# Evaluating pelvic floor muscle contractility using two-dimensional transperineal ultrasonography in patients with pelvic organ prolapse


## Abstract

Aims:

The hiatal anterior-posterior distance (APD), as measured by two-dimensional (2D) transperineal ultrasonography, is an indicator of pelvic floor muscle (PFM) contractility. The function of the pelvic floor is independently related to pelvic organ prolapse (POP) severity. However, little evidence concerning the APD for patients with POP before and after PFM training (PFMT) has been published. Therefore, we analyzed 2D transperineal ultrasonography in women with POP.

Methods:

Twenty-eight women with POP completed a physiotherapist-led PFMT regimen that consisted of 4 months of one-on-one PFMT and lifestyle advice. The APD was measured using 2D transperineal ultrasonography immediately before and after the PFMT period and used to calculate ΔAPD (APD at rest – APD during contraction). Vaginal squeeze pressure during maximum voluntary contractions was also assessed using a manometer. We then analyzed the reliability and the correlation between ΔAPD as measured using 2D transperineal ultrasonography and vaginal squeeze pressure before and after PFMT.

Results:

The APD at rest and during PFM contractions demonstrated intraclass correlation coefficients (ICCs) of 0.89 and 0.88, respectively. The ICC of maximal vaginal squeeze pressure was 0.97 during PFM contractions. Both ΔAPD ($p < 0.01$) and PFM strength ($p < 0.05$) increased significantly after PFMT. PFM strength and ΔAPD were correlated before ($R = 0.53$) and after ($R = 0.68$) PFM training ($p < 0.01$).

Conclusions:

We demonstrated that dynamic 2D transperineal ultrasonography could be used for studying functional changes in patients with POP. The ΔAPD of the levator hiatus has potential as an anatomical surrogate marker for evaluating PFM function in hospitals.

## 1 | INTRODUCTION

According to epidemiological studies, the prevalence of symptomatic pelvic organ prolapse (POP) is 3–6% among women, and up to 50% based on POP quantification stage 0, I, II, and III as follows: 6.4%, 43.3%, 47.7%, and 2.6%, respectively.[1,2] Pelvic floor muscle (PFM) training (PFMT) is widely prescribed for women with POP and is the first-line treatment for POP; recommended by the International Continence Society as Grade A.[3] PFM function is thought to play a significant role in the pathogenesis of POP.[4] PFM kinesiologic function is assessed using relatively reliable measurements, such as digital examination, manometry, and electromyography using a vaginal probe.[5–7] However, there are some patients, for example those immediately after transvaginal surgery or vaginal delivery, who feel discomfort and pain. We also had patients who declined to take part in studies because of cultural factors in Asian countries. Ultrasonography has been developed as an alternative method and a more practical approach for both anatomical and functional assessments. Ultrasonography is considered to be more reproducible and objective, with imaging of deep pelvic floor structures, which are difficult to access by palpation.[8] A ultrasonography transducer placed on the perineum can be used to visualize whole structures, such as the bladder, urethra, rectum, anal canal, and vagina in the midsagittal plane. Braekken et al.[9] found that there were negative correlations between the hiatus area based on three-dimensional (3D) ultrasonography and PFM strength compared with manometer measurements in women with POP. A previous study showed that 2D transperineal ultrasonography measurements of the anterior–posterior distance (APD) of the levator hiatus on ultrasonography during voluntary contraction of the PFM can be used to assess both the supporting function and the contractile function of the pelvic floor in postpartum women.[10] Nevertheless, to date, few reports on APD for patients with POP have described the reliability of 2D transperineal ultrasonography before and after PFMT. We hypothesized that 2D transperineal ultrasonography is reliable to assess PFM functions, and there is correlation between vaginal squeeze pressure and anterior–posterior distance of the lavator hiatus in patients with POP.

## 2 | METHODS

Thirty-one patients with POP participated in this study. The sample size was calculated based on the significant change in PFM strength that occurs after PFMT, and on a previous before and after trial with an effect size of 0.69, a power of 0.8, and a significance level of 0.05.[11] Thus, the sample size was set as 22. We determined that a final sample size of 27, including dropouts, would be appropriate[12]. Only patients who were diagnosed with POP (stage II or III) evaluated using the Pelvic Organ Prolapse

Quantification System[13] by a urologist were included in the present study. Women with POP included in this study visited a urology department from 2013 to 2014. Exclusion criteria were as follows: serious psychiatric or neurological disease, pregnancy, less than 1 year after giving birth, urinary tract infection, gynecology or obstetric surgery, concurrent therapy for incontinence or POP, or hormonal replacement therapy. The ethical approval for this study was obtained from the Research Ethics Committee of our institution (13-502). All participants provided written consent.

One physiotherapist performed the manometry and ultrasonography examinations of PFM function. The physiotherapist checked if each woman could contract their PFM properly. If not, they were taught how to do correct PFM contractions with normal breathing without contracting the abdominal muscles and muscles surrounding the right and left hip joints. We assessed the perineal movement with palpation and inspection to check if PFM contraction occurred properly in this study. We confirmed that all participants could perform correct PFM contractions before starting the examination. The maximum voluntary contraction (MVC) of the PFM was assessed using a manometer (Peritoron®; Cardio-Design Pty, Oakleigh, VIC, Australia), which consisted of an air-filled sensor through the vaginal tube attached to a manometer with a pressure transducer. The manometer was inflated up to 100 $cmH_2O$ in the vagina and reset to zero. Three MVCs were measured for each participant, and the average value was recorded.

The APD was defined as the minimum distance between the hyperechogenic posterior aspect of the pubic symphysis and the anterior border of the hyperechogenic pubovisceral muscle in the mid-sagittal plane by 2D transperineal ultrasonography (Aplio 300®, Toshiba, Tokyo) (Figure 1).[14] A curved array ultrasound transducer (7.5 MHz, PLT-704AT, Toshiba, Japan) was used to image pelvic structures. Images from which the APD measurements were made were obtained by placing a curved array ultrasonography transducer on the perineum in the mid-sagittal plane between the pubic symphysis and the anus. The APD was measured at rest (APD at rest) and during PFM contraction (APD during contraction) (Figure 2). Women were placed in the supine position on a bed with hip joints flexed and slightly abducted. The participants were instructed to contract the PFM as strongly as possible for 10 seconds and to relax their PFM for 10 seconds after each contraction. Dynamic images were obtained during PFM contractions and at rest. At least three cycles of PFM contraction and relaxation were recorded for each individual. We observed the inward movement of the perineum to confirm patients contracted the PFM only without intra-abdominal pressure.[15] The formula used to calculate the difference in terms of distance (in millimeters) between the maximum contraction and rest was as follows: ΔAPD = (APD at rest – APD during contraction). The average value was used.

Reliability tests for vaginal squeeze pressure and ΔAPD were conducted before the commencement of 4 months of PFMT. We conducted tests between 2 different days. The patients were asked not to perform PFMT during reliability tests.

During the PFMT period, all participants attended physiotherapy sessions six times (at 0, 2, 4, 8, 12, and 16 weeks). They received physiotherapist-led one-on-one PFMT and received lifestyle advice from the physiotherapist. In addition, they were instructed to perform three sets of PFMT per day at home and to keep a report of their home exercise adherence using an exercise calendar. The present study was one component of a previous clinical trial that investigated changes in physical activities due to PFMT in patients with POP.[12]

Statistical analysis was conducted using the Statistical Package for the Social Sciences (SPSS) 23.0J, Mac version. In the data analysis, 28 of the 31 original participants completed PFMT and were included. Data distribution was assessed with the Shapiro–Wilk test. Paired-t test was conducted for POP-Q Ba and gh between before and after PFMT. Wilcoxon signed-rank test was conducted for POP-Q other parameters between before and after PFMT. Because the vaginal squeeze pressure and ΔAPD were not normally distributed, we utilized non-parametric statistical methods. Wilcoxon signed-rank test was conducted to analyze changes in pelvic floor function before and after

PFMT. Spearman's rank correlation coefficient was performed to compare vaginal squeeze pressure during MVC and ΔAPD. Data were interpreted as follows: +1 indicates a perfect association between vaginal squeeze pressure and ΔAPD. An alpha of 0.05 was set for the significance level.

## 3 | RESULTS

Thirty-one outpatients who visited the female urology department between November 2013 and May 2014 were assessed. Twenty-eight women with POP (Stage II or III) were included in the study (age: 65.8 ± 7.5 years, mean ± SD; Table 1). POP-Q Aa and Ba were significantly improved (Table 2). ICC values of the length of the APD at rest and during voluntary PFM contractions were 0.89 and 0.88, respectively. The ICC value of maximal vaginal squeeze pressure, as measured using a manometer, was 0.97 during voluntary PFM contractions (Table 3). The PFM strength increased significantly after 4 months of PFMT relative to before PFMT ($p = 0.0001$). ΔAPD also increased significantly ($p < 0.0001$), as shown in Table 4. Moreover, the current study showed that there was a moderate correlation between MVC and ΔAPD both before ($R = 0.53$) and after ($R = 0.68$) PFM training ($p < 0.01$) (Figure 3).

## 4 | DISCUSSION

This was a prospective study that demonstrated a significant correlation between vaginal squeeze pressure and ΔAPD both before and after 4 months of PFMT in patients with POP. APD, as measured using 2D, 3D, and 4D ultrasonography, has been analyzed in nulliparous, primiparous, and patients with POP.[10,14,16] A previous study demonstrated that ultrasonography could be used to visualize the displacement of the anorectal junction during PFM contraction, which produces a decline in the anterior–posterior levator hiatus distance in women.[17] Patients with POP stage II or above were more likely to have weak PFM strength and endurance compared with those with POP stages 0 and I.[4] PFM contractility was significantly associated with POP, and, in addition, PFMT improved PFM strength and prolapse symptoms compared with a control group.[4,18] Braekken et al.[9] provided robust evidence that as vaginal squeeze pressure increased in the PFMT group, pubovisceral muscle thickness increased by 15.6%, and the area of levator hiatus narrowed by 6.3%. Additionally, PFM strength had a positive association with decreased hiatal area (rho = 0.25, p = 0.028).[18] In our study, ΔAPD and vaginal squeeze pressure increased significantly after PFMT relative to measurements in individual participants before PFMT. These results also confirmed that 2D ultrasonography can successfully detect changes in PFM contractility. Thus, 2D ultrasonography can be used for patients with POP in hospital or clinic settings. This method is additionally advantageous because it does not require additional investment in equipment. ΔAPD as measured by 2D ultrasonography may thus serve as an acceptable surrogate marker for PFM strength in patients with POP, as an alternative to measuring vaginal squeeze pressure.

The acquisition of measurements by ultrasonography is considered to be easy, but their accuracy depends on the skill of the operator. Transperineal assessment results in visualization of the pubic symphysis as a bony landmark, which may help in identifying the precise location of anatomical structures in the pelvic floor. We chose this landmark, as reported previously (Figure 1).[10,14,19] In addition, the puborectalis muscle whose fibers form a sling (U) shape arising from the posterior aspect of the pubic symphysis to the rectum in the urogenital diaphragm can be clearly seen with this method. During assessment of ΔAPD, the hyperechoic site of the puborectalis muscle was displaced in the cranial–ventral direction. We also confirmed that the patients were correctly generating PFM contractions, based on observation of the cranially directed displacement without increased abdominal pressure. Using this feedback, the patients were taught the correct method for generating PFM contractions. The Modified Oxford Scale is commonly used for assessing PFM contractions. Dietz et al.[20] showed that the Modified Oxford Scale is a more sensitive predictor of maximum urethral closure pressure compared with hiatal diameters, because the results from digital assessment are positively correlated with the augmentation of urethral closure pressure during PFM contractions ($r = 0.24$, $p = 0.001$). In contrast, no correlation was found between hiatal diameters and digital assessment.[20] Digital assessment, however, requires that trained health professionals digitally assess PFM function. With the transperineal measurements described here, numeric data are acquired easily, and clinicians can easily introduce this method into their clinics for PFM functional assessment without additional training. In this study, a manometer was used to assess vaginal squeeze pressure, which is considered to be a relative not absolute measurement. It can be impacted by vaginal capacitance and/or voluntary controlled PFM contractions, etc. However, a previous study for reliability testing demonstrated that the correlation coefficient between manometry and the digital examination was found to be moderate.[21] We thought that the manometer was reliable enough to measure the vaginal squeeze pressure.

Our results showed a high reliability of measurements of both ΔAPD and vaginal squeeze pressure. A previous study[14,22] and our findings here indicate an good to perfect ICC for APD, suggesting a high degree of reproducibility in this study. Measuring increases in vaginal squeeze pressure during contraction of the PFM with a manometer shows acceptable reliability[5,7,21]. It is widely performed in test-retest and re-evaluations used by different examiners. The present study achieved almost perfect agreement, with ICC values of 0.96 (for same-day measurements) and 0.97 (for different-day measurements) for vaginal squeeze pressure with maximal PFM contraction.

2D transperineal ultrasonography allows visualization from the pubic symphysis to the anorectal junction with a depth of 8 cm. We measured the distance between the posterior aspect of the pubic symphysis and the anorectal junction and could thus quantify displacement of the anorectal junction during PFM contraction compared with its position at rest, which is considered indicative of the movement of the levator ani muscle. Although the puborectalis muscles cannot be separately distinguished from the pubococcygeus muscle,[23] imaging of the perineum in the sagittal plane detects the highly echogenic part of the anorectal junction due to the posterior attachment of the pubovisceral muscle. The ΔAPD indicates the ventral displacement of the pubovisceral muscle during voluntary PFM contraction, and cranial movement between the PFM at rest and during contraction. This could suggest that the voluntarily augmented urethral closure pressure can be represented by measuring ΔAPD and is positively associated with PFM contractility.[20]

We provided supervised PFMT for all patients with POP for 4 months.[12] The results showed significant improvement in vaginal squeeze pressure and ΔAPD after PFMT compared with before PFMT. Additionally, PFMT improves POP-related symptoms, such as frequently going to the bathroom to urinate, stress urinary incontinence, post-micturition dribble, and feeling vaginal bulge interfering with emptying of the bowels in our previous study. A previous study that analyzed risk factors for POP demonstrated that PFM strength is a independent factor for POP.[4] PFMT is recommended as Grade A for pelvic floor symptoms on POP.[3] Additionally, a meta-analysis concluded that PFMT is effective for increasing PFM strength and improving POP symptoms and stage, compared with controls.[24] The significant increase in ΔAPD can be interpreted to represent increased PFM function, and by extension the potential to improve some POP-related symptoms.

This study had the following limitations. The small sample size of this study is a reflection of the small number of individuals who seek treatment for lower urinary tract symptoms in Japan.[25] We found difficulty in including patients with mild to moderate POP in the present conditions. Because physiotherapy has yet to be fully covered by public insurance in women's health, very few physiotherapists treat patients with POP in a clinical setting. The present study involved a quasi-experimental design without a control group. Because of the study design, it was not possible to determine the cause and effect relationship. Larger randomized control trials will be needed to overcome this limitation in the future.

## 5 | CONCLUSIONS

We propose that ΔAPD of the levator hiatus could represent an anatomical measurement for assessing PFM function in clinic and hospital settings. Moreover, dynamic 2D transperineal ultrasonography could be a method for studying functional changes in individuals with POP.

## 6 | REFERENCES


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**Financial Disclaimers/Conflict of Interest statement**

None

## LEGENDS

Table 1.

BMI: body mass index (kg/m$^2$), POP-Q: Pelvic Organ Prolapse Quantification System

Data are indicated as follows; body mass index: mean ± SD, age and parity: median (minimum – maximum), POP-Q Stage, type of POP, and numbers of women who had an occupation, regular exercise, or sexual intercourse: n (%).

Table 2.

The data are presented as medians (minimum – maximum). Ns are not shown because they were not significant. Aa: 3 cm proximal to or above the hymenal ring anteriorly, Ap: 3 cm proximal to or above the hymenal ring posteriorly, C: the anterior apex (cervix), D: the posterior apex (pouch of Douglas), gh: the genital hiatus, pb: the perineal body, tvl: the total vaginal length

Table 3.

The data from day 1 and 2 are shown as means ± SD

ICC are presented as medians (minimum – maximum) (n=6)

Table 4.

The data are shown as means ± SD. The significance level was set at 0.05. n.s: not significant

Figure 1.

The APD corresponds to the length of the black double-headed arrow between the posterior aspect of the pubic symphysis and the anorectal junction. ΔAPD was defined as APD at rest – APD during contraction. This drawing represents the pelvic floor of a patient with POP and shows the dislocation of the posterior bladder into the vagina.

Figure 2.

Measurement of APD at rest and during contraction. (a, b) Images from 2D transperineal ultrasonography in the mid-sagittal plane show the minimal hiatal diameter (white double-headed arrow) between the posterior aspect of the pubic symphysis and the anorectal junction at rest (a) and during contraction (b). The pubovisceral muscle is determined based on the hyperechogenic region posterior to the anorectal junction[14]. P, pubic symphysis; B, bladder; R, rectum; A, anus.

Figure 3.

Correlation between ΔAPD and vaginal squeeze pressure before and after PFMT. Data are shown for all participants (n = 28).

Table 1. Demographic characteristics of all participants (n=28)

| Characteristic | Value[a] |
| --- | --- |
| Age (years) | 67 (49–76) |
| BMI | 23.1 ± 3.3 |
| Parity | 2 (2–3) |
| POP-Q Stage II | 16 (57.1) |
| POP-Q Stage III | 12 (42.9) |
| Type of POP: Anterior vaginal wall | 27 (96.5) |
| Posterior vaginal wall | 0 (0.0) |
| Apical prolapse | 1 (3.5) |

Table2. POP-Q data before and after PFMT in patients with POP (n=28)

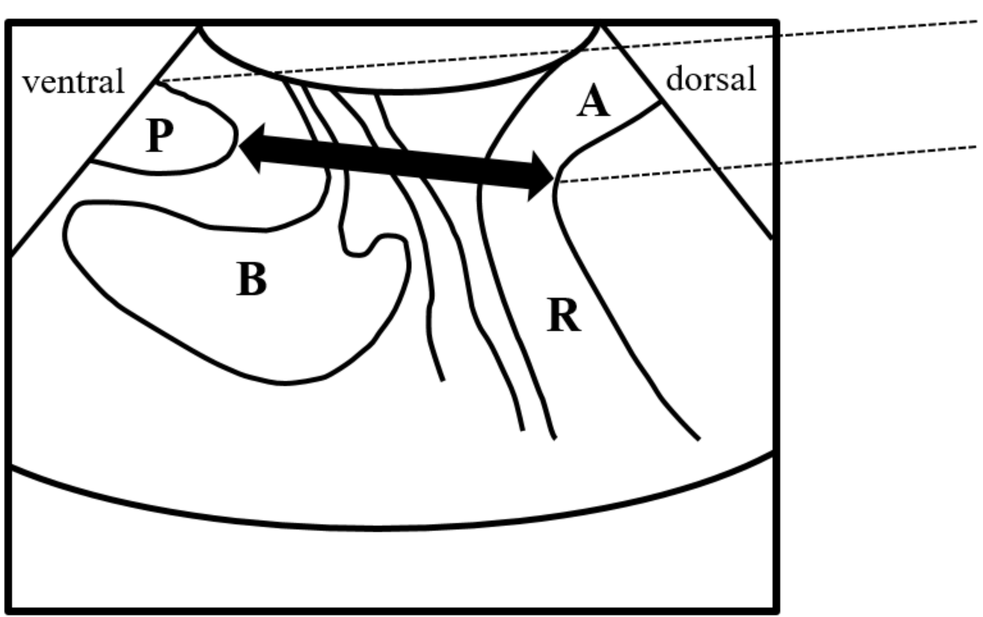
| | **Before PFMT** | | | **After PFMT** | | | **p value** |
|---|---|---|---|---|---|---|---|
| | **Median** | **Min** | **Max** | **Median** | **Min** | **Max** | |
| Aa | 1.0 | -2.0 | 2.5 | 0.5 | -2.5 | 2.5 | 0.0024 |
| Ba | 1.0 | -1.5 | 4.0 | 0.5 | -2.5 | 3.5 | 0.0005 |
| C | -4.0 | -6.0 | 2.5 | -5.0 | -6.5 | 2.0 | Ns |
| gh | 3.8 | 2.0 | 5.5 | 3.5 | 1.0 | 5.0 | 0.0080 |
| pb | 3.0 | 2.0 | 3.5 | 3.0 | 2.0 | 4.0 | Ns |
| tvl | 7.5 | 6.0 | 8.5 | 7.5 | 7.0 | 9.0 | Ns |
| Ap | -2.5 | -3.0 | 1.5 | -3.0 | -3.0 | 1.0 | Ns |
| Bp | -2.5 | -3.0 | 1.5 | -3.0 | -3.0 | 1.0 | Ns |
| D | -6.0 | -7.0 | -2.0 | -6.5 | -8.0 | -3.0 | Ns |

Table 3. Reliability indexes of each PFM function (n=5)

| Characteristic | Day 1 | Day 2 | ICC |
|---|---|---|---|
| APD at rest (mm) | 59.3 ± 4.7 | 58.6 ± 5.1 | 0.89 (0.39–0.99) |
| APD during PFM contraction (mm) | 47.9 ± 3.2 | 49.3 ± 2.8 | 0.88 (0.37–0.99) |
| Vaginal squeeze pressure (cm$H_2O$) | 20.8 ± 10.6 | 21.6 ± 9.3 | 0.97 (0.80–0.99) |

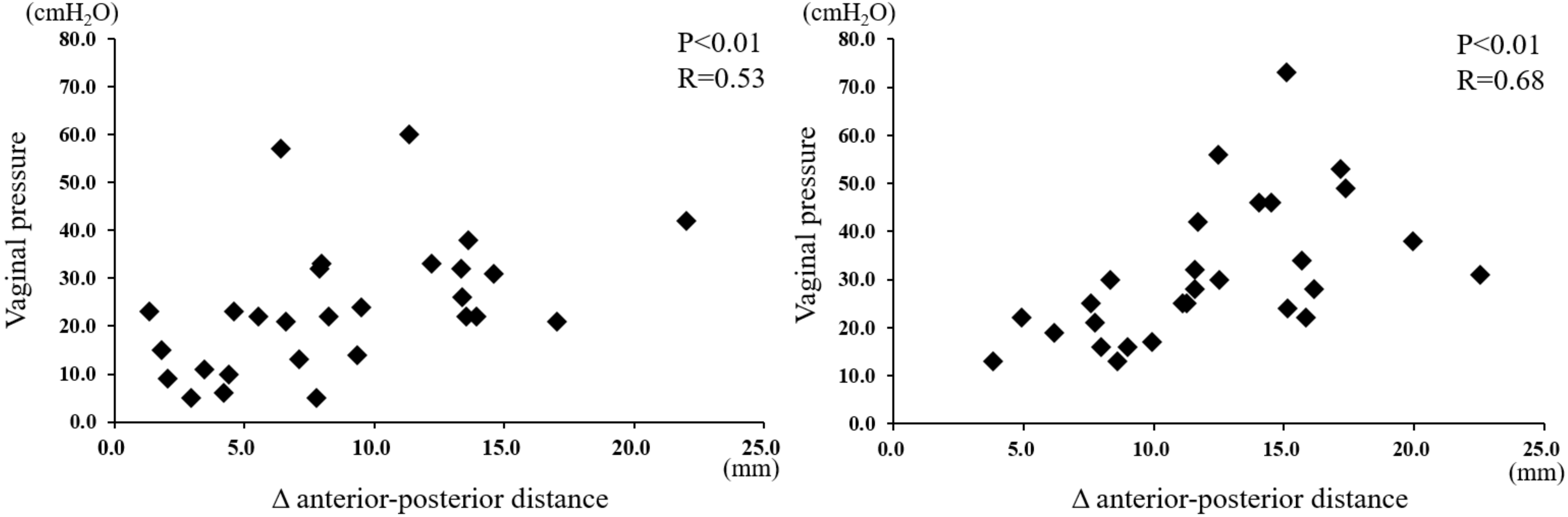
Table 4. Changes in PFM functions before and after PFMT (n=28)

| Characteristic | Before PFMT | After PFMT | p-value |
|---|---|---|---|
| APD at rest (mm) | 50.7 ± 6.4 | 51.3 ± 4.3 | n.s. |
| APD during PFM contraction (mm) | 42.5 ± 6.0 | 39.1 ± 5.3 | <0.0001 |
| ΔAPD (mm) | 8.9 ± 5.1 | 12.1 ± 4.4 | <0.0001 |
| Vaginal squeeze pressure ($cmH_2O$) | 24.0 ± 13.9 | 31.2 ± 14.5 | 0.0001 |



ventral
dorsal
P
B
R
A
Posterior aspect of pubic synphysis
Anorectal junction
P: pubic synphysis
B: bladder
R: rectum
A: anus


P: pubic synphysis
B: bladder
R: rectum
A: anus



(cmH$_2$O)
Vaginal pressure
P<0.01
R=0.53
Δ anterior-posterior distance
(mm)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
5.0
15.0
25.0
(cmH$_2$O)
Vaginal pressure
P<0.01
R=0.68
Δ anterior-posterior distance
(mm)