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Electromyographic evaluation of synergist muscles of the pelvic floor muscle depending on the pelvis setting in menopausal women: A prospective observational study

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ABSTRACT

Background: Pelvic floor muscle (PFM) training is recommended to increase their strength and endurance. Muscles which act synergistically with PFM are taken into consideration in the therapeutic management of weakened PFM.

Research question: how does electromyography activity of the synergists muscle to PFM change concerning pelvis position and does the greater bioelectric activity of synergist muscles affect PFM function?

Methods: A prospective, observational study evaluating the surface electromyography (sEMG) activity of selected synergist muscles of the PFM depending on the orientation of the pelvis. One hundred thirty-one menopausal women registered for the study were screened for inclusion and exclusion criteria, and by the results, eighty-two participants were enrolled for measurements. The comparisons of results between the values obtained in different positions of the pelvis (anterior pelvic tilt – P1, posterior pelvic tilt – P2 and neutral pelvic tilt – P3) were performed using Kruskal–Wallis test. A multivariate linear regression analysis was used to assess relationships between the bioelectrical activity of PFM and activity of all tested muscles – rectus abdominis (RA), gluteus maximus (GM), and adductor magnus (AM).

Results: Higher RA, GM, AM bioelectrical activity was observed in the P2 as compared to P3 (during resting and functional PFM activity)($p < 0.05$). Multivariate linear regression did not find the association between the bioelectrical activity of PFM and the activity of all synergist muscles in each position.

Significance: sEMG activity of selected muscles acting synergistically with PFM differ depending on the pelvis position and is the highest in the posterior pelvic tilt. Greater activity of the synergists, resulting from the pelvic position, does not affect the myoelectric activity of PFM. It seems that muscles that act synergistically with PFM may not play such a significant role in the therapeutic management of PFM.

1. Introduction

Continuous learning and application of new knowledge in daily clinical practice are two major goals and challenges for all physical therapists. Contemporary advances in the field of medical rehabilitation allow for the implementation of innovative, objective, and frequently non-invasive diagnostic and therapeutic methods, based on highly advanced techniques. Evaluation of pelvic floor muscle (PFM) function should involve precise diagnostic methods and identify factors that might affect its activity [1,2].

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About 50% of women in the menopausal period have symptoms associated with the genitourinary system [3,4]. The most frequently recorded symptoms are dyspareunia, vaginal dryness, difficulty urinating, urinary incontinence, frequent urination, and recurrent infections. Very often the cause of these symptoms is failure and weakness of PFM leading to lowering of the pelvic organs [3,4]. Weak PFM may also contribute to the occurrence of lower urinary tract symptoms, bowel symptoms, vaginal symptoms, sexual dysfunction, and pelvic pain [5]. Many authors recommend PFM training to increase its strength and endurance [6–8]. However, some authors consider that maximum PFM contraction is only possible with synergistic muscle co-contraction [9–11]. Also, muscles that act synergistically with PFM are taken into consideration in the therapeutic management of weakened PFM. According to the literature [9,10,12–14], abdominal muscles, adductor muscles of the thigh, and the posterior muscle group of the lower limb girdle have beneficial effects on PFM. Their activity enhances PFM tension, and the lack of synergist muscle activity can render PFM tension impossible in some cases [12,15]. Based on the data mentioned above, it is vital to pay attention to muscles acting synergistically with PFM during the diagnostic process and to use them in preventive management of urogynecological diseases.

The study aimed to assess surface electromyography (sEMG) of selected synergist muscles of the PFM in different positions of the pelvis (anterior pelvic tilt, posterior pelvic tilt, and neutral pelvic tilt), as well as to determine the correlation between the myoelectric activity of the synergists and PFM. We assumed that higher synergist muscle (rectus abdominis (RA), gluteus maximus (GM), and adductor magnus (AM)) activity would depend on pelvic tilt and increase PFM bioelectrical activity.

Detailed questions and research hypotheses:

1 How does the myographic activity of the synergists to PFM change concerning pelvis position?

The research hypothesis assumes that sEMG of synergists depends on the position and movement of the pelvis. The highest sEMG of RA and GM will be able to observe in the posterior pelvic tilt, while AM muscles will be demonstrated the highest sEMG activity in the anterior pelvic tilt.

2 Does greater bioelectric activity of synergist muscles affect PFM sEMG activity?

Higher activity of synergist muscles resulting from the pelvis position affects the myoelectric activity of PFM is expected.

2. Material and methods

2.1. Design

This study was a prospective, cross-sectional observational study evaluating the sEMG activity of selected synergist muscles of the PFM depending on the orientation of the pelvis in menopausal women. Studies were carried out and described according to the STROBE guidelines for observational studies [16].

2.2. Participants, therapists, centers

The presented studies were approved by the Bioethics Committee of the Wroclaw Medical University on 5th July 2012 with the approval number (KB – 611/2012). The study was a part of a research project funded by the National Science Centre in the “Preludium” by the decision number DEC – 2011/03/N/NZ7/00505. Moreover, the study was registered at the Australian New Zealand Clinical Trials Registry platform (ACTRN12613001144707) as a prospective observational study.

The study was carried out at the Department and Clinic of Urology of the University Hospital in Wroclaw between December 2012 and December 2015. The target group of this study was women in the menopausal period. Women recruited for the study were patients at the Department and Clinic of Urology, University Hospital in Wroclaw and volunteers who responded to a notice published in the media. All women recruited were evaluated to the criteria. The inclusion criteria: written informed consent, no contraindications for the sEMG measurements, doctor's and physiotherapist’s permission to participate in the study, overall well-being on the day of the examination, no previous participation in a rehabilitation program related to pelvic floor muscles. The exclusion criteria: age over 75 years, no history of menopause, gynecological surgeries or surgeries in the abdomen, pelvis, lower extremities – in the last 10 years, pelvis or spine pain on the examination day, lumbar or pelvic pain in the last 6 months, injuries of the lower extremities, history of cesarean section, episodes of reproductive organ prolapse, incontinence of a third degree, fecal incontinence, the presence of any neurological symptoms, contraindications for measurements, such as infection or allergies to nickel.

2.3. Outcome measures

Measurements were performed in three different positions of the pelvis in the standing position: anterior pelvic tilt (P1), posterior pelvic tilt (P2) and neutral pelvic tilt (P3). The order of the positions was established randomly for each participant using a random integer generator (www.random.org). Participants of the study took one of the three positions and held it for the duration of the measurements. During taking of positions P1 and P2, the participant was asked to tilt the pelvis forward (P1) and backward (P2) maximally in a standing position. In position P3, it was required to stand in a relaxed position without any changes to the pelvic position (without straining the additional muscles). In P3, no corrections of pelvis setting were indicated – the task of the participants was not to try to activate additional muscles in this pelvis setting. Before the final measurements, the participant was taught by an experienced physiotherapist to perform maximum pelvic movements and to take positions. During pelvic movements, the patient did not perform additional movements of the upper trunk. The initial measurements were taken to check the correct positioning of the electrodes. After setting the pelvis in a given position, the participants made maximal contractions of PFM. To assess functional PFM activity, the participant was asked to perform five five-second maximal contractions of PFM. Between each of these contractions, there was a five-second measurement of relaxation of these muscles (resting bioelectric activity). Functional PFM activity was calculated as the average of these five contractions. The resting PFM activity was calculated as the average of five intervals between contractions. Additionally, there was a 60-second rest between the pelvis settings (no sEMG measurements). Next, each participant was asked to perform five movements of the pelvis forward and backward without aware contractions of PFM. Bioelectric activity was assessed with an electromyographic instrument and with surface and endovaginal electrodes. The inclination angle was measured with an inclinometer.

Electromyographic measurements were conducted using MyoSystem 1400L (Noraxon, USA), with eight channels and with surface and endovaginal electrodes. To record the sEMG signal from the PFM, a pear-shaped endovaginal electrode, the Life - Care Vaginal Probe PR-02 (Everyway Medical Instruments Co., Ltd., Taiwan), was used. Technical specifications were compatible with ISEK and SENIAM standards. Electromyographic data were bandpass – filtered between 50 and 1000 Hz (FIR filter – finite impulse response filter), rectified and smoothed using 50 ms RMS (root mean square) and were expressed in microvolts (μV). Also, functional sEMG was expressed as a percentage of resting sEMG. Sampling frequency was 1000 Hz.

The bioelectric activity of selected muscles (RA, GM, and AM) acting synergistically with PFM was evaluated using disposable surface, self-adhesive, silver-silver chloride electrodes (Ag/AgCl). RA electrodes

were positioned on the lower part of the muscle, superiorly to the umbilicus [17]. GM electrodes were placed midway between the sacrum and the greater trochanter [18]. AM electrodes were positioned on the medial part of the thigh, between the posterior edge of the gracilis, medial muscle of the thigh, and the medial edge of the posterior muscles of the lower limb girdle at approximately the one-third proximal point [19]. Monopolar reference electrodes were positioned on the anterior superior iliac spine [19].

A digital inclinometer Duometr PLUS (OPIW, Poland) was used for the measurement of the pelvis inclination angle. The examination of the pelvic inclination angle was done in three positions of the pelvis, termed P1, P2, and P3. The angle has measured the angle between a straight line connecting the anterior superior iliac spine and the posterior superior iliac spine and a line defining a horizontal plane. Negative values meant that the pelvis was set up in a large posterior pelvic tilt – the posterior superior iliac spines were below the horizontal plane. Inclinometer arms were placed on the anterior superior iliac spine and to the posterior superior iliac spine. The angle of the pelvis inclination was read from a digital display located on the inclinometer. The measurement was performed three times, on the right and the left side. Pelvic tilt angle measurements were carried out before the evaluation sEMG.

2.4. Data analysis

Statistical analysis was performed using Statistica 12 (StatSoft, Inc., USA) under the license of the Medical University in Wroclaw. The sample size was assessed by pilot studies [9]. The study compared the differences in resting bioelectrical activity of PFM between two orientations of the pelvis, in forward (P1) and backward inclination (P1 vs. P2). Prior data indicated that the difference between P1 and P2 is normally distributed with standard deviation of 1.5 μV. If the true difference in the mean of bioelectrical activity between positions of the pelvis is 0.7 μV than to be able to reject the null hypothesis 78 subjects will be needed. Power analysis was set at 0.8. The Type I error probability associated with this test of this null hypothesis was 0.05.

For the measurable variables, the arithmetic means, standard deviation and range of variation (extreme values) were calculated. All tested quantitative variables were tested with a Shapiro-Wilk test to determine the distribution. The comparisons of results between the values obtained in P1, P2, and P3 were performed using a nonparametric ANOVA Kruskal– Wallis analysis and multiple comparisons (Dunn's test). Determination of the differences between the results obtained during forward and backward pelvis movements was made using the Mann-Whitney U-test. To assess the reliability and repeatability of measurements for resting and functional sEMG activity and the pelvis inclination angle, an intraclass correlation coefficient (ICC) was calculated. The Spearman rho test was used to analyze the linear association between the evaluated variables. Finally, a multivariate linear regression analysis was used to assess relationships between the bioelectrical activity of PFM and bioelectrical activity of all synergistic muscles tested. For all comparisons, the level of $\alpha = 0.05$ was assumed, and the obtained *p*-values were rounded to three decimal places.

3. Results

The target group for this study was women in the menopausal period. One hundred and thirty-one women were screened for inclusion and exclusion criteria. By the screen results, 82 participants were enrolled for measurements (Fig. 1).

Table 1 shows characteristics of the study group. It contains basic information, such as age, height, weight, and BMI. In the present study, the main factor that influenced the results was the pelvis orientation. There were three orientations of the pelvis, termed P1, P2, and P3. The pelvic orientations were measured from both sides. The orientation angle in P1 on the right side was 10.0–40.0° (mean ($\bar{x}$); $\bar{x} = 20.3°$; standard deviation (SD); SD = 5.4°) and the orientation on the left side was also 10.0–40.0° ($\bar{x} = 19.5°$; SD = 5.2°). In P2, the orientation angle on the right side was -11.0–12.0° ($\bar{x} = 0.7°$; SD = 5.7°), and the orientation angle on the left side was -11.0–12.0° ($\bar{x} = 0.6°$; SD = 5.7°). In P3, the orientation angle on the right side was 2.0–21.0° ($\bar{x} = 10.6°$; SD = 3.8°), and the orientation angle on the left side was 3.0–21.0° ($\bar{x} = 10.2°$; SD = 3.7). It is worth adding that, the setting of pelvis the in P3 is on average in an anterior position. In each case of the pelvis inclination angle, ICC result was $r >= 0.90$ ($p < 0.05$).

The following section contains the results of the sEMG activity of selected muscles. First, the results of pelvic tilt are presented (Tables 2–4). The resting and functional activities of the AM muscle in P1, P2, and P3 are presented in Table 2. The lowest activity was registered in P3 in all comparisons of sEMG activity (AM, P3, right side: resting sEMG activity – 4.8 ± 1.9 μV; functional sEMG activity – 6.1 ± 3.2 μV; left side: resting sEMG activity – 5.6 ± 4.3 μV; functional sEMG activity – 6.5 ± 4.4 μV). There were no statistically significant differences between P1 and P2 (Table 2, $p > 0.05$). In addition, there were no statistically significant differences between positions, taking into account functional sEMG expressed as a percentage of resting sEMG of the AM muscle (Table 2).

The resting and functional activities of the RA muscle in P1, P2, and P3 are presented in Table 3. The highest activity was registered in P2 in all comparisons of sEMG activity of that muscle and different pelvic tilts (RA, P2, right side: resting sEMG activity – 6.0 ± 3.7 μV; functional sEMG activity – 6.5 ± 4.0 μV; left side: resting sEMG activity – 5.8 ± 2.1 μV; functional sEMG activity – 6.2 ± 2.6 μV). There were no statistically significant differences between P1 and P3 (Table 3, $p > 0.05$). There were no statistically significant differences between positions, taking into account functional sEMG expressed as a percentage of resting sEMG of the RA muscle (Table 3).

The resting and functional activities of the GM muscle in P1, P2, and P3 are presented in Table 4. The highest activity was registered in P2 in all comparisons of sEMG activity of that muscle and different pelvic tilts (GM, P2, right side: resting sEMG activity – 11.5 ± 9.0 μV; functional sEMG activity – 20.2 ± 17.8 μV; left side: resting sEMG activity – 12.7 ± 11.3 μV; functional sEMG activity – 22.6 ± 21.4 μV). Nevertheless, there were no statistically significant differences between P1 and P2 observed in three cases (during resting activity of PFM – right and left side and during functional activity of sEMG of PFM – right side; post-hoc tests in Table 4). Additionally, there were no statistically significant differences between P1 and P3 (Table 4, $p > 0.05$). Also, the statistically significant differences between positions were observed, taking into account functional sEMG expressed as a percentage of resting sEMG of the GM muscle (Table 4). On the right and left sides, the highest increase was observed in P2 (right side: increase by 74%; left side: increase by 77%).

Also, statistical analysis of sEMG activity during anterior and posterior pelvic movement of the investigated synergists muscles was performed (Table 5). All synergist muscles on both sides demonstrated higher activity during the posterior tilt ($p < 0.05$) (Table 5). In each case of sEMG measurements, ICC result was $r >= 0.90$ ($p < 0.05$).

Analysis of the correlation between PFM and AM, RA, or GM activity was performed. The results were subdivided into PFM activity (resting and functional) and the evaluated side of synergist muscles. No statistically significant correlations between the variables were found. Multivariate linear regression did not find associations between the resting bioelectrical activity of PFM and the activity of all synergist muscles in each position. Similar results were registered to take into account the functional bioelectrical activity of PFM.

4. Discussion

The present study was an attempt to evaluate the relationship between pelvis setting, PFM bioelectric activity and bioelectrical activity of synergistic muscles for PFM. Finding a connection between the

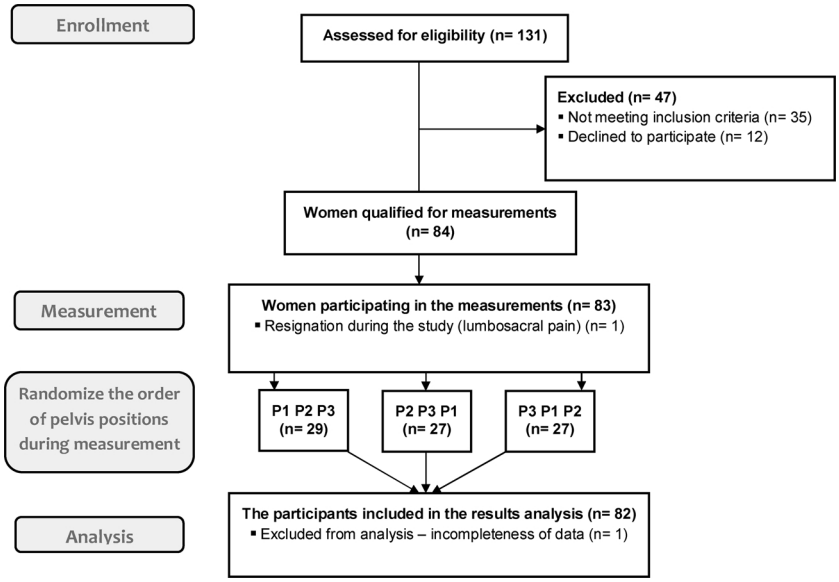

Fig. 1. The flow of study participants during the entire project.

Table 1
Characteristic of the study group (n = 82).

	n	$\bar{x}$	Me	min	max	SD
Age [years]	82	65	65	50	74	6
Weight [kg]	82	69	69	51	101	11
Height [m]	82	1.61	1.62	1.46	1.72	0.05
BMI [kg/m^2]	82	27	26	19	37	4
Number of births	82	2	2	0	6	1
Menopausal age [years]	82	51	52	40	60	5

n - the number of participants; $\bar{x}$ - mean; Me - median; min - minimum; max - maximum; SD - standard deviation.

functioning of these structures may cause the improvement of conservative treatment in women with pelvic floor muscle dysfunctions. The aim of the study was to assess how different pelvic positions affect the electromyographic evaluation of selected synergistic muscles for PFM and to assess the relationship between these synergistic muscles and PFM. According to the literature [9,12–14,20–22], muscles that co-activate with PFM include abdominal muscles, adductor muscles of the thigh, and muscles of the lower limb girdle. Much attention has been given to abdominal muscles due to their auxiliary functions as, together with pulmonary suction force, they provide support for the viscera and help relieve pressure to the pelvic floor [12–14]. Hip adductors on the other hand act as synergists and may increase their PFM contraction [9,11,22–24].

In our study, higher AM, RA, and GM bioelectrical activity have been observed in the posterior pelvic tilt compared to the neutral tilt (during resting and functional PFM activity). In the case of RA, the values of sEMG activity in the posterior tilt were higher than in the anterior tilt, which may indicate that the posterior pelvic tilt affects PFM bioelectrical activity to the greatest extent. However, direct correlations between PFM sEMG activity and the investigated synergists lack statistical significance. The literature offers only a few reports [9,22,25] demonstrating the effect of the body position, including pelvic tilt, on the activity of muscles which act synergistically with

Table 2
Comparison of sEMG activity of the AM (left and right side) registered in P1, P2, and P3 during resting and functional PFM activity (n = 82).

	Side	PFM bioelectrical activity	Position of pelvis	$\bar{x}$	Me	Min	Max	SD	*p*-value* (*main effect*)	*p*-value** (post-hoc analysis)
AM	Right	Resting [μV]	P1	6.0	5.8	1.9	11.7	2.1	**p < 0.001**	P1:P2 p = 1.000
			P2	6.1	5.6	1.9	19.4	2.6		**P1:P3 p < 0.001**
			P3	4.8	4.7	1.9	14.3	1.9		**P2:P3 p < 0.001**
		Functional [μV]	P1	7.5	6.9	2.0	18.5	3.4	**p < 0.001**	P1:P2 p = 1.000
			P2	7.8	7.0	1.9	22.1	3.8		**P1:P3 p = 0.005**
			P3	6.1	5.2	1.9	22.8	3.2		**P2:P3 p = 0.001**
		Functional [% of resting]	P1	123.9	114.7	64.7	300.5	32.8	p = 0.80	–
			P2	127.1	116.0	73.4	397.4	42.6		
			P3	126.4	113.2	80.3	367.9	42.7		
	Left	Resting [μV]	P1	6.5	5.3	2.2	31.8	4.1	**p = 0.004**	P1:P2 p = 1.000
			P2	6.6	5.5	2.3	42.9	4.9		**P1:P3 p = 0.017**
			P3	5.6	4.3	2.2	35.8	4.3		**P2:P3 p = 0.011**
		Functional [μV]	P1	7.8	6.8	2.3	29.0	4.6	**p = 0.006**	P1:P2 p = .343
			P2	8.4	6.6	2.3	48.5	6.5		**P1:P3 p = 0.024**
			P3	6.5	5.5	2.3	35.8	4.4		**P2:P3 p = 0.013**
		Functional [% of resting]	P1	120.1	112.6	87.3	249.6	27.9	p = 0.53	–
			P2	127.4	113.1	67.0	455.5	49.0		
			P3	118.5	112.3	74.6	219.2	27.3		

AM - adductor magnus; μV - microvolts; $\bar{x}$ - mean; Me - median; min - minimum; max - maximum; SD - standard deviation.
P1 - position 1 (anterior pelvic tilt); P2 - position 2 (posterior pelvic tilt); P3 - position 3 (neutral pelvic tilt).
* Kruskal–Wallis test.
** Dunn's test.

Table 3
Comparison of sEMG activity of RA (left and right side) registered in P1, P2, and P3 during resting and functional PFM activity (n = 82).

	Side	PFM bioelectrical activity	Position of pelvis	$\bar{x}$	Me	Min	Max	SD	*p*-value* (*main effect*)	*p*-value** (post-hoc analysis)
RA	Right	Resting [μV]	P1	4.6	4.6	3.1	8.1	0.9	**p = 0.001**	**P1:P2 p = 0.001**
			P2	6.0	5.2	2.7	31.9	3.7		P1:P3 p = 1.000
			P3	4.9	4.6	2.7	31.3	3.0		**P2:P3 p = 0.004**
		Functional [μV]	P1	4.8	4.7	2.8	8.8	1.1	**p < 0.001**	**P1:P2 p < 0.001**
			P2	6.5	5.4	2.7	32.8	4.0		P1:P3 p = 1.000
			P3	5.1	4.8	2.8	31.4	3.0		**P2:P3 p = 0.001**
		Functional [% of resting]	P1	104.4	103.6	85.0	138.5	7.3	p = 0.09	–
			P2	107.2	106.3	83.1	186.5	12.1		
			P3	104.4	103.8	82.9	145.1	7.2		
	Left	Resting [μV]	P1	4.7	4.5	3.3	8.4	0.8	**p < 0.001**	**P1:P2 p < 0.001**
			P2	5.8	5.5	3.2	17.1	2.1		P1:P3 p = 1.000
			P3	4.8	4.6	3.4	9.5	1.0		**P2:P3 p < 0.001**
		Functional [μV]	P1	4.9	4.8	3.3	9.5	0.9	**p < 0.000**	**P1:P2 p < 0.001**
			P2	6.2	5.6	3.2	17.9	2.6		P1:P3 p = 1.000
			P3	5.0	5.0	3.5	8.9	1.0		**P2:P3 p < 0.001**
		Functional [% of resting]	P1	103.8	103.2	87.2	138.0	7.0	p = 0.51	–
			P2	106.4	106.2	88.4	179.3	11.1		
			P3	105.4	105.0	87.2	138.4	8.3		

RA - rectus abdominis; μV - microvolts; $\bar{x}$ - mean; Me - median; min - minimum; max - maximum; SD - standard deviation.
P1 - position 1 (anterior pelvic tilt); P2 - position 2 (posterior pelvic tilt); P3 - position 3 (neutral pelvic tilt).
* Kruskal–Wallis test.
** Dunn's test.

Table 4
Comparison of sEMG activity of GM (left and right side) registered in P1, P2, and P3 during resting and functional PFM activity (n = 82).

	Side	PFM bioelectrical activity	Position of pelvis	$\bar{x}$	Me	Min	Max	SD	*p*-value* (*main effect*)	*p*-value** (post-hoc analysis)
GM	Right	Resting [μV]	P1	10.2	8.4	1.9	37.8	7.3	**p = 0.002**	P1:P2 p = 1.000
			P2	11.5	9.6	2.0	49.0	9.0		P1:P3 p = 0.057
			P3	8.1	6.3	1.9	35.0	6.4		**P2:P3 p = 0.002**
		Functional [μV]	P1	13.7	11.0	2.0	59.0	10.6	**p < 0.001**	P1:P2 p = 0.143
			P2	20.2	16.2	2.1	77.9	17.8		P1:P3 p = 0.180
			P3	11.7	8.4	2.0	72.8	11.1		**P2:P3 p < 0.001**
		Functional [% of resting]	P1	134.0	121.8	96.4	294.2	42.9	**p = 0.001**	**P1:P2 p = 0.002**
			P2	173.9	159.3	76.1	819.6	107.4		P1:P3 p = 1.000
			P3	145.3	123.4	74.9	1070.2	106.8		**P2:P3 p = 0.004**
	Left	Resting [μV]	P1	9.5	8.1	2.5	34.4	6.3	**p = 0.001**	P1:P2 p = 0.349
			P2	12.7	9.8	2.5	68.9	11.3		P1:P3 p = 0.092
			P3	8.2	6.3	2.5	38.7	6.8		**P2:P3 p < 0.001**
		Functional [μV]	P1	13.7	11.3	2.5	71.2	11.8	**p < 0.001**	**P1:P2 p = 0.021**
			P2	22.6	16.2	2.5	96.3	21.4		P1:P3 p = 0.689
			P3	13.6	9.9	2.5	103.9	15.9		**P2:P3 p < 0.001**
		Functional [% of resting]	P1	139.8	123.7	94.3	567.3	64.8	**p = 0.005**	**P1:P2 p = 0.005**
			P2	176.8	157.9	70.9	680.1	102.0		P1:P3 p = 0.180
			P3	157.0	120.9	91.1	1183.6	120.9		P2:P3 p = 0.063

GM - gluteus maximus; μV - microvolts; $\bar{x}$ - mean; Me - median; min - minimum; max - maximum; SD - standard deviation.
P1 - position 1 (anterior pelvic tilt); P2 - position 2 (posterior pelvic tilt); P3 - position 3 (neutral pelvic tilt).
* Kruskal–Wallis test.
** Dunn's test.

PFM. Capson et al. [22], in their study on the changes in abdominal muscle activity in various positions of the body, reported that the greatest bioelectric activity of external and internal oblique abdominal muscles was observed in a relaxed standing position compared to the standing position with increased or decreased lordosis angles [22]. Sapsford et al. [13], found that abdominal and PFM activity was lower in a slump supported sitting position with trunk flexion compared to an active sitting position, which might prove synergistic co-activation of the muscles in question. Bo and Stien [26] described co-activity patterns of various muscle groups, including PFM and hip muscles. They observed that contraction of hip adductors, GM, and abdominal muscles resulted in PFM contraction, by the rules of synergy, whereas Soljanik et al. [27], demonstrated a correlation between levator ani and GM, which manifested as simultaneous activation in 97% of the cases.

As we already mentioned, the effect of abdominal muscle activity on PFM has been widely discussed in the literature. Co-activation of the abdominal muscles and PFM has been reported by independent teams of researchers supervised by Arab [12], Devreese [15], or Thompson [28]. Greater abdominal muscle activity was observed during PFM contraction, with the converse situation observed during abdominal muscle contraction. Additionally, Devreese et al. [15] suggested that stress urinary incontinence may be the result of an unbalance between PFM and the lower section of the abdominal muscles. More detailed results were reported by Junginger et al. [29] who demonstrated a correlation between functional co-activity of PFM, abdominal muscles, and elevation of the bladder neck. The proper function of the abdominal muscles may lower intravaginal pressure during PFM contractions, which is the consequence of their additional functions, such as supporting the viscera and regulation of the intra-abdominal pressure [10].

Taking into account the previous studies described above, it seems safe to conclude that the investigated synergist muscles, pelvic position, and PFM are linked. In the absence of proof for a direct correlation between synergist muscles and PFM in this research, further research on the strength of that relationship is necessary. Synergist muscles might

Table 5
Comparison of the results of the sEMG activity of selected synergist muscles obtained during forward and backward movement of the pelvis (n = 82).

The bioelectrical activity of muscle:	Side	Pelvis movement	$\bar{x}$	Me	Min	Max	SD	*p*-value*
AM [μV]	Right	Forward	9.6	8.7	2.0	28.8	5.2	**p = 0.012**
		Backward	11.5	10.4	2.0	39.5	6.5	
	Left	Forward	10.5	9.2	2.4	41.8	6.9	**p = 0.025**
		Backward	12.8	12.2	2.4	70.1	9.1	
RA [μV]	Right	Forward	7.0	6.1	3.7	29.7	4.7	**p = 0.004**
		Backward	7.8	6.8	3.8	25.9	4.7	
	Left	Forward	6.9	6.4	3.7	17.3	2.5	**p = 0.015**
		Backward	7.6	7.2	4.0	20.6	2.9	
GM [μV]	Right	Forward	14.6	12.8	2.5	71.0	11.3	**p < 0.001**
		Backward	25.3	23.4	2.5	123.0	20.5	
	Left	Forward	15.7	13.5	2.5	125.1	15.3	**p < 0.001**
		Backward	27.4	22.4	2.5	129.3	22.7	

AM - adductor magnus, RA - rectus abdominis, GM - gluteus maximus; μV - microvolts; $\bar{x}$ - mean; Me - median; min - minimum; max - maximum; SD - standard deviation.

* Mann–Whitney *U* test.

play an important role in generating greater PFM tension, which would facilitate PFM training in the affected individuals [12–14]. However, findings of the current study do not support this hypothesis.

A limitation of the study was the lack of evaluation of other muscles. Some studies draw attention to the important accessory functions of transversus abdominis and the abdominal internal and external oblique muscles. The choice of the muscles to assess in this study was due to the limitations of the research equipment, which was only able to simultaneously evaluate PFM and three pairs of other muscles. The promising results of this study encourage further investigation. The new projects will take into account the results presented in this study and additional aspects that may also affect the increase in the bioelectric activity of PFM.

Also, standardization methods of sEMG results have some limitations [30–32]. Some difficulty may be in the obtaining a volition, maximum contraction of the muscles, therefore, MVC normalization was not selected. It was decided on the normalization method related to the expression of functional sEMG as a percentage of resting sEMG. It is worth emphasizing that the normalization values are more stable and easier to interpret than the microvolts.

5. Conclusion

Electromyographic activity of selected muscles acting synergistically with PFM (RA, GM, AM) depends on pelvis position and is the highest in the posterior pelvic tilt. Increased activity of the synergists, resulting from pelvis position, does not affect the myoelectric activity of PFM. It seems that muscles that act synergistically with PFM may not play such a significant role in the therapeutic management of PFM. However, this requires further evaluation in the research, including the assessment of other muscles which may improve PFM strength.

Conflict of interest

None.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.gaitpost.2019.04.024.

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