International Urogynecology Journal (2022) 33:2391–2400
https://doi.org/10.1007/s00192-022-05119-3

ORIGINAL ARTICLE

Are clinically recommended pelvic floor muscle relaxation positions really efficient for muscle relaxation?

Özge Çeliker Tosun[1] · Damla Korkmaz Dayıcan[2] · İrem Keser[3] · Sefa Kurt[4] · Meriç Yıldırım[1] · Gökhan Tosun[5]

Received: 3 November 2021 / Accepted: 3 February 2022 / Published online: 24 February 2022

Abstract

Introduction and hypothesis Various positions for pelvic floor muscle (PFM) relaxation are recommended during PFM training in physiotherapy clinics. To our knowledge, there is no study addressing the most effective position for PFM and abdominal muscle relaxation. Therefore, the current study aimed to investigate the effect of different relaxation positions on PFM and abdominal muscle functions in women with urinary incontinence (UI).

Methods Sixty-seven women diagnosed with UI were enrolled in the study. The type, frequency, and amount of UI were assessed with the International Incontinence Questionnaire-Short Form and bladder diary. Superficial electromyography was used to assess PFM and abdominal muscle functions during three relaxation positions: modified butterfly pose (P1), modified child pose (P2), and modified deep squat with block (P3). Friedman variance analyses and Wilcoxon signed rank test with Bonferroni corrections were used to evaluate the difference between positions.

Results The most efficient position for PFM relaxation was P1 and followed by P3 and P2, respectively. The order was also the same for abdominal muscles ($p<0.001$), P1 > P3 > P2. The rectus abdominis (RA) was the most affected muscle during PFM relaxation. The extent of relaxation of RA muscle increased as the extent of PFM relaxation increased ($r=0.298$, $p=0.016$). No difference was found between different types of UI during the same position in terms of PFM relaxation extents ($p>0.05$).

Conclusions Efficient PFM relaxation is maintained during positions recommended in physiotherapy clinics. The extent of PFM and abdominal muscle relaxation varies according to the positions.

Keywords Abdominal muscle · Electromyography · Pelvic floor muscle · Relaxation position

Urinary incontinence (UI) is defined as "the complaint of involuntary loss of urine" by the International Urogynecological Association (IUGA)/International Continence Society (ICS) [1]. PFM has four primary functions including opening (relaxation), closing (contraction), support, and sexual function [2]. Relaxation of PFM is as important as contraction [3]. Voluntary relaxation is the ability of the individual to release the muscles voluntarily after a contraction. In other words, PFM relaxation is the return to the resting state after the contraction. Involuntary relaxation occurs

✉ Damla Korkmaz Dayıcan
kkorkmazdamla@gmail.com

Özge Çeliker Tosun
bakikuday@gmail.com; ozge.tosun@deu.edu.tr

İrem Keser
iremcatal93@gmail.com

Sefa Kurt
sefakurt@gmail.com

Meriç Yıldırım
mericsenduran@hotmail.com

Gökhan Tosun
drgokhan77@gmail.com

1 Faculty of Physical Therapy and Rehabilitation, Dokuz Eylül University, Izmir, Turkey

2 Department of Physiotherapy and Rehabilitation, Faculty of Health Sciences, Biruni University, Istanbul, Turkey

3 Institute of Health Sciences, Dokuz Eylül University, Izmir, Turkey

4 Department of Obstetrics and Gynecology, Dokuz Eylül University, Izmir, Turkey

5 Department of Obstetrics and Gynecology, Tepecik Education and Research Hospital, Izmir, Turkey

during normal micturition, defecation, and Valsalva maneuver [4]. PFM has to be released to allow normal micturition and defecation [3]. Muscles with diminished ability to relax result in dysfunctions of micturition, defecation, and sexual functions. Therefore, relaxation training has an important role in pelvic floor rehabilitation programs [5].

Introduction

Body position and lumbopelvic posture affect electromyographic activities of PFM and abdominal muscles. There are many studies investigating the functions of PFM and abdominal muscles using superficial electromyography (EMG) in different positions [6–8]. There is a synergistic relationship between PFM and abdominal muscles. This synergistic relationship occurs during both PFM contractions and abdominal maneuvers and is important to regulate intraabdominal pressure to maintain continence [9, 10]. The synergistic relationship between PFM and abdominal muscles may be disrupted in women with UI. Women with UI present decreased PFM activity and increased abdominal muscle activity compared to continent women [11]. Studies mostly focus on the ability to contract rather than the relaxation of PFM and ignore the relationship between PFM and abdominal muscles during relaxation. However, according to the IUGA/ICS joint report, normal functioning of PFM depends on the patient's voluntary and involuntary ability to contract and relax the muscles [5].

PFM must be able to contract and shorten as well as relax and extend for optimal function. Considering the length-tension relationship of skeletal muscles, a muscle is unable to produce maximum contraction force within its shortest and longest positions [12]. In case of insufficient PFM relaxation, long-term problems may occur including shortening, stretching, spasms, and various dysfunctions [13]. The inability of the muscle to provide the contractile force at optimal lengths results in the inability to prevent urine or stool loss and stabilize trunk, also slowing blood flow and reducing the length of connective tissue, which will further compress the structures supported by the connective tissue including pelvic nerves, inducing trigger point formation within the muscle [12]. Excessive muscle tension also decreases muscle strength and endurance, leading to insufficient support of pelvic organs, pelvic organ prolapse, and incontinence; decreases the anorectal angle, complicating defecation; increases the need for intra-abdominal pressure by preventing the onset of micturition; and increases the risk of hemorrhoids due to constipation [2]; it can adversely affect the contribution of the PFM to respiratory function [14]. Therefore, relaxation training of PFM muscles within the pelvic floor rehabilitation programs may help to achieve functional muscle length, providing stronger and more functional muscle contraction, and prevent negative consequences of muscle tightness [5, 15].

To the best of our knowledge, there is a lack in the literature regarding the most effective relaxation position and the relationship between PFM and abdominal muscle functions in different relaxation positions. We think that determining effective positions for PFM and abdominal muscle contraction and relaxation may provide position-specific adjustments in PFM training protocols and may increase the success of treatment programs.

Treatments for PFM function of women with UI in physiotherapy clinics include Kegel exercises, PFM training, hypopressive exercises, and various other kinds of exercises. However, there are limited data on the most effective position for all these exercise applications [16–18]. These studies mostly focus on PFM contraction ruling out the relaxation function. Further studies are required to address the effects of common exercises which are clinically recommended for all PFM and abdominal muscle functions. Therefore, the objective of the current study was to investigate the effects of different relaxation positions on the relaxation function of PFM and abdominal muscles in women with UI using superficial EMG.

Materials and methods

Seventy-six women > 18 years of age and diagnosed with UI by the Department of Obstetrics and Gynecology, Medical Faculty, Dokuz Eylul University, were enrolled in this descriptive, cross-sectional study. Women who were pregnant, were in the post-partum period, were menstruating, had active urinary tract infections, had a history of incontinence or abdominal surgery, or had neurological, orthopedic, or psychiatric comorbidities were excluded from the study. Five of these individuals were not eligible according to the inclusion criteria, and four did not volunteer to participate in the study. Therefore, assessments of 67 women were finished, and their data were analyzed.

The study was conducted in accordance with the ethical standards of the Helsinki Declaration and was approved by the Institutional Non-invasive Research Ethics Board (number: 4399-GOA). All the individuals gave written consent to participate in the study after receiving appropriate verbal and written information.

Procedure and outcome measures

Sociodemographic features of the participants were collected via the face-to-face questioning technique. Age (years), body weight (kg), body mass index (kg/m^2), educational level, occupation, and marital status were recorded on the data collection form. Additionally, family history, lifestyle habits, medical and surgical history, obstetric, gynecological, gastrointestinal, and urological history were questioned in detail. The type, frequency, extent, and effect of UI on daily functions were assessed with 'International Consultation on Incontinence Questionnaire-Short Form' (ICIQ-SF) and a 3-day bladder diary [19].

EMG assessment of relaxation functions of PFM and abdominal muscles

Electromyographic activities of PFM and abdominal muscles were assessed using a superficial EMG device (NeuroTrac MyoPlus 4 PRO, Verity Medical Ltd., UK). Technical specifications of the device include:

1.0 Dual channel EMG

1.1. EMG range: 0.2 to 2000 μV root mean square (RMS) (continuous)
1.2. Sensitivity: 0.l-μV RMS
1.3. Accuracy: 4% of μV reading ± 0.3 μV at 200 Hz
1.4. Selectable bandpass filter −3 dB bandwidth (width: 18 Hz ± 4 Hz to 370 Hz ± 10%, reading < 235 microvolts; 10 Hz ± 3 Hz to 370 Hz ± 10%, reading > 235 microvolts. Narrow: 100 Hz ± 5% Hz to 370 Hz ± 10%)
1.5. Notch filter: 50 Hz (Canada 60 Hz)–33 dB (0.1% accuracy)
1.6. Common mode rejection ratio: 130 dB minimum @50 Hz
1.7. Work/rest periods: 2–99 s
1.8. Number of trials: 1–99.

EMG device was connected to a laptop with the software of the producer. The network connection of the two pieces of equipment was cut off during the recordings to prevent significant interference. The graphical outcome of the measurements was reflected to the monitor of the laptop from the monitor of the device.

A cylinder endovaginal probe with two metal sensors (Verity Medical Ltd., UK) was used to record the electromyographic activity of deep PFM. The height of the probe was 8.7 cm, and the diameter was 2.6 cm. The endovaginal probe was inserted into the vagina after antiallergic gel application.

Electromyographic activities of superficial PFM and abdominal muscles (rectus abdominis, transversus abdominis, internal abdominal oblique, external abdominal oblique) were assessed using single-use, superficial, self-adhesive, silver-silver chloride (Ag/Ag CI) electrodes. The diameter of circular electrodes was 3.2 cm. The skin was cleaned with an alcohol-soaked cloth before superficial electrode application to diminish skin impedance [20]. Superficial electrodes were attached on the muscles parallel to muscle fibers: rectus abdominis (RA): 1.5 cm laterally and distally to umbilicus [8]; transversus abdominis (TA): 2 cm superior to symphysis pubis and parallel to superior pubic ramus [9]; internal abdominal oblique (IO): 2 cm superior to the midline between symphysis pubis and spina iliaca anterior superior (SIAS) [10]; external abdominal oblique (EO): inferior to the 8th costa with a 45° angle to the medial border of the clavicle [21]; superficial PFM: on two sides of the perineal body (at 3–9 o'clock) [22]; monopolar reference electrode: onto the right SIAS to prevent external interference [9]. A hypoallergic high-adhesive medical bond was attached to the electrodes to maintain the contact and to prevent artifacts that might be caused by the movement of the electrodes.

The participants were asked to empty their bladders before the assessment. They were informed about the definition, location, and functions of PFM and an efficient PFM contraction using anatomical models. A correct PFM contraction was taught to the individuals using digital palpation to prevent straining and the contraction of different muscles [4]. The participants were asked to squeeze the fingers of the physiotherapist and pull inwards/upwards, similar to continence [9]. The assessments were carried out in three different relaxation positions. An experienced physiotherapist had informed the participants about the necessity of relaxing all PFM after the "relax" command and forcefully contracting and pulling the PFM inwards without contracting their abdominal, hip, and thigh muscles, keeping in their abdomens and holding their breath after hearing the "contract" command [9]. Later, the participants were asked to perform maximum contractions for 6 s and relax for 6 s between the contractions [7]. The contractions and relaxation sets were done in the same order in each of the three positions. Measurements were repeated three times in each position, and 2-min rests were allowed between the positions to prevent muscle fatigue [9]. Minimum, maximum, mean, standard deviation, maximum voluntary contraction (MVC) %, durations to initiate contractions, and relaxations were automatically recorded by the device after three measurements. The results of the electromyographic activities of the muscles were recorded in microvolt (μV) and percentage (%). Patients tried to prevent additional muscle activities during the measurements. Movements of the upper body and extremities were not allowed during the positions. The neutral position of the pelvis was preserved. Control measurements were made to check the correct positions of the electrodes during the first measurements [11].

Normalized EMG data are more valid and easy to interpret than EMG data expressed in microvolts [23]. In microvolt measurements, it is impossible to estimate the neuromuscular input as the data are highly affected by the local signal noise. Therefore, the records may be different even in the same positions during the same movements. MVC normalization allows the quantitative and direct comparison of muscle activities between subjects or within subjects' muscles during different tests [24]. Parallel to the literature, we have presented EMG activities of PFM and abdominal muscles in both mean in microvolts and normalized mean data (MVC %) and discussed our results according to normalized mean data.

Relaxation positions

Before data collection, the physiotherapists researched PFM relaxation positions commonly advised by visual and written media and books. The three most recommended positions were chosen for the current study. There were some differences in the hand and foot positions for these three positions in media applications. Three physiotherapists made EMG measurements in each original position on their own. The same experiments were also carried out on three women with UI. Thereafter, the positions were modified because of some problems during EMG measurements that might affect data accuracy. The final positions were as follows:

P1: This position had different names in the media: "flat frog, diaphragmatic breathing, and reclined butterfly pose." The hip joint was placed in flexion, abduction, and external rotation; the knee joint was placed in flexion while the participant was in the supine position. A standard pillow was placed under the head while the arms were placed on both sides of the body with upwards palms. Two pillows were placed under the knees to minimize the tightness of adductor muscles, and the contact of the feet with the bed was maintained. The pelvis was placed in a neutral position (Fig. 1).

P2: The name of this position in the media is "child pose." First, the individual came into a crawling position. Then, she leaned forward, having forearm support with contact between the upper part of her feet and the floor and also between each of the toes, and was positioned sitting on her hips, slightly backward, with the knees having an angel wider than the hips. Contact of the individual's hips and feet was not allowed in order to prevent pressure on the electrodes and avoid affecting the electromyographic signals (Fig. 2).

P3: This position has different names in the media: "relaxed flat frog, deep squat pose, and deep squat with block." The individual was told to sit on two yoga blocks of 7.5 × 15 × 23-cm size while her knees were above hip level in the squat position. Block-supported media practice was chosen. This position was chosen to provide support and prevent electromyographic signals from being affected by movements as it could be difficult for the individual to hold the position (Fig. 3).

Statistical analysis

All the data collected with superficial EMG, questionnaire, and bladder diary were digitized and transferred to a computer. The data were checked and revised. Statistical Package for the Social Sciences 25 was used for statistical analysis. The normality of the data distribution was checked with Kolmogorov-Smirnov/Shapiro-Wilk tests. For descriptive statistics, numbers and percentages were used for categorical variables whereas mean ± standard deviation, median, interquartile range, and minimum and maximum were used for continuous variables. Friedman variance analysis was used to compare PFM and abdominal muscle functions in three different positions, as our data were not normally distributed. Significant results were then analyzed by post-hoc tests using Wilcoxon signed ranks test with Bonferroni

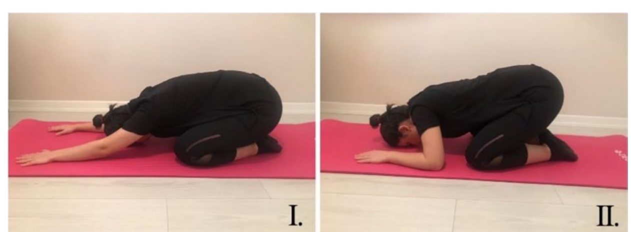

Fig. 2 I. Child pose, II. modified child pose (P2)

Fig. 1 I. Flat frog pose, II. diaphragmatic breathing pose, III. reclined butterfly pose, IV. modified butterfly pose (P1).

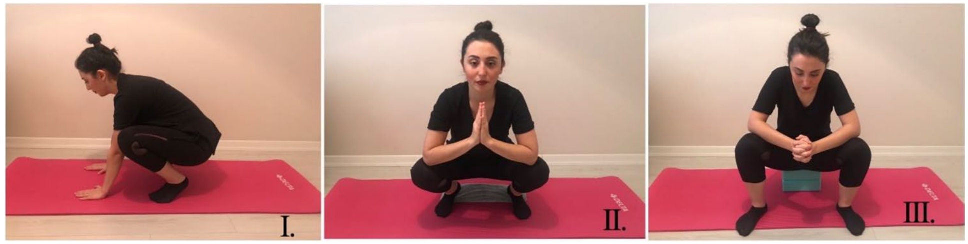

Fig. 3 I. Relaxed flat frog pose, II. deep squat pose, III. modified deep squat with block (P3)

correction. The relationship between PFM and abdominal muscle functions during different positions was investigated with Spearman correlation analysis. Correlations were classified according to rho values as very weak (rho = 0–0.19), weak (rho = 0.2–0.39), medium (rho = 0.40–0.59), strong (rho = 0.6–0.79), and very strong (rho = 0.8–1). Kruskal-Wallis test was used to compare PFM function during different positions between different types of UI. The time to initiate contraction of PFM and abdominal muscles in different positions was compared using Friedman variance analysis. The significance level was set at 0.05, except for post-hoc analysis, in which the significance level was set at 0.016 (0.05/3) after Bonferroni corrections [25].

Prior to the study, the power analysis was performed using G Power 3.0 program based on the results of the study of Sapford et al., and 60 subjects were found adequate considering 95% (5% type I error level) confidence interval and 80% power [26].

Results

Sixty-seven women with UI (mean age 52.6 ± 7.6 years) participated in the study. Demographic features, gynecological/obstetrical data, and bladder diary parameters and ICIQ-SF results of the participants are shown in Table 1; 59.7% of the women had mixed UI, 35.8% had urge UI, and 4.5% had stress UI.

P1 was the most efficient relaxation position for both superficial and deep PFM ($\boldsymbol{p} < 0.001$). The following positions were P3 and P2, respectively. Normalized standard activities of RA (median: 14.8%), TA (median: 14.1%), IO (median: 16.5%), and EO (median: 11.4%) were also the lowest during P1 ($p < 0.001$). The following positions were P3 and P2, respectively (Table 2).

When correlation analysis was performed on whether the relaxation extent of abdominal muscles (normalized mean resting activity) increased as the relaxation extent of PFM increased, RA relaxation was positively correlated with PFM relaxation in P1 (r = 0.298, $\boldsymbol{p} = 0.016$) and P3 (r = 0.286, $\boldsymbol{p} = 0.021$), and IO relaxation was positively correlated with PFM relaxation in P2 (r = 0.405, $\boldsymbol{p} = 0.001$).

There was no significant difference between different types of UI related to the mean and normalized mean resting activities of both superficial and deep PFM during P1, P2, and P3 ($\boldsymbol{p} > 0.05$) (Table 3).

Discussion

Various therapeutic methods including respiratory training, relaxation training, manual techniques, down training, vaginal dilator applications, biofeedback and electrical stimulation, PFM training, yoga, and Pilates are used in the clinic to reduce the tone and relax the PFM [12, 15, 27, 28]. Detection of the most effective PFM relaxation position will provide the application of the most appropriate and efficient intervention. Many different positions are recommended in physiotherapy clinics in which the extent of PFM and abdominal muscle relaxation may vary depending on the position. Our results have shown that modified butterfly pose was the most efficient position to release both PFM and abdominal muscles, followed by modified deep squat with block and modified child pose positions, respectively, while all three of these positions provideed relaxation for both muscle groups. This order of the three positions can be chosen for an efficient PFM relaxation program (modified butterfly pose > modified deep squat with block > modified child pose).

Our data showed a correlated increase in the relaxation extent of RA and PFM in modified butterfly pose and modified deep squat with block positions. Similarly, the extent of IO relaxation increased as PFM relaxation increased in the modified child pose position. These results suggest that PFM relaxation mostly affects the extent of RA relaxation. Therefore, we conclude that RA muscle relaxation should be added to treatment programs in conditions in which PFM tonus increases.

PFM has a continuous low motor unit activation potential even during the resting state. This resting activity is a result of the many slow-switch type 1 muscle fibers located in deep PFM [6]. Body position and lumbopelvic posture affect the resting activity of PFM [21]. Chmielewska et al. investigated PFM activity using an intravaginal probe in three different positions including supine, sitting, and standing in nulliparous women. They found the lowest PFM resting activity in the supine position [6]. Similarly, in the study of Capson et al., PFM resting activity was lower in supine

Table 1 Demographic features, obstetrical/gynecological data, and bladder diary and ICIQ-SF data of the participants

Demographic features	Minimum–maximum	X ± SD*/ median (IQR**)
Age (years)	29–66	52.6 ± 7.6*
Body weight (kg)	62–98	79 (70–89)**
BMI (kg/m^2)	23.7–40	33 (28.6–34.2)**
Obstetrical/gynecological data	Min–max	X ± SD
Number of pregnancies (*n*)	2–6	3.2 ± 1.3
Number of labors (*n*)	1–4	2.3 ± 0.9
Number of abortions (*n*)	0–4	0.2 ± 0.8
Number of children (*n*)	1–4	2.1 ± 0.7
Age at first birth (years)	17–32	22.7 ± 5.0
Birth weight of the baby (kg)	3–4.5	3.7 ± 0.3
	***N* = 64**	%
Type of delivery	Vaginal	51
	Cesarean section	13
Dystocia	Yes	22
	No	42
Episiotomy	Yes	45
	No	19
Assistive device during labor	Yes	5
	No	59
Incontinence during pregnancy	Yes	17
	No	47
Bladder diary parameters	Min–max	X ± SD
Amount of liquid intake (cc)	1233.3–6066.7	2658 ± 1269
Number of urge micturitions (*n*)	1–16.7	6.3 ± 4.7
Number of micturitions (*n*)	1–18	9.8 ± 4.3
Number of incontinence events (*n*)	1–12	3.1 ± 3
ICIQ-SF	*N* = 67	%
Frequency of incontinence events ICIQ-SF3	1 or less/week	29.9
	2–3 times/week	4.4
	1 time/day	13.4
	A few times a day	47.8
	Always	7.5
Amount of incontinence ICIQ-SF4	Little	61.1
	Medium	31.4
	Plenty	7.5
	Min–max	X ± SD
Effect of incontinence on daily life ICIQ-SF5	0–10	4.6 ± 3.0
Total score (3rd + 4th + 5th questions)	0–20	10 ± 5.4

*X ± SD: mean ± standard deviation, **IQR: interquartile range, Min: minimum, Max: maximum, BMI: body mass index, *n*: number, ICIQ-SF: International Consultation on Incontinence Questionnaire-Short Form

position compared to standing in nulliparous and continent women [21]. In the standing position, the increased pressure on the bladder and urethra due to the effect of the force of gravity on the pelvic floor and abdominal organs increases the tonus of PFM, while in supine position, the force of gravity affects the area posterior to the abdominal cavity rather than the pelvic floor [6]. Parallel to the literature, our results indicated supine position as the most efficient PFM relaxation position. However, the butterfly pose is usually recommended in clinics rather than the supine hook position for relaxation. As the legs are not supported in supine hook position, the extent of relaxation may be less than in butterfly pose position. Further studies are required to compare the extent of relaxation in these two positions. Halski et al. compared the resting activity of PFM among three different supine positions (decreased anterior pelvic tilt,

Table 2. Comparison of the mean activities and normalized mean activities (MVC %) of pelvic floor and abdominal muscles during relaxation among three different position

Muscles EMG Activities $N=67$	Muscle activity during relaxation (μV) Position					Muscle activity during relaxation (MVC %) Position				
	P1 Median (IQR)	P2 Median (IQR)	P3 Median (IQR)	p*	p**	P1 Median (IQR)	P2 Median (IQR)	P3 Median (IQR)	p*	p**
Deep PFM	4.5 (3.0–6.0)	9.3 (6.1–12.2)	5.1 (3.3–7.6)	**0.000**	P1:P2 = 0.000 P1:P3 = 0.009 P2:P3 = 0.000	7.0 (5.1–10.9)	13.7 (10.6–19.9)	10.2 (7.1–16.9)	**0.000**	P1:P2 = 0.000 P1:P3 = 0.000 P2:P3 = 0.003
Superficial PFM	3.7 (2.8–5.1)	5.2 (4.0–6.9)	3.9 (2.9–4.8)	**0.000**	P1:P2 = 0.000 P1:P3 = 0.886 P2:P3 = 0.000	10.6 (7.0–16.8)	16.1 (9.5–21.1)	11.6 (8.8–20.2)	**0.000**	P1:P2 = 0.000 P1:P3 = 0.032 P2:P3 = 0.076
RA	1.5 (1.1–2.1)	3.3 (2.5–4.1)	1.9 (1.3–2.2)	**0.000**	P1:P2 = 0.000 P1:P3 = 0.000 P2:P3 = 0.000	14.8 (13.0–18.2)	22.5 (16.8–29.9)	15.9 (13.3–19.9)	**0.000**	P1:P2 = 0.000 P1:P3 = 0.086 P2:P3 = 0.000
TA	2.4 (1.6–2.8)	4.1 (2.8–5.3)	3.2 (2.5–4.1)	**0.000**	P1:P2 = 0.000 P1:P3 = 0.000 P2:P3 = 0.009	14.1 (9.6–21.4)	25.9 (20.0–32.2)	20.8 (15.6–24.9)	**0.000**	P1:P2 = 0.000 P1:P3 = 0.000 P2:P3 = 0.001
IO	2.7 (1.7–3.5)	4.0 (3.0–5.3)	3.9 (2.8–5.2)	**0.000**	P1:P2 = 0.000 P1:P3 = 0.000 P2:P3 = 0.797	16.5 (10.9–22.1)	25.6 (21.0–32.5)	22.2 (16.8–28.4)	**0.000**	P1:P2 = 0.000 P1:P3 = 0.000 P2:P3 = 0.013
EO	6.3 (4.6–7.4)	8.0 (6.2–10.1)	6.4 (4.9–7.8)	**0.000**	P1:P2 = 0.000 P1:P3 = 0.505 P2:P3 = 0.000	11.4 (9.8–13.1)	16.4 (14.0–18.2)	12.5 (10.6–14.0)	**0.000**	P1:P2 = 0.000 P1:P3 = 0.000 P2:P3 = 0.000

*Friedman variance analyses, **Wilcoxon test with Bonferroni correction, IQR: interquartile range, PFM: pelvic floor muscles, P1: supine hook position, P2: crawling position, P3: squat position, $p < 0.05$

Table 3 Comparison of mean and normalized relaxation resting activity (MVC %) of pelvic floor muscles in three positions according to the type of incontinence

Muscles	Position	Type of UI	Muscle activity during relaxation (μV) Median	x^2	p*	Type of UI	Muscle activity during relaxation (MVC %) Median	x^2	p*
Deep PFM	**P1**	**Stress**	41.50	3.288	0.193	**Stress**	29.33	0.120	0.942
		Urge	27.32			**Urge**	33.05		
		Mixed	35.49			**Mixed**	33.25		
	P2	**Stress**	45.00	2.189	0.335	**Stress**	37.00	0.320	0.852
		Urge	28.93			**Urge**	32.66		
		Mixed	32.75			**Mixed**	31.22		
	P3	**Stress**	35.50	1.130	0.568	**Stress**	28.67	0.178	0.915
		Urge	29.52			**Urge**	32.84		
		Mixed	34.73			**Mixed**	33.41		
Superficial PFM	**P1**	**Stress**	56.17	7.619	0.052	**Stress**	46.00	3.827	0.148
		Urge	22.04			**Urge**	28.33		
		Mixed	36.51			**Mixed**	36.50		
	P2	**Stress**	43.83	4.714	0.095	**Stress**	33.00	0.267	0.875
		Urge	38.27			**Urge**	31.44		
		Mixed	28.82			**Mixed**	33.99		
	P3	**Stress**	48.17	1.699	0.428	**Stress**	34.17	0.027	0.987
		Urge	32.73			**Urge**	33.48		
		Mixed	33.70			**Mixed**	34.30		

neutral pelvis, and increased anterior pelvic tilt) and found that increased anterior pelvic tilt resulted in lower activity suggesting supine position as the most favorable position for PFM relaxation [7]. Force of gravity affects mostly the posterior part of the abdominal cavity in butterfly pose position. Therefore, we believe that its low impact on the PFM tonus results in the most efficient relaxation of abdominal muscles due to their synergistic relationship with PFM.

Unlike our results, Chmielewska et al. found the least resting activity of PFM in the order of supine, standing, and sitting positions in continent women without any significant differences between the positions [6]. Ptaszkowski et al. investigated the relationship between lumbopelvic posture and the activity of PFM using an intravaginal probe in postmenopausal women with stress UI in three different pelvis postures (anterior pelvic tilt, posterior pelvic tilt, and neutral pelvic tilt) identified by a pelvic inclinometer and found no significant differences between the measurements [23]. Chen et al. investigated the relationship between PFM activity and pelvic tilt angle generated by different ankle positions (dorsiflexion, plantar flexion, and horizontal position) during standing in women with stress UI. Different from the literature, they found the lowest PFM resting activity during ankle plantar flexion and the highest activity during ankle dorsiflexion [29]. However, the results of the study were not discussed adequately although the positions routinely recommended in clinics might affect the extent of PFM relaxation, even because of ankle positions.

Sapsford et al. compared PFM and abdominal muscle (EO and IO) activities at different sitting positions between women with and without stress UI and found lower activities during supported sitting compared to unsupported sitting posture [25]. Chmielewska et al. indicated lower PFM and abdominal muscle (RA and TA) resting activities during supine compared to standing and sitting positions [6]. Our findings were similar to these results.

Additionally, we have investigated whether the extent of abdominal muscle relaxation increased as the extent of PFM relaxation increased and found a correlated increase in RA and PFM relaxation in modified butterfly pose and modified deep squat with block positions. IO relaxation was also correlated with PFM relaxation in the modified child pose position. RA relaxation was mostly affected by PFM relaxation. Further studies are needed to investigate the relationship between PFM and abdominal muscle relaxation as there is a lack of literature focusing on this issue.

Leitner et al. compared PFM activity between continent and incontinent women during 7, 11, and 15 km/h running and found that the time to initiate relaxation after the maximum contraction was > 2 s in continent women compared to women with stress UI [30]. In this current study, the time to initiate relaxation was < 2 s in all the women with UI. Further studies are required to investigate the time to initiate contraction and relaxation in different positions.

PFM activity has an important role in every type of UI although the underlying mechanism of different types varies.

Ateş et al. reported similarities between the PFM activities of women with stress UI, urge UI, and mixed UI and found that PFM strength was not affected by the type of UI [31]. PFM strength did not differ according to the type of UI in Kaya et al.'s study; however, PFM endurance was lower in women in mixed UI compared to the women with stress UI [32]. In our study, we did not find any differences in the extent of PFM relaxation between different types of UI during each position. From this aspect to the best of our knowledge, our study is the first to investigate the relationship between PFM relaxation and UI type.

Strengths and limitations

The heterogeneity of the participants with different types of UI is one of our limitations. Lack of a control group including continent women is another. Additionally, we have evaluated a specific muscle group in synergy with PFM. However, some studies pay attention to the functions of other synergistic muscles, such as the adductor magnus and gluteus maximus.

The positions used in this current study had different forms in the media. However, the results can even be affected by the ankle position. Therefore, the limited number of positions chosen for relaxation is one of our limitations. During EMG measurements, we used the same blocks and pads to improve the quality of the signals and provide standardization. We used these supports to prevent the probable difficulty in holding the same position for a prolonged time and need to change position constantly during the measurements. However, the main our results could be affected by the use of supports.

Strengths of our study include EMG assessment (Neurotract Myoplus 4 Pro) of PFM and abdominal muscle activities, which provides more reliable data compared to other measurement methods. The objective digital data automatically provided by the device and the possibility to evaluate the isolated activity of PFM without the effect of abdominal muscles are the advantages of our assessment method. We also believe that investigation of PFM and abdominal muscle activities in different relaxation positions has fulfilled the lack in the literature.

Conclusion

PFM and abdominal muscles relaxed in the same positions. The greatest relaxation was achieved in the modified butterfly pose position. Modified deep squat with block and modified child pose positions followed, respectively. All these muscles can release in three positions, and the extent of relaxation is affected by the positions.

The extent of RA relaxation increases as the extent of PFM relaxation increases in the modified butterfly pose position, and the extent of PFM relaxation mostly affects that of RA. There is no difference in terms of PFM relaxation when in the same position in different types of UI. The type of UI does not affect the extent of relaxation.

In conclusion, the position affects the extents of PFM and abdominal muscle relaxation. Efficient relaxation is achieved by the routinely recommended positions for PFM relaxation in physiotherapy clinics. The choice of positions may be an important factor for the success of PFM training. Further studies are needed to implement the most effective protocols and positions for PFM training.

Acknowledgements The authors have no conflicts of interest.

Author contributions Çeliker Tosun Ö: Protocol/project development, Data collection and management, Data analysis, Manuscript writing/editing.

Korkmaz Dayıcan D: Protocol/project development, Data collection, Data analysis.

Keser İ: Protocol/project development, Data management.

Kurt S: Protocol/project development, Data collection.

Yıldırım M: Data analysis, Manuscript writing/editing.

Tosun G: Manuscript writing/editing.

Declarations

Conflict of interest None.

Consent Written informed consent was obtained from the patients for publication of these Images in the International Urogynecology Journal and any accompanying images. The person in the figures is one the authors of the current manuscript, D.K.D. The showing of her face in the pictures has been approved by the legal representative.

This work has not been presented at a prior conference or meeting congress.

References

1. Haylen BT, de Ridder D, Freeman RM, Swift SE, Berghmans B, et al. An International Urogynecological Association (IUGA)/International Continence Society (ICS) joint report on the terminology for female pelvic floor dysfunction. Int Urogynecol J. 2010;21:5–26. https://doi.org/10.1007/s00192-009-0976-9.
2. Mazur-Bialy AI, Kołomańska-Bogucka D, Nowakowski C, Tim S. Urinary incontinence in women: modern methods of physiotherapy as a support for surgical treatment or independent therapy. J Clin Med. 2020;9(4):1211. https://doi.org/10.3390/jcm9041211.
3. Eickmeyer SM. Anatomy and physiology of the pelvic floor. Phys Med Rehabil Clin N Am. 2017;28(3):455–60. https://doi.org/10.1016/j.pmr.2017.03.003.
4. Messelink B, Benson T, Berghmans B, Bo K, Corcos J, Fowler C, Nijeholt GA. Standardization of terminology of pelvic floor muscle function and dysfunction: report from the pelvic floor clinical assessment group of the international continence society. Int Urogynecol J. 2005;24(4):374. https://doi.org/10.1007/s00192-016-3123-4.

5. Bo K, Frawley HC, Haylen BT, Abramov Y, Almeida FG, Berghmans B, Wells A. An international Urogynecological association (IUGA)/international continence society (ICS) joint report on the terminology for the conservative and nonpharmacological management of female pelvic floor dysfunction. Int Urogynecol J. 2017;28(2):191–213. https://doi.org/10.1007/s00192-016-3123-4.
6. Chmielewska D, Stania M, Sobota G, Kwaśna K, Błaszczak E, Taradaj J, Juras G. Impact of different body positions on bioelectrical activity of the pelvic floor muscles in nulliparous continent women. Biomed Res Int. 2015;2015:2015. https://doi.org/10.1155/2015/905897.
7. Halski T, Ptaszkowski K, Słupska L, Dymarek R, Paprocka-Borowicz M. Relationship between lower limb position and pelvic floor muscle surface electromyography activity in menopausal women: a prospective observational study. Clin Interv Aging. 2017;12:75. https://doi.org/10.2147/CIA.S121467.
8. Ptaszkowski K, Zdrojowy R, Slupska L, Bartnicki J, Dembowski J, Halski T, Paprocka-Borowicz M. Assessment of bioelectrical activity of pelvic floor muscles depending on the orientation of the pelvis in menopausal women with symptoms of stress urinary incontinence: continued observational study. Eur J Phys Rehabil Med. 2017;53(4):564–74. https://doi.org/10.23736/S1973-9087.17.04475-6.
9. Madill SJ, McLean L. Quantification of abdominal and pelvic floor muscle synergies in response to voluntary pelvic floor muscle contractions. J Electromyogr Kinesiol. 2008;10(6):955–64. https://doi.org/10.1016/j.jelekin.2007.05.001.
10. Neumann P, Gill V. Pelvic floor and abdominal muscle interaction: EMG activity and intra-abdominal pressure. Int Urogynecol J Pelvic Floor Dysfunct. 2002;13(2):125–32. https://doi.org/10.1007/s001920200027.
11. Ptaszkowski K, Paprocka-Borowicz M, Słupska L, Bartnicki J, Dymarek R, Rosińczuk J, Zdrojowy R. Assessment of bioelectrical activity of synergistic muscles during pelvic floor muscles activation in postmenopausal women with and without stress urinary incontinence: a preliminary observational study. Clin Interv Aging. 2015;10:1521. https://doi.org/10.2147/CIA.S89852.
12. Bradley MH, Rawlins A, Brinker CA. Physical therapy treatment of pelvic pain. Phys Med Rehabil Clin N Am. 2017;28(3):589–601. https://doi.org/10.1016/j.pmr.2017.03.009.
13. Wehbe SA, Whitmore K, Kellogg-Spadt S. Continuing medical education: urogenital complaints and female sexual dysfunction. J Sex Med. 2010;7(5):1704–13. https://doi.org/10.1111/j.1743-6109.2008.01198.x.
14. Tahan N, Rasouli O, Arab AM, Khademi K, et al. Reliability of the ultrasound measurements of abdominal muscles activity when activated with and without pelvic floor muscles contraction. J Back Musculoskelet Rehabil. 2014;27(3):339–47. https://doi.org/10.3233/BMR-130453.
15. Scott KM, Gosai E, Bradley MH, Walton S, Hynan LS, Lemack G, Roehrborn C. İndividualized pelvic physical therapy for the treatment of post-prostatectomy stress urinary incontinence and pelvic pain. Int Urol Nephrol. 2020;52(4):655–9. https://doi.org/10.1007/s11255-019-02343-7.
16. Nightingale G, Chandrakumaran K, Phillips C. The effect of modified Pilates-based positions on pelvic floor electromyographic (EMG) activity; a pilot study. Int Urogynecol J. 2021;32(2):287–92. https://doi.org/10.1007/s00192-020-04529-5.
17. Cuña-Carrera D, Alonso-Calvete A, Soto-González M, Lantarón-Caeiro EM. How do the abdominal muscles change during hypopressive exercise? Medicina. 2021;57(7):702. https://doi.org/10.3390/medicina57070702.
18. Siff LN, Hill AJ, Walters SJ, Walters G, Walters MD. The effect of commonly performed exercises on the levator hiatus area and the length and strength of pelvic floor muscles in postpartum women. Female Pelvic Med Reconstr Surg. 2020;26(1):61–6. https://doi.org/10.1097/SPV.0000000000000590.
19. Hajebrahimi S, Nourizadeh D, Hamedani R, Pezeshki MZ. Validity and reliability of the international consultation on incontinence questionnaire-urinary incontinence short form and its correlation with urodynamic findings. Urol J. 2012;9(4):685–90.
20. Halski T, Słupska L, Dymarek R, Bartnicki J, Halska U, Król A, Ptaszkowski K. Evaluation of bioelectrical activity of pelvic floor muscles and synergistic muscles depending on orientation of pelvis in menopausal women with symptoms of stress urinary incontinence: a preliminary observational study. Biomed Res Int. 2014;2014. https://doi.org/10.1155/2014/274938.
21. Capson AC, Nashed J, Mclean L. The role of lumbopelvic posture in pelvic floor muscle activation in continent women. J Electromyogr Kinesiol. 2011;21(1):166–77. https://doi.org/10.1016/j.jelekin.2010.07.017.
22. Flury N, Koenig I, Radlinger L. Crosstalk considerations in studies evaluating pelvic floor muscles using surface electromyography in women: a scoping review. Arch Gynecol Obstet. 2017;2295(4):799–809. https://doi.org/10.1007/s00404-017-4300-5.
23. Ptaszkowski K, Zdrojowy R, Ptaszkowska L, Bartnicki J, Taradaj J, Paprocka-Borowicz M. Electromyographic evaluation of synergist muscles of the pelvic floor muscle depending on the pelvis setting in menopausal women: a prospective observational study. Gait & Posture. 2019;71:170–6. https://doi.org/10.1016/j.gaitpost.2019.04.024.
24. Konrad P. The ABC of EMG: a practical introduction to kinesiological electromyography. USA: Noraxon Inc; 2005.
25. Harvey KL. SPSS survival manual: a step-by-step guide to data analysis using SPSS version 15. Nurse researcher (through 2013) 2009;16(3): 89.
26. Sapsford RR, Hodges PW, Richardson CA, Cooper DH, Markwell SJ, Jull GA. Co-activation of the abdominal and pelvic floor muscles during voluntary exercises. Neurourol Urodyn. 2001;20(1):31–42. https://doi.org/10.1002/1520-6777(2001)20:1<31::aid-nau5>3.0.co;2-p.
27. Morin M, Binik YM, Bourbonnais D, Khalifé S, et al. Heightened pelvic floor muscle tone and altered contractility in women with provoked vestibulodynia. J Sex Med. 2017;14(4):592–600. https://doi.org/10.1016/j.jsxm.2017.02.012.
28. Padoa A, McLean L, Morin M, Vandyken C. The overactive pelvic floor (OPF) and sexual dysfunction. Part 2: evaluation and treatment of sexual dysfunction in OPF Patients. Sex. Med Rev. 2021;9(1):76–92. https://doi.org/10.1016/j.sxmr.2020.04.002.
29. Chen CH, Huang MH, Chen TW, Weng MC, Lee CL, Wang GJ. Relationship between ankle position and pelvic floor muscle activity in female stress urinary incontinence. Urology. 2005;66(2):288–92. https://doi.org/10.1016/j.urology.2005.03.034.
30. Leitner M, Moser H, Eichelberger P, Kuhn A, Radlinger L. Pelvic floor muscle activity during fast voluntary contractions in continent and incontinent women. Neurourol Urodyn. 2019;38(2):625–31. https://doi.org/10.1002/nau.23911.
31. Ateş A, Özengin N, Bakar Y. A comparison pelvic floor muscle strength and quality of life in regard to urinary incontinence type: a retrospective study. Turkiye Klinikleri J Med Sci. 2019;4(2):147–54. https://doi.org/10.5336/healthsci.2018-62723.
32. Serap K, Akbayrak T, Orhan C, Beksaç S. A comparison of patient characteristics and urinary parameters in women with various types of urinary incontinence: a retrospective study. J Exerc Rehabil. 2015;2(3):93–100.

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.