastrointestinal disorders. *J Gastrointestin Liver Dis*. 2006;15:237–241.

25 Wyman JF, Choi SC, Harkins SW, et al. The urinary diary in evaluation of incontinent women: a test-retest analysis. *Obstet Gynecol*. 1988;71:812–817.

26 Avery K, Donovan J, Peters TJ, et al. ICIQ: a brief and robust measure for evaluating the symptoms and impact of urinary incontinence. *Neurourol Urodyn*. 2004;23:322–330.

27 Cotterill N, Norton C, Avery KN, et al. Psychometric evaluation of a new patient-completed questionnaire for evaluating anal incontinence symptoms and impact on quality of life: the ICIQ-B. *Dis Colon Rectum*. 2011;54:1235–1250.

28 Price N, Jackson SR, Avery K, et al. Development and psychometric evaluation of the ICIQ Vaginal Symptoms Questionnaire: the ICIQ-VS. *BJOG*. 2006; 113:700–712.

29 Reissing ED, Binik YM, Khalifé S, et al. Vaginal spasm, pain, and behavior: an empirical investigation of the diagnosis of vaginismus. *Arch Sex Behav*. 2004;33:5–17.

30 Laycock J, Jerwood D. Pelvic floor muscle assessment: the PERFECT scheme. *Physiotherapy*. 2001;87:631–642.

31 Dumoulin C, Bourbonnais D, Lemieux MC. Development of a dynamometer for measuring the isometric force of the pelvic floor musculature. *Neurourol Urodyn*. 2003;22:648–653.

32 Dumoulin C, Gravel D, Bourbonnais D, et al. Reliability of dynamometric measurements of the pelvic floor musculature. *Neurourol Urodyn*. 2004;23:134–142.

33 Morin M, Gravel D, Bourbonnais D, et al. Reliability of dynamometric passive properties of the pelvic floor muscles in postmenopausal women with stress urinary incontinence. *Neurourol Urodyn*. 2008;27:819–825.

34 Morin M, Dumoulin C, Gravel D, et al. Reliability of speed of contraction and endurance dynamometric measurements of the pelvic floor musculature in stress incontinent parous women. *Neurourol Urodyn*. 2007;26:397–403.

35 McGaw B, Glass GV. Choice of the metric for effect size in meta-analysis. *American Educational Research Journal*. 1980;17:325–337.

36 Goktas SB, Gun I, Yildiz T, et al. The effect of total hysterectomy on sexual function and depression. *Pak J Med Sci*. 2015;31:700–705.

37 Katz A. Sexuality and hysterectomy: finding the right words—responding to patients' concerns about the potential effects of surgery. *Am J Nurs*. 2005;105:65–68.

38 Birder L, de Groat W, Mills I, et al. Neural control of the lower urinary tract: peripheral and spinal mechanisms. *Neurourol Urodyn*. 2010;29:128–139.

39 Yiou R, Costa P, Haab F, Delmas V. Functional anatomy of the pelvic floor. *Prog Urol*. 2009;19:916–925.

40 Izquierdo M, Aguado X, Gonzalez R, et al. Maximal and explosive force production capacity and balance performance in men of different ages. *Eur J Appl Physiol Occup Physiol*. 1999;79:260–267.

41 Folland JP, Buckthorpe MW, Hannah R. Human capacity for explosive force production: neural and contractile determinants. *Scand J Med Sci Sports*. 2014;24:894–906.

42 Aagaard P, Simonsen EB, Andersen JL, et al. Increased rate of force development and neural drive of human skeletal muscle following resistance training. *J Appl Physiol (1985)*. 2002;93:1318–1326.

43 Harridge SD, Bottinelli R, Canepari M, et al. Whole-muscle and single-fibre contractile properties and myosin heavy chain isoforms in humans. *Pflugers Arch*. 1996;432:913–920.

44 Gervaz P, Hennig R, Buechler M, et al. Long-term expression of fibrogenic cytokines in radiation-induced damage to the internal anal sphincter. *Swiss Surg*. 2003;9:193–197.

45 Coakley FV, Hricak H, Wefer AE, et al. Brachytherapy for prostate cancer: endorectal MR imaging of local treatment-related changes. *Radiology*. 2001; 219:817–821.

46 Miller MS, Bedrin NG, Ades PA, et al. Molecular determinants of force production in human skeletal muscle fibers: effects of myosin isoform expression and cross-sectional area. *Am J Physiol Cell Physiol*. 2015;308:C473–C484.

47 Lovegrove Jones RC, Peng O, Stokes M, et al. Mechanisms of pelvic floor muscle function and the effect on the urethra during a cough. *Eur Urol*. 2010;57:1101–1110.

48 Flay LD, Matthews JH. The effects of radiotherapy and surgery on the sexual function of women treated for cervical cancer. *Int J Radiat Oncol Biol Phys*. 1995;31:399–404.

49 Hartman P, Diddle AW. Vaginal stenosis following irradiation therapy for carcinoma of the cervix uteri. *Cancer*. 1972;30:426–429.

50 Nunns D, Williamson K, Swaney L, Davy M. The morbidity of surgery and adjuvant radiotherapy in the management of endometrial carcinoma. *Int J Gynecol Cancer*. 2000;10:233–238.

51 Renehan AG, Tyson M, Egger M, et al. Body-mass index and incidence of cancer: a systematic review and meta-analysis of prospective observational studies. *Lancet*. 2008;371:569–578.

52 Smith RA, von Eschenbach AC, Wender R, et al. American Cancer Society guidelines for the early detection of cancer: update of early detection guidelines for prostate, colorectal, and endometrial cancers. Also: update 2001--testing for early lung cancer detection. *CA Cancer J Clin*. 2001;51:38–75.

53 Altman D, Cartwright R, Milsom I, et al. Epidemiology of urinary incontinence (UI) and other lower urinary tract symptoms (LUTS), pelvic organ prolapse (POP) and anal incontinence (AI). In: Abrams P, Khoury S, Wein A, eds. *Incontinence*. Paris, France: European Association of Urology; 2013:15–108.

54 Chen LJ, Kirschner-Hermanns R, Wagg AS, et al. Incontinence in the frail elderly. In: Abrams P, Khoury S, Wein A, eds. *Incontinence*. Paris, France: European Association of Urology. 2013: 1001–1100.

55 Pfisterer MH, Griffiths DJ, Schaefer W, Resnick NM. The effect of age on lower urinary tract function: a study in women. *J Am Geriatr Soc*. 2006;54:405–412.

56 Trowbridge ER, Wei JT, Fenner DE, et al. Effects of aging on lower urinary tract and pelvic floor function in nulliparous women. *Obstet Gynecol*. 2007;109: 715–720.

57 Hannestad YS, Rortveit G, Daltveit AK, Hunskaar S. Are smoking and other lifestyle factors associated with female urinary incontinence? The Norwegian EPINCONT Study. *BJOG.* 2003;110: 247–254.

58 Erekson EA, Sung VW, DiSilvestro PA, Myers DL. Urinary symptoms and impact on quality of life in women after treatment for endometrial cancer. *Int Urogynecol J Pelvic Floor Dysfunct*. 2009;20:159–163.

59 Dumoulin C, Hay-Smith EJ, Mac Habée-Séguin G, Pelvic floor muscle training versus no treatment, or inactive control treatments, for urinary incontinence in women. *Cochrane Database Syst Rev*. 2014;(5):CD005654.

60 Bø K. Pelvic floor muscle training is effective in treatment of female stress urinary incontinence, but how does it work? *Int Urogynecol J Pelvic Floor Dysfunct*. 2004;15:76–84.

61 Dumoulin C, Glazener C, Jenkinson D. Determining the optimal pelvic floor muscle training regimen for women with stress urinary incontinence. *Neurourol Urodyn*. 2011;30:746–753.

62 Miles T, Johnson N. Vaginal dilator therapy for women receiving pelvic radiotherapy. *Cochrane Database Syst Rev*. 2014;(9):CD007291.