ARTICLE

Pelvic Floor Morphometric Differences in Elderly Women with or without Urinary Incontinence

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ABSTRACT

Purpose: Urinary incontinence (UI) affects as many as 50% of women aged 60 years and older, but UI pathophysiology, specifically in elderly women, remains unclear. A better understanding of morphometric differences between continent and urinary incontinent elderly women is needed to improve the effectiveness of conservative treatment approaches. We hypothesized that morphometric differences in the pelvic floor muscles (PFM) among elderly women with and without UI could be observed using three- and four-dimensional (3D/4D) transperineal ultrasound (TPU) imaging. ***Method:*** A total of 40 elderly women (20 women with and 20 women without UI), with a mean age of 67.10 (SD 4.94) years, participated in the study. This was a case-control study in which TPU images were taken under three conditions: rest, maximal voluntary contraction (MVC), and Valsalva. Independent *t*-tests were conducted to compare measurements between the groups. ***Results:*** The study revealed statistically significant differences between the groups. At rest, the levator hiatal area and transverse diameter were bigger, and the PFM position was lower in the incontinent group. During MVC, all axial plane parameters were bigger in the incontinent group. In the sagittal plane, PFM position was again lower in the incontinent group. During Valsalva, the anorectal angle was wider in the women with incontinence. ***Conclusion:*** PFM morphometric differences were present and were observed using 3D/4D TPU imaging in elderly women with and without UI.

Key Words: elderly women; pelvic floor; transperineal ultrasonography; urinary incontinence.

RÉSUMÉ

Objectif : jusqu'à 50 % des femmes de 60 ans et plus souffrent d'incontinence urinaire (IU), toutefois la physiopathologie de l'IU demeure incomprise, particulièrement chez les femmes âgées. Il s'avère nécessaire de mieux comprendre les différences morphométriques entre les femmes âgées continentes et incontinentes pour améliorer les interventions thérapeutiques conservatrices. Les auteurs ont avancé l'hypothèse qu'ils pourraient observer les différences morphométriques des muscles du plancher pelvien (MPP) des femmes âgées présentant ou non une IU au moyen de l'échographie transpérinéale (ÉTP) tridimensionnelle et quadridimensionnelle (3D/4D). ***Méthodologie :*** au total, 40 femmes âgées (20 femmes ayant une IU et 20 sans IU), de 67,10 ans (ÉT 4,94) en moyenne, ont participé à l'étude. Dans cette étude cas-témoins, les mesures d'ÉTP ont été prises dans trois conditions : au repos, pendant une contraction maximale volontaire (CMV) et pendant la manœuvre de Valsalva. Les auteurs ont effectué des tests de Student indépendants pour comparer les mesures entre les groupes. ***Résultats :*** l'étude a révélé des différences statistiquement significatives entre les groupes. Au repos, le groupe de femmes incontinentes présentait un hiatus du releveur de l'anus avec une aire et un diamètre transverse plus grands ainsi q'une position des MPP plus basse. Pendant la CMV des MPP, tous les paramètres du plan axial étaient plus grands chez les femmes incontinentes. Dans le plan sagittal, la position des MPP était plus basse dans le groupe des femmes incontinentes. Pendant la manœuvre de Valsalva, l'angle anorectal était plus grand chez les femmes incontinentes. ***Conclusion :*** les chercheurs ont observé des différences morphométriques des MPP avec l'ÉTP 3D/4D chez les femmes âgées ayant ou non une IU.

Urinary incontinence (UI), a highly prevalent health problem, affects as many as 50% of women aged 60 years and older.[1] The majority of women believe that UI is a normal part of aging; consequently, fewer than half of those with this health problem report it to their health care provider.[2] Yet research has indicated that, in 8 out of 10 cases, UI can be cured or the symptoms reduced using conservative management treatments.[3,4]

The pelvic floor muscles (PFM) play an important (twofold) role in urinary continence.[5] First, an intentional,

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effective PFM contraction (lifting the PFM in a cranial and forward direction) before and during effort or exertion clamps the urethra and increases the urethral pressure, preventing urine leakage. Second, the bladder neck (BN), which is resistant to stretching, receives support from strong, toned PFM, thereby limiting its downward movement during effort and exertion and preventing urine leakage.[5] Hence, PFM training, an effective and efficient intervention for reducing symptom severity, is recommended as the first-line treatment for stress UI and mixed UI in women of all ages.[4,6]

Progress has been made in understanding the pathophysiology of UI in adult women using PFM assessment tools such as digital palpation, dynamometry, electromyography, and ultrasound (US) at rest, during PFM maximal voluntary contraction (MVC) or during effort (e.g., cough or Valsalva manoeuvre),[7] but the pathophysiology of UI in elderly women—in whom the prevalence is highest—remains unclear. Only a few studies in this subpopulation used MRI, dynamometry, and digital palpation[7,8] to study pathophysiology, and none used US.

Because older women present with specific muscular changes related to menopause and aging (sarcopenia), it is possible for those with UI to present with different PFM dysfunctions than younger women. To enable PFM training intervention to better target these dysfunctions associated with UI, the understanding of specific morphometric differences between continent and incontinent elderly women must be expanded.[9]

Three- and four-dimensional (3D–4D) transperineal US (TPU) imaging implies the acquisition of volume US data (3D) and the real-time acquisition of volume US data over time (4D). They allow one to obtain enhanced documentation of the PFM functional anatomy at rest, during a PFM MVC, and during a Valsalva manoeuvre, three situations in which the PFM morphometry and function has been shown to be different in younger women.[10,11] Yet few studies have compared the PFM in continent versus incontinent women using TPU imaging,[10,12–14] and none have specifically targeted elderly women.

The aim of this study was to compare pelvic floor morphometry between continent and incontinent elderly women using 3D–4D TPU imaging under three conditions: rest, MVC, and Valsalva. We hypothesized that significant differences in PFM morphometry and BN support would be observed between incontinent (stress and mixed UI) and continent older women.

METHODS

Study design and population

We used a cross-sectional study design with a convenience sample to gather information on the pelvic floor morphometry of continent and incontinent elderly women from 2009 to 2012. We recruited community-dwelling women from a larger parent study and by placing advertisements in newspapers and senior citizens' centres in the city of Montreal.

Continent or incontinent (symptoms of stress UI or mixed UI are defined below) candidates were included if they were aged 60 years or older, lived at home, were independently ambulatory, were able to give informed consent, and had not changed their hormone prescription in the previous 6 months. Women were excluded if they were unable to understand written and verbal instructions in French or English; had participated in PFM training within the past year; had incontinence due to neurological causes; had incontinence risk factors known to interfere with normal PFM function, such as severe obesity (BMI > 35 kg/m^2),[15] chronic constipation,[16] or important genital prolapse (>2 according to the Pelvic Organ Prolapse Quantification system)[17]; or had any other medical problems that would have interfered with the study.

UI was defined as at least one weekly episode of involuntary urine loss during the preceding 3 months, as reported by the participants. This validated indicator of UI has been used before in UI-focused cohort studies and randomized controlled trials.[18] The UI type was established using the self-diagnostic item of the Urogenital Distress Inventory (UDI), in which lower scores indicate fewer urogenital symptoms.[19] Women with stress UI or mixed UI had involuntary urine loss on effort, exertion, sneezing, or coughing (Questions 4 and 6) or on both effort and urgency (Questions 3, 4, 6, and 7), respectively. Continence was defined as the absence of any involuntary urine leakage in the previous 12 months, as verified by the UDI.[19]

Women interested in participating in the study were invited to contact the research assistant to take part in a telephone-screening interview and to be informed about the study's objectives and procedures. On the basis of the criteria mentioned earlier, an evaluator confirmed each woman's eligibility. Research participants received financial compensation for travel expenses. The study was reviewed by the ethics committee of the Research Centre of the Geriatric Institute of the University of Montreal and approved under reference number CER IUGM 2009–1205. All participants provided written, informed consent before the evaluation.

To control for the potential effects of age, BMI, and parity, we matched participants across the two groups on the basis of age (±5 y), BMI (±3 kg/m^2), and vaginal deliveries (whether they had had a vaginal delivery or not: yes or no; if yes, ±2 deliveries).

Transperineal ultrasound imaging measurement procedure

The research participant emptied her bladder. Then a physiotherapist (CD), using vaginal palpation, taught each participant to perform PFM contractions correctly:

"Squeeze and lift from the front and back together combined as to retain urine and gas";[20(p.5)] after this, the participant underwent a TPU imaging assessment in the supine position with hips and knees flexed and feet flat on the table.

Pelvic floor images were acquired by one of two researchers (MM and JK) using an Acuson Antares system (Siemens Canada Ltd., Mississauga, ON) with a 3–5 MHz curvilinear 3D–4D probe. Images were taken under three conditions: at rest (3D), on MVC (4D), and during a Valsalva manoeuvre (4D).[21] In the rest condition, women were instructed to relax their muscles. During the MVC, participants were instructed to contract their PFM as hard as they could for 8 seconds as though they were retaining urine and gas; this was repeated twice, with 2 minutes rest between trials.

During the Valsalva manoeuvre, participants were instructed to push for 8 seconds as though they were passing stool; this was repeated three times.[21] As described by Majida and colleagues,[22] we used images of the most effective MVC (i.e., most reduced levator hiatus antero-posterior [LHap] diameter) and Valsalva manoeuvre (i.e., most caudal displacement of the BN) for analysis. An investigator (SF) who was blind to the participants' continence status processed data sets offline using the syngo fourSight ViewTool, version 3.1 (Siemens Canada Ltd., Mississauga, ON).

Main outcome measures

We took TPU imaging measurements in the axial and sagittal planes (see Figure 1). We measured the LHap diameter, the LH transverse (LHt) diameter, and the LH area (LHarea) using axial plane images. We then measured each parameter in the "plane of minimal dimensions."[21(p.31)] We used sagittal images to measure the position of the BN: the distance of the BN from the inferior and posterior margin of the pubic symphysis (X, Y), the anorectal angle, and the position (height) of the PFM, as measured by the distance from the apex of the anorectal angle to a horizontal reference line through the symphysis pubis, similar to the previously described MRI measurement (M line).[23] During MVC, we measured the cranioventral displacement of the BN as the hypotenuse of a right-angled triangle ($\sqrt{\Delta BN(X)^2 + \Delta BN(Y)^2}$). We calculated the dorsocaudal displacement of the BN on Valsalva using the same formula. The parameters extracted for each group and condition are presented in detail in Appendix.

Statistical analysis

To estimate the intrarater test–retest reliability for each TPU imaging parameter under the three conditions, images from 10 individuals were chosen at random and measured twice, at a 1-week interval, by the evaluator (SF). For intrarater test–retest reliability, intra-class correlation coefficients (ICCs) with 95% CIs were used. The ICCs, coefficients of variation, and standard errors of measurement were calculated between the first and second sets of measurements for each condition. Furthermore, blinded descriptive statistical analysis was used to compare the demographic data and PFM TPU imaging parameters between the continent and the incontinent groups. The frequency distributions and ranges were analyzed to detect outliers that could have signalled potential errors. All data were analyzed as grouped data, without nominal identifiers. The heterogeneity of the variances was tested, and the appropriate corrections were applied when needed.

We used independent Student's t-tests to compare the demographic data and TPU imaging measurements between the two groups. We used χ^2 tests for dichotomous variables. The statistically significant 2-tailed

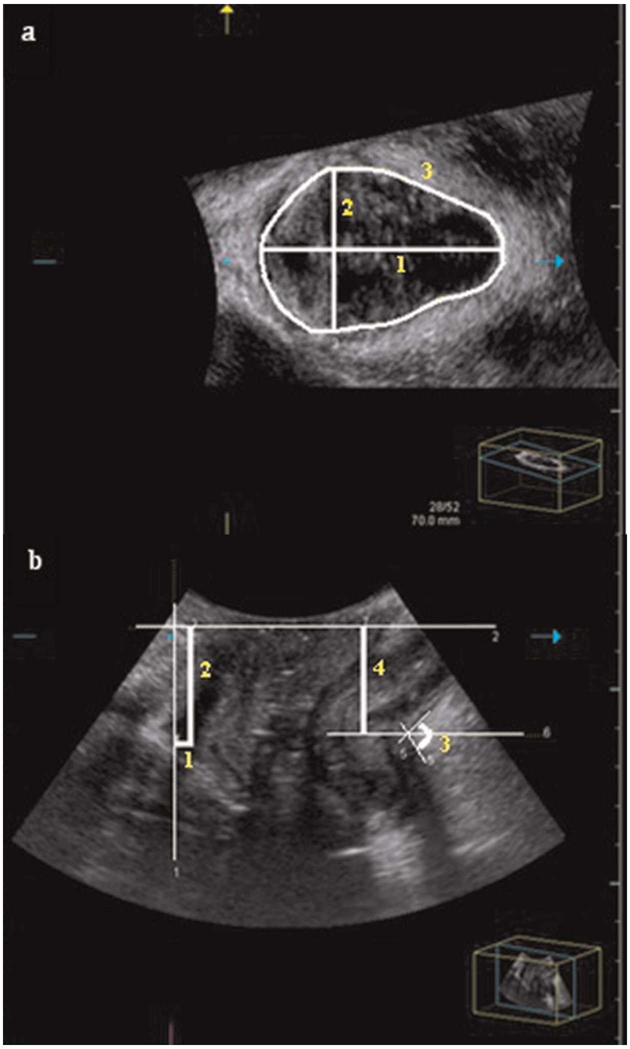

Figure 1 Images of pelvic floor transperineal US: (a) In the axial plane, three parameters were measured: (1) LHap distance, (2) LHt distance, (3) LHarea; (b) in the sagittal plane, four parameters were measured: (1) BN position X, (2) BN position Y, (3) anorectal angle, (4) PFM position (height). LHap = levator hiatus antero-posterior; LHt = levator hiatus transverse; LHarea = levator hiatus area; BN = bladder neck; PFM = pelvic floor muscle.

Table 1 Intrarater Test–Retest Analyses for 3D/4D Transperineal Ultrasound Imaging Parameters

	ICC			SEM*		
Parameter	Rest	MVC	Valsalva	Rest	MVC	Valsalva
LHarea, mm^2	0.784	0.834	0.644	174.56	175.73	246.58
LHap	0.907	0.915	0.893	2.86	2.59	3.03
LHt	0.625	0.856	0.640	2.24	1.68	2.49
BN position X	0.826	0.817	0.814	1.72	2.71	3.63
BN position Y	0.837	0.942	0.926	2.36	1.53	2.74
Anorectal angle, °	0.753	0.878	0.711	8.06	4.94	9.29
PFM position	0.793	0.981	0.825	1.48	0.98	4.53

*In millimetres, except where otherwise indicated.
3D/4D = three and four dimensional; ICC = intra-class correlation coefficient; SEM = standard error of measurement; MVC = maximal voluntary contraction; LHarea = levator hiatus area; LHap = levator hiatus anterior–posterior; LHt = levator hiatus transverse; BN = bladder neck; PFM = pelvic floor muscles.

Table 2 Demographic Data

	Group; mean (SD)*		
Characteristic	Continent, $n = 20$	UI, $n = 20$	p-value
Age, y	66.50 (4.83)	67.70 (5.10)	0.45
BMI, kg/m^2	23.83 (3.02)	24.67 (3.80)	0.44
Vaginal deliveries, no.	2.20 (1.51)	1.75 (1.25)	0.31
Hysterectomies, no. positive (%)	6 (30)	10 (50)	0.20
UDI score (total/300)	9.07 (11.19)	113.40 (40.95)	$<0.001^{\dagger}$

*Unless otherwise indicated.
† $p < 0.05$.
UI = urinary incontinent; UDI = Urogenital Distress Inventory.

p-value level was set at 0.05. Statistical analyses were performed using IBM SPSS Statistics, version 19.0 (IBM Corporation, Armonk, NY). Finally, to better appreciate the significance of our TPU imaging data, we evaluated the effect sizes with η^2, where $\eta^2 \leq 0.06$ indicates a small effect, $\eta^2 \leq 0.14$ indicates a medium effect, and $\eta^2 > 0.14$ indicates a large effect.[24]

RESULTS

Intrarater reliability evaluations for all seven pelvic floor measurements (three axial and four sagittal) were conducted on 10 participants' images. The results are presented in Table 1.

A total of 40 women aged 60–79 years old, with a mean age of 67.10 (SD 4.94), participated in the study (20 women with incontinence and 20 women without). Refer to Table 2 for the demographic characteristics of each group. There were no statistically significant differences between the groups in terms of age, BMI, number of vaginal deliveries, or number of hysterectomies. However, for the UDI scores reflecting the impact of bladder symptoms, calculated as described by Shumaker and colleagues (lower scores indicated less bother),[19] there was a statistically significant difference between the groups favouring the continent group ($p < 0.001$).

Table 3 shows the PFM morphometric parameters for both groups, as assessed in the axial and sagittal planes at rest, during an MVC, and during a Valsalva manoeuvre. Many statistically significant differences were found between the groups. At rest, the LHarea ($p = 0.032$) and LHt ($p = 0.014$; with an η^2 of 0.159, indicating a large effect size) were significantly larger, and the PFM position was lower (i.e., anorectal angle more caudal) ($p = 0.031$) in the incontinent group compared to the continent group. During the MVC, the LHarea ($p = 0.002$), LHap ($p = 0.001$), and LHt ($p = 0.043$) were significantly larger in the incontinent group than in the continent group. In addition, incontinent women's PFM position was significantly lower (i.e., anorectal angle more caudal) ($p = 0.001$) than that of the continent group. All these parameters except LHt (with a moderate effect size) showed a large effect size, with all η^2s $\geq$ 0.14. During the Valsalva, the two groups showed no statistically significant differences, except for a wider anorectal angle ($p = 0.021$; η^2 = moderate effect size) in the incontinent group.

DISCUSSION

In agreement with our initial hypothesis, the main finding of this study was that there are PFM morphometric differences between incontinent and continent elderly

Table 3 Comparison of PFM Morphometric Parameters between the Groups

Condition and measurement	Group; mean (SD) Continent, $n = 20$	UI, $n = 20$	Mean difference	95% CI	p-value (t)	Effect size, η^2
Rest						
LHarea, mm^2	14,330 (345.38)	16,781 (316.29)*	245.26	−467.86, −22.65	0.032†	0.125
LHap, mm	53.16 (8.99)	58.01 (6.92)‡	4.86	−10.18, 0.47	0.07	0.086
LHt, mm	35.79 (3.97)	39.34 (4.42)*	3.56	−6.35, −0.76	0.014†	0.159
BN position X, mm	7.76 (7.02)	9.11 (4.03)‡	0.51	−3.10, 4.13	0.47	0.013
BN position Y, mm	29.98 (5.77)	29.47 (5.16)‡	1.34	−5.09, 2.40	0.78	0.002
Anorectal angle, °	111.15 (10.69)	112.95 (13.00)§	1.80	−9.50, 5.91	0.64	0.006
PFM position, mm	24.04 (8.43)	18.73 (5.72)‡	5.30	0.51, 10.10	0.031†	0.122
MVC						
LHarea, mm^2	11,024 (261.46)	14,504 (387.97)	348.01	−559.79, −136.23	0.002†	0.225
LHap, mm	41.68 (7.71)	50.72 (8.73)	9.04	−14.31, −3.77	0.001†	0.241
LHt, mm	35.15 (4.43)	38.23 (4.89)	3.08	−6.07, −0.10	0.043†	0.103
BN CV displacement, mm	9.16 (5.54)	7.96 (5.98)§	1.23	−2.56, 5.02	0.51	0.011
Anorectal angle, °	107.40 (13.76)	111.65 (11.61)	4.25	−12.40, 3.90	0.30	0.028
PFM position, mm	26.63 (8.25)	18.25 (6.04)	8.38	3.74, 13.02	0.001†	0.261
Valsalva						
LHarea, mm^2	18,853 (683.15)¶	18,783 (435.64)**	6.97	−411.08, 425.02	0.97	0.001
LHap, mm	60.85 (11.97)	58.57 (8.62)‡	2.28	−4.66, 9.21	0.51	0.012
LHt, mm	41.20 (7.60)	41.99 (5.33)	0.79	−5.59, 4.00	0.74	0.003
BN DC displacement, mm	18.17 (11.29)§	18.80 (12.63)§	0.63	−8.73, 7.47	0.88	0.019
Anorectal angle, °	109.7 (10.54)	119.45 (14.72)	9.75	−17.95, −1.55	0.021†	0.132
PFM position, mm	14.08 (10.79)	11.65 (8.33)§	2.43	−3.85, 8.71	0.44	0.016

*Images from three participants were unclear; it was impossible to take the measurements.
† $p < 0.05$.
‡ Images from two participants were unclear; it was impossible to take the measurements.
§ Images from one participant were unclear; it was impossible to take the measurements.
¶ Images from five participants were not available for analysis because the posterior border of the LH was missing on the recorded volumes.
** Images from four participants were not available for analysis because the posterior border of the LH was missing on the recorded volumes.
PFM = pelvic floor muscle; UI = urinary incontinent; LHarea = levator hiatus area; LHap = levator hiatus anterior-posterior; LHt = levator hiatus transverse; BN = bladder neck; MVC = maximal voluntary contraction; CV = cranioventral; DC = dorsocaudal.

women. Our data demonstrated with moderate to large effect size that, at rest, both the LHarea and the LHt diameters were larger and the PFM position was lower (i.e., the anorectal angle was located more caudally) in the incontinent group than in the continent group; during MVC, all axial parameters were significantly larger and, again, the PFM position was lower (i.e., the anorectal angle was located more caudally) in the incontinent women; and during Valsalva, the anorectal angle was wider in the incontinent women.

Repeatability of image reading

The intra-rater image measurement reproducibility was good to very good for all parameters (ICCs = 0.625–0.981), as per Altman's benchmark scale for the classification of reliability values, whereby ICC values of 0.61–0.80 are considered to be good and values of 0.81–1.00 are considered to be very good.[24]

Rest condition

Our findings in the rest condition concur with Hoyte and colleagues'[25] 2001 MRI study of a cohort of 30 women (mean age 52 y), which demonstrated that the LHt diameter was significantly larger in women with stress UI compared than in asymptomatic women. Similarly, the 2004 Morin and colleagues[26] dynamometry (measurement of PFM force) study assessing PFM showed that women with stress UI (mean age 34 y) had lower passive force (muscle tone and passive resistance of surrounding non-muscular tissues) at rest than did continent women. Morin and colleagues' observations suggested pelvic floor laxity, at rest, in women with UI, a hypothesis supported by the findings of this study: The TPU imaging measurements in the sagittal plane demonstrated that the PFM (anorectal angle, apex position) were more caudally located in incontinent women, a result that could also indicate weaker pelvic support.

To our knowledge, this is the first time that the PFM position (height) parameter, using TPU imaging, has been used to study pelvic floor biometry in incontinent women. We chose this parameter because it was similar to M-line and because previous MRI studies have often measured an M-line parameter, "a line drawn perpendicularly from the pubococcegeous line to the apex of the anorectal angle";[23(p.1615)] this is an important morphometric parameter differentiating incontinent and continent women and a good predictor of PFM training effectiveness.[27] Furthermore, our findings concur with the 2015 MRI study by Pontbriand-Drolet and colleagues[8] of elderly participants with mixed UI (mean age 68 y); it found a longer M-line at rest in mixed UI-afflicted women, indicating a lower PFM position (i.e., more caudal position of the anorectal angle). Thus, our results add to the body of evidence that suggests that elderly incontinent women have less pelvic floor support at rest, resulting in a more caudal position of the anorectal angle, than continent women.

Maximal voluntary contraction condition

During MVC, axial parameters were all significantly larger in the incontinent group than the continent group. These results indirectly concur with the 2004 TPU imaging study by Morkved and colleagues[10] (using a different imaging protocol), which compared PFM thickness between incontinent and continent, nulliparous pregnant women (mean age 28 y). The study found that continent women had a significantly higher increment in PFM thickness (from rest to MVC), which strongly correlated with a higher vaginal squeeze pressure (measured using a vaginal balloon catheter).[10] Our results also concur with Chamochumbi and colleagues'[28] dynamometry study (mean age 43 y), which showed that women with stress UI have a lower antero-posterior active force during MVC than continent women. Thus, our study appears to concur with the imaging, pressure, and strength analysis results in these studies.

Although a cranioventral displacement of the BN during MVC was noted in the sagittal plane for both groups, we found no significant statistical difference. This is consistent with the TPU imaging studies of both Thompson and colleagues[12] and Wijma and colleagues,[13] which also measured BN displacement during MVC; neither found a significant difference between incontinent and continent women. It is noteworthy that both the methodology and the participants' mean age and age range differed in those two studies compared with the present study. Furthermore, the Thompson and colleagues[12] study took measurements during a full bladder, and the Wijma and colleagues[13] study used a different image orientation. Both previous studies and ours found the displacement to be less pronounced in incontinent women, but the large variability among the participants may have made demonstrating group differences difficult. These MVC results, combined, support Bo's[5] hypothesis that PFM that are stretched or in a caudal position may be non-optimally situated to contract maximally or to compress the urethra against the pubic bone during an MVC.

Valsalva condition

For the Valsalva condition, we found the anorectal angle to be wider in incontinent women. This could indicate that when intra-abdominal pressure increases, the PFM of incontinent women are less resistant to this pressure. To our knowledge, there are no morphometric studies using TPU imaging that confirm or contradict this observation in incontinent women.

Our study found no statistical differences between the groups in BN mobility during the Valsalva. This contrasts with the 2002 findings of Dietz and colleagues,[29] which demonstrated a greater BN descent during Valsalva associated with stress UI, suggesting that it was a good predictor of women suffering from stress UI. Comparatively, the Dietz and colleagues study included participants with a wider age range and used a different method (urodynamic evaluation) to determine UI. Furthermore, in our study, co-activation of the PFM was found in 45% (9 out of 20) of the incontinent participants, which could have confounded the Valsalva results. Although the evaluator provided auditory biofeedback, the incontinent women may have instinctively refrained from performing a maximum Valsalva to prevent leakage.

Our study is the first to compare pelvic floor morphometry between incontinent and continent elderly women using TPU imaging. Previous studies comparing pelvic floor morphometry between incontinent and continent women using TPU imaging conducted in adult women with a mean age of 40 (SD 3) years did not observe any differences during an MVC or Valsalva.[12,13]

Currently, PFM exercises are universally used as the first-line treatment for stress UI and mixed UI; however, the recommended training parameters vary widely on the basis of different assumptions of how PFM training affects continence.[4–6,9] Our findings suggest that there may be distinct differences in pelvic floor morphometry in elderly women with and without UI. This information contributes to knowledge of PFM anatomical geometry and function in elderly incontinent women and will inform the development of better targeted PFM training for this population.

Our study presented some limitations. First, the intra-rater reliability applied to the measuring of the images rather than acquiring and measuring the images on two occasions. This may have underestimated real error, which includes both acquiring and interpreting the data. Second, the number of study participants may have limited the generalization of our study results. Third, we determined the UI type on the basis of the validated UDI questionnaire (symptoms), not on a urodynamic evaluation (signs). Because this was an exploratory study in an elderly population, we considered urodynamic evaluation to be too invasive; however, this method has been shown to be reliable in determining UI type,[30] and future studies to advance the understanding of UI pathophysiology should use urodynamics in addition to symptom questionnaires to determine UI type. Fourth, the number of significance tests we conducted may have increased the chance of type 1 error. Finally, the US equipment also imposed a limitation: In some instances in which a participant's hiatal area was very large, the US's 70° angle of acquisition did not extend to the outer hiatal boundaries during a Valsalva manoeuvre.[8]

Further investigation of morphometric differences between incontinent and continent elderly women in a larger cohort with a urodynamically proven UI type, and using US equipment with less technological limitation, will continue to inform the development of targeted PFM training protocols specific to elderly women to ultimately improve the efficacy of PFM training for UI in this population.

CONCLUSION

This study is significant in that, to our knowledge, it is the first to study pelvic floor morphometry in elderly women, with and without UI, using 3D–4D TPU imaging. The results suggest that there are differences in pelvic floor morphometry between incontinent and continent elderly women, with moderate to large effect sizes.

KEY MESSAGES

What is already known on this topic

Urinary incontinence (UI) affects as many as 50% of women aged 60 years and older; however, UI pathophysiology, specifically in elderly women, remains unclear.

What this study adds

There are distinct differences in pelvic floor morphometry at rest, during pelvic floor muscle maximal voluntary contraction (MVC), and during Valsalva between elderly incontinent and continent women. Physiotherapists should consider, and aim through their pelvic floor muscle rehabilitation approach, to reduce muscle morphometry differences at rest, during pelvic floor muscle MVC, and during Valsalva.

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APPENDIX

Morphometric measurements

	Measurements	Description
Axial plane	(1) LHap*	LH distance between the inferior border of the pubic symphysis anteriorly and the pubovisceral muscle posteriorly [1]
	(2) LHt*	LH transverse diameter at the widest distance between inner margins of the pubovisceral muscle, perpendicular to the LHap distance [1]
	(3) LHarea*	LH area, bordered laterally and posteriorly by the pubovisceral muscle, and anteriorly by the inferior border of the pubic symphysis [1]
Sagittal plane	Horizontal reference line*	Horizontal line through the inferior margin of the symphysis pubis [2]
	Vertical reference line*	Vertical line through the posterior margin of the symphysis pubis [2]
	Pelvic floor reference line*	Horizontal line through the apex of the anorectal angle [3]
	(1) BN (X)*	The BN position relative to the posterior margin of the symphysis pubis [4]
	(2) BN (Y)*	The BN position relative to the inferior margin of the symphysis pubis [4]
	(3) Anorectal angle*	Angle formed by the pubovisceral muscle and measured at the intersection of the lines drawn along the posterior walls of the anal canal and the rectum [1]
	(4) PFM height*	Distance between the inferior edge of the pubic symphysis (horizontal reference line) and the apex of the anorectal angle (pelvic floor reference line) [3]
	(5) Cranioventral displacement**	Cranioventral shift of the pelvic organs at MVC, calculated by comparing BN measurements at rest and on MVC [5]
	(6) Dorsocaudal displacement***	Dorsocaudal displacement on Valsalva is calculated by comparing BN measurements at rest and on Valsalva [6]