

# Relationship between lower limb position and pelvic floor muscle surface electromyography activity in menopausal women: a prospective observational study

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**Objectives:** In physiotherapeutic practice, special attention is being given to the reciprocal anatomical, physiological, and biomechanical relationship of the pelvis and the structures connected to it. However, the scientific literature shows mainly the theoretical information about their mutual connections. The lack of information about these relations from a practical aspect coupled with the paucity of scientific papers on the impact of posture changes on the pelvic floor led the authors to conduct this study. The primary aim of this study was to compare the resting and functional bioelectrical activities of pelvic floor muscles (PFMs) depending on three different positions of the lower limbs (positions A, B, and C) in the supine position.

**Materials and methods:** This was a prospective observational study evaluating resting and functional activities of the PFM depending on the position of the lower limbs. The study was carried out at the Department and Clinic of Urology, University Hospital in Wrocław, Poland and the target group were women in the menopausal period. Bioelectrical activity of PFM was recorded using a surface electromyographic instrument in the supine position. Results of the values obtained in A, B, and C positions were compared using a one-way analysis of variance.

**Results:** In position A, the average resting surface electromyography (sEMG) activity of PFM was  $6.9 \pm 2.6 \mu V$ ; in position B, the result was  $6.9 \pm 2.5 \mu V$  and in position C, the resting sEMG activity was  $5.7 \pm 1.8 \mu V$  ( $P=0.0102$ ). The results of the functional bioelectrical activity of PFM were as follows: position A –  $20.3 \pm 11.8 \mu V$ , position B –  $19.9 \pm 10.6 \mu V$ , and position C –  $25.3 \pm 10.9 \mu V$  ( $P=0.0104$ ).

**Conclusion:** The results showed that in the supine position, the PFM achieved the lowest resting activity and the highest functional activity. Therefore, the supine position can be recommended for the diagnosis and therapy of weakened PFM.

**Keywords:** pelvic floor muscles, menopause, surface electromyography, synergistic muscle

## Introduction

Stress urinary incontinence (SUI), pelvic organ prolapse, and chronic pelvic pain are frequent complaints of women in perimenopause and menopause and result mainly from pelvic floor insufficiency. Proper statics of the pelvic floor provides adequate support for the urethra and bladder, which determines the correct mechanism of continence. Anatomical disorders such as loss of support for the bladder base and the proximal urethra are a direct cause of SUI.<sup>1-3</sup> Women diagnosed with SUI demonstrated changed configuration of these structures as well as disorders in their functioning. Among the

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causes of these changes are the weakening of connective tissue structures and the loosening of connections within the pelvic floor.<sup>4–7</sup> It is believed that the menopause plays the most significant role in this pathogenesis. Symptoms related to the urogenital system may affect 50% of women in this period.<sup>3,8–13</sup> Many authors<sup>3,9,12,14–17</sup> indicate a decreased level of estrogens as the main cause of the symptoms. One of the key roles of estrogens, which may be impaired during menopause, is their influence on the synthesis and metabolism of collagen, eg, within the lower urinary tract, and on the increase in the number of muscle fibers of the detrusor muscle as well as other muscles comprising the pelvic floor.<sup>3,14–16</sup> During the menopause, a reduced number of estrogen receptors in the epithelia of the urethra, bladder triangle, or vaginal mucosa can be observed. This decrease is also seen in the structures supporting the pelvic organs, eg, uterosacral ligament, levator ani muscle, and pubocervical fascia.<sup>11,15,18–21</sup>

The other cause of disorders in the statics of the pelvic floor is damage to the muscle and connective tissue structures due to vaginal deliveries.<sup>11,22–24</sup> Botelho et al<sup>24</sup> reported a significant loss of muscle contractility during electromyography (EMG) evaluation in women who underwent vaginal delivery. In patients who had undergone cesarean section, a decrease in muscle function was not observed. Another significant factor increasing the risk of severe perineal trauma is an episiotomy. It should be stated that despite many studies on the negative impact of episiotomy on the pelvic floor, in many countries, it is still a routine practice. A study conducted by Blondel et al<sup>25</sup> based on the Euro-Peristat Project demonstrated that many European countries had episiotomy rates >60% (Poland 67.5%, Romania 68.2%, Portugal 72.9%, and Cyprus 75%).

Recent randomized clinical trials have shown that currently the most comprehensive therapeutic procedure in SUI are properly chosen and properly executed pelvic floor muscle (PFM) exercises along with the use of objective, minimally invasive and safe diagnostic methods (eg, EMG).<sup>24,26,27</sup> In physiotherapeutic practice, special attention is being given to the reciprocal anatomical, physiological, and biomechanical relationship of the pelvis and the structures connected to it. However, the scientific literature<sup>6,7,28–33</sup> shows mainly theoretical information about their mutual connections.

The lack of information about these relations from the practical aspect as well as the paucity of scientific papers<sup>31,33–35</sup> on the impact of posture changes on the pelvic floor and the function of the lower urinary tract prompted this study. The authors attempted to answer the question of whether the position of the lower limbs, affecting the different orientations of the pelvis, can influence PFM activity.

## Aim

The primary aim of this study was to compare the resting and functional bioelectrical activities of PFM depending on three different positions of the lower limbs (position A, B, C) in the supine position. The secondary goal was to compare the surface electromyography (sEMG) activity of selected synergists of the PFM, eg, adductor magnus (AM), rectus abdominis (RA), and gluteus maximus (GM; two sides: left and right), in different positions of the lower limbs in the supine position as well as to determine the relationship between the myoelectric activity of the PFM and synergist muscles.

## Materials and methods

This was a prospective, cross-sectional observational study evaluating resting and functional activities of the PFM depending on the position of the lower limbs in menopausal women. The presented study is a part of the research project funded by the National Science Centre in the “Preludium” call on the basis of the decision number DEC – 2011/03/N/NZ7/00505. The study was approved by the Bioethics Committee of the Wrocław Medical University on 5 July 2012 with the approval number KB – 611/2012. Moreover, the study was registered at the Australian New Zealand Clinical Trials Registry platform (ACTRN12613001144707<sup>36</sup>) as a prospective observational study.

The study was carried out at the Department and Clinic of Urology of University Hospital in Wrocław between December 2012 and December 2014.

The target group were women in the menopausal period. All recruited women were subjected to evaluation by the inclusion and exclusion criteria in order to qualify for the appropriate study group. The inclusion criteria assumed in the study included written informed consent, doctor’s and/or physiotherapist’s permission to participate in the study, the overall well-being on the day of examination and no contraindications for the sEMG measurements. The exclusion criteria included age older than 75 years; no history of menopause; gynecological surgery – surgery in the abdomen, pelvis, and lower extremities – in the last 10 years; injuries to the lower extremities, pelvis or, spine on the examination day; contraindications for measurements – infection, menstruation, and allergies to nickel; the occurrence of pain during the examination and withdrawing during the examination.

The visit protocol with the participants included an interview, instruction on the purpose of measurement and testing procedures and sEMG measurement of the PFMs and their synergists in three positions of lower limbs. The measurements were performed with the lower limbs in three different

positions (Figure 1): position A (position of lower limbs in 90° of flexion in hip and knee joints; the limbs were placed freely on adequately profiled wedges – decreased anterior pelvic tilt), position B (position of lower limbs with a slight flexion of hip and knee joints; intermediate pelvic position) and position C (supine position; lower limbs without flexion in hip and knee joints and upper limbs resting freely on the couch – increased anterior pelvic tilt).

The order of the positions was established randomly for each participant by the Random Integer Generator ([www.random.org](http://www.random.org)).

The participants, after setting the pelvis in a particular position, made five 5-second maximal contractions of the PFM (functional sEMG activity) with a 5-second rest between contractions (resting sEMG activity). The rest between measurements in the consecutive position was 60 seconds.

The resting and functional bioelectric activities were measured using the MyoSystem 1400L (Noraxon, Scottsdale, AZ, USA) with eight channels, along with the surface and endovaginal electrodes. The specification of the device fulfills the requirements set out in ISEK (International Society of Electrophysiology and Kinesiology) and SENIAM (Surface ElectroMyoGraphy for the Non-Invasive Assessment of Muscle) publications. The equipment for recording bioelectric

potentials includes main unit with a built-in analog to digital converter (ADC) card; signal amplifiers and preamplifiers; a computer with MyoResearch XP Master Edition software, version 1.04; compatible surface and vaginal electrodes. The measuring set was characterized with the sEMG recording frequency in the range of 10–450 Hz. The frequency range for the amplifier was 10 Hz for high-pass cutoff, with the 500 Hz filter for the low-pass cutoff. The level of common mode rejection amounted to a minimum of 100 dB, and input impedance for EMG channels was >100 MΩ. The system was characterized by the high sensitivity of the recorded EMG signal – 1 μV. To record the sEMG signal from the PFM, a pear-shaped endovaginal electrode Life-Care Vaginal Probe PR-02 (Everyway Medical Instruments Co., Ltd., New Taipei City, Taiwan) was used.

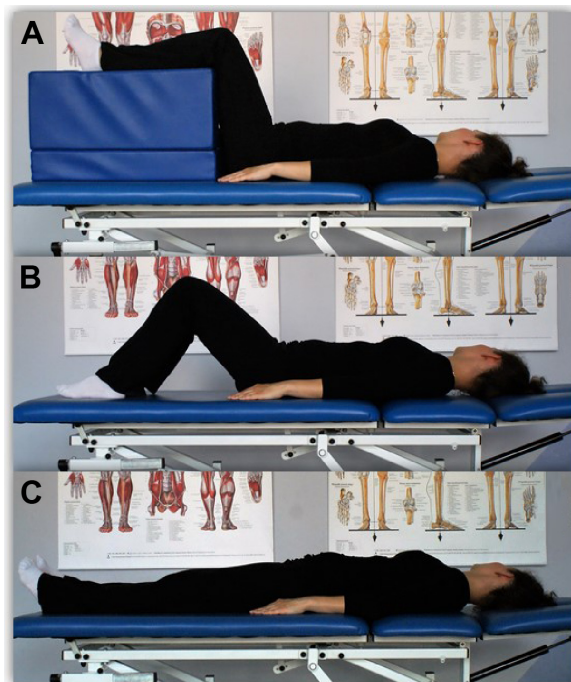
The physical examination was conducted with the use of standardized assessment scales for menopause and the symptoms of urinary incontinence. Menopause Rating Scale (MRS) was used to evaluate the symptoms of menopause.

Statistical analysis was performed using Statistica 12 (StatSoft, Inc., Tulsa, OK, USA) under the license of the Medical University in Wrocław. For the measurable variables, the arithmetic mean, standard deviation (SD) and extreme values were calculated. All quantitative variables were tested with the Shapiro–Wilk test to determine the type of distribution. Comparisons of results between the values obtained in the A, B, and C positions were performed using a parametric test, one-way analysis of variance (ANOVA) along with post hoc testing (Tukey's test) or the nonparametric ANOVA Kruskal–Wallis analysis and multiple comparisons of mean ranks, depending on the fulfillment of the test assumptions. A multivariate linear regression analysis was used to assess relationships between the bioelectrical activity of PFM and bioelectrical activity of all tested synergists (AM, RA, GM – left and right sides). For all comparisons, a level of  $\alpha=0.05$  was assumed, and the obtained *P*-values were rounded to four decimal places.

## Results

### Characteristics of the study group

A total of 55 women, aged between 50 and 75 years ( $\bar{x}=64.9$  years; SD =5.3 years), participated in the study. The characteristics of the group are presented in Table 1. All women underwent the menopause between 40 and 60 years of age ( $\bar{x}=50.7$  years; SD =5.0 years). Each participant in the MRS questionnaire reported symptoms typical for the menopause and postmenopause periods. The results of the MRS questionnaire ranged between 1 and 23 points ( $\bar{x}=10.9$  points; SD =5.7 points).



**Figure 1** Three different positions of lower limbs used during the measurements.  
**Notes:** (A) Position A: position of lower limbs in 90° of flexion in hip and knee joints – decreased anterior pelvic tilt. (B) Position B: position of lower limbs with a slight flexion of hip and knee joints – intermediate pelvic position. (C) Position C: supine position (lower limbs without flexion in hip and knee joints) – increased anterior pelvic tilt.

**Table 1** The characteristics of the study group

Characteristics	n	$\bar{x}$	Min	Max	SD
Age (years)	55	64.9	50.0	75.0	5.3
Weight (kg)	55	66.8	50.0	92.0	10.2
Height (m)	55	1.61	1.47	1.72	0.05
BMI (kg/m <sup>2</sup> )	55	25.7	18.8	35.3	3.9
Number of births	55	1.5	0.0	3.0	0.9
Menopausal age (years)	55	50.7	40.0	60.0	5.0
Total score of the MRS	55	10.9	1.0	23.0	5.7

**Abbreviations:** n, number of participants;  $\bar{x}$ , mean; Min, minimum; Max, maximum; SD, standard deviation; BMI, body mass index; MRS, Menopause Rating Scale.

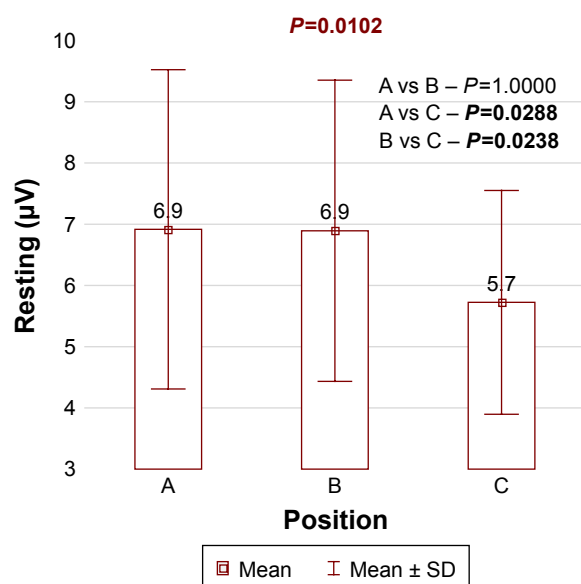
## Primary result

In position A, the average resting sEMG activity of the PFM was 6.9  $\mu$ V (min–max: 3.3–15.3  $\mu$ V; SD = 2.6  $\mu$ V); in position B also, the result was 6.9  $\mu$ V (min–max: 3.0–14.8  $\mu$ V; SD = 2.5  $\mu$ V); and in position C, the resting sEMG activity was 5.7  $\mu$ V (min–max: 2.6–11.7  $\mu$ V; SD = 1.8  $\mu$ V). The results differed significantly ( $P=0.0102$ ; Figure 2).

The results of the functional bioelectrical activity of the PFM were as follows: position A – 20.3  $\mu$ V (min–max: 4.5–55.1  $\mu$ V; SD = 11.8  $\mu$ V), position B – 19.9  $\mu$ V (min–max: 5.8–48.2  $\mu$ V; SD = 10.6  $\mu$ V), and position C – 25.3  $\mu$ V (min–max: 10.0–63.8  $\mu$ V; SD = 10.9  $\mu$ V). The differences were statistically significant ( $P=0.0104$ ; Figure 3).

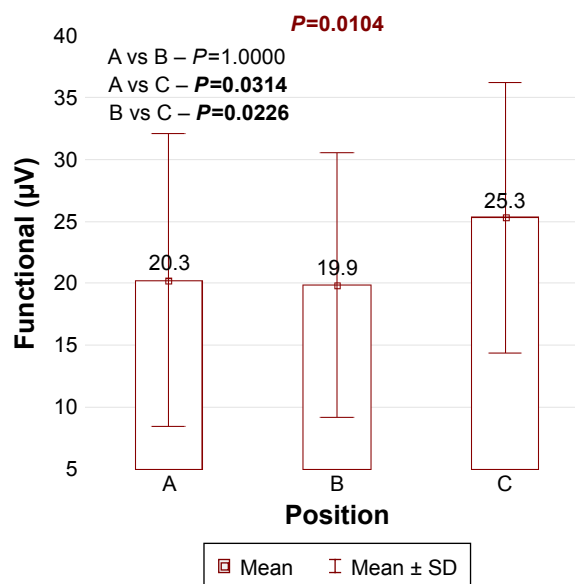
## Secondary result

The highest bioelectrical potential of AM (left and right sides), both during the resting and functional activities of the PFM,

**Figure 2** The comparison of the resting bioelectrical activity of PFM obtained in the three studied positions: A, B, and C.

**Notes:** Position A: position of lower limbs in 90° of flexion in hip and knee joints – decreased anterior pelvic tilt. Position B: position of lower limbs with a slight flexion of hip and knee joints – intermediate pelvic position. Position C: supine position (lower limbs without flexion in hip and knee joints) – increased anterior pelvic tilt. Bold values are statistically significant ( $P<0.05$ ).

**Abbreviations:** PFM, pelvic floor muscle; SD, standard deviation.

**Figure 3** Comparison of the functional bioelectrical activity of PFM obtained in the three studied positions: A, B, and C.

**Notes:** Position A: position of lower limbs in 90° of flexion in hip and knee joints – decreased anterior pelvic tilt. Position B: position of lower limbs with a slight flexion of hip and knee joints – intermediate pelvic position. Position C: supine position (lower limbs without flexion in hip and knee joints) – increased anterior pelvic tilt. Bold values are statistically significant ( $P<0.05$ ).

**Abbreviations:** PFM, pelvic floor muscle; SD, standard deviation.

was obtained in position B. In the case of RA sEMG activity, there were no statistically significant differences between the results obtained in all positions. The highest sEMG of the GM (on the right side) during the resting and functional activities of the PFM was observed in positions A and B. On the left side, there were no statistically significant differences between positions. The results are shown in Tables 2–4.

Multivariate linear regression did not find any association between the resting bioelectrical activity of the PFM and the bioelectrical activity of all synergist muscles in each position (Table 5). Similar results were registered taking into account the functional bioelectrical activity of the PFM (Table 6).

## Discussion

The primary aim of the study was to compare the resting and functional bioelectrical activities of PFM in different positions. It was shown that in the supine position (C), the resting sEMG activity of the PFM reached the lowest values (5.7  $\mu$ V). Both in the position with lower limbs placed on wedges (A) and with lower limbs slightly bent (B), the resting activity achieved the same values (6.9  $\mu$ V). The results confirm the use of the supine position as the most conducive to PFM relaxation. It would seem that this phenomenon may indirectly result from the relaxation of synergist muscles, especially the AM and GM (in the supine position, their insertions are relatively close, which contributes to lower resting

**Table 2** The comparison of sEMG activity of AM (left and right sides) registered in A, B, and C positions during the resting and functional PFM activities

Bioelectrical activity of muscle	Side	PFM bioelectrical activity	Position	n	$\bar{x}$	Min	Max	SD	P-value (main effect)	P-value (post hoc analysis)
AM muscle ( $\mu V$ )	Right	Resting	A	55	4.1	2.2	9.7	1.2	0.0000	A:B =0.0000
			B	55	8.7	2.7	26.7	5.9		A:C =0.7597
			C	55	3.9	2.0	10.0	1.4		B:C =0.0000
		Functional	A	55	4.5	2.4	11.7	1.6	0.0000	A:B =0.0000
			B	55	9.9	3.0	31.9	7.0		A:C =0.7584
			C	55	4.6	2.0	20.3	3.2		B:C =0.0000
	Left	Resting	A	55	4.5	2.5	13.4	2.0	0.0000	A:B =0.0000
			B	55	8.5	2.6	31.9	5.9		A:C =0.4018
			C	55	3.9	2.4	9.2	1.2		B:C =0.0000
		Functional	A	55	5.3	2.7	20.2	3.3	0.0000	A:B =0.0001
			B	55	10.0	2.7	30.1	6.8		A:C =0.2513
			C	55	4.7	2.6	20.4	3.1		B:C =0.0000

**Notes:** Position A: position of lower limbs in 90° of flexion in hip and knee joints – decreased anterior pelvic tilt. Position B: position of lower limbs with a slight flexion of hip and knee joints – intermediate pelvic position. Position C: supine position (lower limbs without flexion in hip and knee joints) – increased anterior pelvic tilt.

**Abbreviations:** sEMG, surface electromyography; AM, adductor magnus; PFM, pelvic floor muscle; n, number of participants;  $\bar{x}$ , mean; Min, minimum; Max, maximum; SD, standard deviation.

potential), but the authors did not report any association between PFM and the synergists.

The literature reveals only few research studies related to the relationship between posture and the PFM activity. Bø and Finckenhagen<sup>37</sup> evaluated the strength of PFM in two different positions. They conducted the measurement of resting pressure, maximum squeeze pressure, and holding periods in seconds, both in supine and standing positions. Although they noted significantly higher vaginal resting pressure in the standing position, there were no differences between these two positions in maximal strength and holding time. In the present study, the highest functional sEMG was registered in the supine position (25.3  $\mu V$ ). Therefore, it seems that this

position is justifiably the most commonly used for both the diagnosis and treatment of SUI.<sup>37</sup>

The relationship between the position and the PFM was also assessed by Chen et al.<sup>35</sup> They evaluated 39 incontinent women to determine the changes in PFM activity during various pelvic tilt angles created by horizontal, dorsiflexed, and plantar-flexed ankle positions. To change the pelvic tilt angle, an adjustable angle platform to set the ankles in a particular position was used. According to the authors, the horizontal position was the neutral position of the pelvis, the dorsiflexed ankle position facilitated the anterior pelvic tilt, and the plantar-flexed ankle position caused the posterior pelvic tilt. The results of this study showed that higher

**Table 3** Comparison of sEMG activity of RA (left and right sides) registered in A, B, and C positions during the resting and functional PFM activities

Bioelectrical activity of muscle	Side	PFM bioelectrical activity	Position	n	$\bar{x}$	Min	Max	SD	P-value (main effect)	P-value (post hoc analysis)
RA ( $\mu V$ )	Right	Resting	A	55	4.7	2.8	8.2	1.3	0.1114	A:B =0.9997
			B	55	4.7	2.9	8.3	1.1		A:C =0.1649
			C	55	5.3	2.8	16.8	2.5		B:C =0.1569
		Functional	A	55	4.9	2.9	8.5	1.3	0.1846	A:B =0.9735
			B	55	5.0	2.9	8.4	1.3		A:C =0.2055
			C	55	5.5	2.4	16.6	2.5		B:C =0.3013
	Left	Resting	A	55	4.9	3.0	9.6	1.1	0.5674	A:B =0.8430
			B	55	4.8	3.0	7.9	0.9		A:C =0.8669
			C	55	5.0	3.2	8.2	1.1		B:C =0.5352
		Functional	A	55	5.0	3.0	7.5	1.0	0.7744	A:B =0.9972
			B	55	5.1	3.0	7.8	1.1		A:C =0.7909
			C	55	5.2	3.2	8.0	1.0		B:C =0.8305

**Notes:** Position A: position of lower limbs in 90° of flexion in hip and knee joints – decreased anterior pelvic tilt. Position B: position of lower limbs with a slight flexion of hip and knee joints – intermediate pelvic position. Position C: supine position (lower limbs without flexion in hip and knee joints) – increased anterior pelvic tilt.

**Abbreviations:** sEMG, surface electromyography; RA, rectus abdominis; PFM, pelvic floor muscle; n, number of participants;  $\bar{x}$ , mean; Min, minimum; Max, maximum; SD, standard deviation.

**Table 4** The comparison of sEMG activity of GM (left and right sides) registered in A, B, and C positions during the resting and functional PFM activities

Bioelectrical activity of muscle	Side	PFM bioelectrical activity	Position	n	$\bar{x}$	Min	Max	SD	P-value (main effect)	P-value (post hoc analysis)
GM ( $\mu$ V)	Right	Resting	A	55	4.6	2.2	25.6	3.7	0.0392	A:B =0.9065
			B	55	4.7	2.1	24.6	3.7		A:C =0.4018
			C	55	3.9	2.0	24.8	3.2		B:C =0.0342
		Functional	A	55	5.4	2.1	28.4	4.9	0.0109	A:B =1.0000
			B	55	5.8	2.0	36.1	5.6		A:C =0.0685
			C	55	4.3	2.0	24.8	3.3		B:C =0.0135
	Left	Resting	A	55	3.6	2.5	21.2	2.5	0.0799	A:B =0.5534
			B	55	3.8	2.6	22.1	2.6		A:C =1.0000
			C	55	3.6	2.6	24.7	2.9		B:C =0.0762
		Functional	A	55	4.8	2.5	27.0	4.3	0.1373	A:B =1.0000
			B	55	4.9	2.5	34.5	5.0		A:C =0.7135
			C	55	4.1	2.6	24.6	3.4		B:C =0.1429

**Notes:** Position A: position of lower limbs in 90° of flexion in hip and knee joints – decreased anterior pelvic tilt. Position B: position of lower limbs with a slight flexion of hip and knee joints – intermediate pelvic position. Position C: supine position (lower limbs without flexion in hip and knee joints) – increased anterior pelvic tilt.

**Abbreviations:** sEMG, surface electromyography; GM, gluteus maximus; PFM, pelvic floor muscle; n, number of participants;  $\bar{x}$ , mean; Min, minimum; Max, maximum; SD, standard deviation.

**Table 5** Results of the multiple linear regression of the resting bioelectrical activity of PFM in positions A, B, and C

Bioelectrical activity of muscle	Resting bioelectrical activity of PFM in position											
	A				B				C			
	$\beta$	P-value	-95% CI	+95% CI	$\beta$	P-value	-95% CI	+95% CI	$\beta$	P-value	-95% CI	+95% CI
AM (right)	0.14	0.3569	-0.35	0.95	0.17	0.3592	-0.08	0.23	0.12	0.4331	-0.23	0.53
AM (left)	0.24	0.2380	-0.21	0.83	0.04	0.8379	-0.15	0.18	0.18	0.3214	0.19	0.64
RA (right)	-0.09	0.6183	-0.95	0.57	-0.14	0.4151	-1.05	0.44	-0.29	0.0754	-0.45	0.02
RA (left)	-0.03	0.8839	-0.91	0.78	-0.12	0.4765	-1.20	0.57	-0.03	0.8366	-0.55	0.44
GM (right)	0.09	0.5699	-0.17	0.30	0.09	0.6500	-0.20	0.32	0.10	0.4968	-0.11	0.21
GM (left)	-0.23	0.2559	-0.67	0.18	0.04	0.8223	-0.30	0.37	-0.10	0.4632	-0.24	0.11

**Notes:** Position A: position of lower limbs in 90° of flexion in hip and knee joints – decreased anterior pelvic tilt. Position B: position of lower limbs with a slight flexion of hip and knee joints – intermediate pelvic position. Position C: supine position (lower limbs without flexion in hip and knee joints) – increased anterior pelvic tilt.

**Abbreviations:** PFM, pelvic floor muscle; CI, confidence interval; AM, adductor magnus; RA, rectus abdominis; GM, gluteus maximus.

**Table 6** Results of the multiple linear regression of the functional bioelectrical activity of PFM in positions A, B, and C

Bioelectrical activity of muscle	Functional bioelectrical activity of PFM in position											
	A				B				C			
	$\beta$	P-value	-95% CI	+95% CI	$\beta$	P-value	-95% CI	+95% CI	$\beta$	P-value	-95% CI	+95% CI
AM (right)	0.22	0.1695	-0.74	4.10	-0.14	0.4012	-0.74	0.30	-0.08	0.6426	-1.44	0.90
AM (left)	0.13	0.4774	-0.85	1.79	0.20	0.2580	-0.24	0.86	0.21	0.2255	-0.47	1.96
RA (right)	0.03	0.8829	-3.16	3.66	-0.04	0.7938	-3.28	2.52	-0.09	0.5356	-1.72	0.91
RA (left)	0.03	0.8689	-3.98	4.70	0.11	0.5118	-2.32	4.59	-0.01	0.9550	-3.32	3.14
GM (right)	-0.05	0.7931	-1.03	0.79	-0.09	0.7217	-1.16	0.81	0.04	0.7805	-0.82	1.08
GM (left)	-0.27	0.2013	-1.90	0.41	0.05	0.8352	-0.94	1.16	-0.18	0.2213	-1.50	0.36

**Notes:** Position A: position of lower limbs in 90° of flexion in hip and knee joints – decreased anterior pelvic tilt. Position B: position of lower limbs with a slight flexion of hip and knee joints – intermediate pelvic position. Position C: supine position (lower limbs without flexion in hip and knee joints) – increased anterior pelvic tilt.

**Abbreviations:** PFM, pelvic floor muscle; CI, confidence interval; AM, adductor magnus; RA, rectus abdominis; GM, gluteus maximus.

PFM EMG activity occurred in the horizontal position and when standing with the ankles in the dorsiflexion position (when the pelvis tilts anteriorly) than when standing with the ankles in the plantar flexion position. The results of Chen et al<sup>35</sup> are similar to our observations as, in the supine position (C), in which the participants achieved the highest functional PFM activity, the pelvis tends to roll forward the most.

In the scientific literature,<sup>32–35,38,39</sup> some authors highlight a close correlation and cross-functional connections between the pelvis, the PFM, and other structures of the area. Incorrect pelvis position can contribute to topographical changes in the position of the proximal part of the urethra and bladder neck with respect to the surrounding structures, including the urogenital diaphragm.<sup>7,40</sup> The course of the urethra in healthy women is generally straightforward, and its curvature can be observed in the strong lift of the pelvic floor, with a large filling of the rectum, or lowering of the pelvic floor and bladder. When the pelvis orientation is correct, the urethra is directed obliquely downward and forward, almost vertically, which allows the free flow of urine during relaxation of the sphincter.<sup>41–45</sup> The more perpendicular the course of the urethra with respect to the pelvic floor, the greater the closing force of its lumen is generated by the PFM. However, according to Capson et al,<sup>34</sup> in the hypolordotic posture, the angle between the urethra and the PFM is greater than in a neutral or hyperlordotic posture, which does not explain, as discussed in this study, the higher sEMG activity achieved in an anterior pelvic tilt position.

The scientific literature also reports on the influence of synergist muscles on PFM. It is believed that muscles around the hip joint (especially, the AM and GM) may increase the activity of the PFM,<sup>46–51</sup> while the abdominal muscles, by affecting the muscle corset of the trunk, can unweight the PFM.

In the current study, the most visible differences of the activity of the synergist muscles were observed within the AM. The lowest values of electrical potential (resting and functional) of these muscles were in the supine position. However, the highest sEMG values were observed in position B, in which the feet were supported. The feet support in this position could elicit postural reactions. In positions A and C, the feet did not have the support, which might result in lower sEMG activity of the AM muscles. It can also be assumed that the AM would therefore be strongly activated in the standing position. A significant relationship between the activation of the AM and the PFM was shown by Norton and Baker.<sup>52</sup> They conducted a cough stress test in a standing

position, standing with the legs crossed, and standing with the body inclined. The authors showed less urine leakage while standing with the legs crossed than while standing in a normal position ( $P < 0.01$ ), which may show the strong effect of the AM muscles on PFM performance. Furthermore, Bø and Stien<sup>41</sup> observed that the contraction of, eg, the adductor muscles, leads to the activation of the PFM.

Other muscles interacting with the pelvic floor are the GM and abdominal muscles. We did not observe any significant changes within RA in any of the positions. Sapsford et al<sup>53</sup> noticed that during slump-supported sitting, the activity of the PFM was lower compared to unsupported sitting positions (which require greater muscle involvement). The authors postulated that particular abdominal exercises would activate the PFM. Similar to the AM, the resting and functional activities of the GM in the supine position were the lowest. The highest values of these muscles were observed in position B. Morin et al<sup>54</sup> noticed that hip muscles, mainly the rotator and gluteal group, facilitate PFM activation.

PFM exercises are recommended as a first-line treatment of SUI. Although the differences in PFM activity in different positions are still controversial, a supine position seems to be the most suitable for assessing the function and mechanism of PFM, especially in women with SUI.<sup>37</sup> In light of the abovementioned scientific reports and what is reported in this article, the relationship among PFM, synergist muscles and the pelvic tilt merits further investigation.

## Limitations

The assessment of activity of only a certain synergistic muscles (RA, AM, GM) is a limitation of this study. The attempt to evaluate the other abdominal muscles would be very meaningful. In the literature, it is noted that the transverse abdominal muscle as well as external and internal oblique muscles play an important accessory functions in PFM performance. The decision on the assessment of selected muscles came out of the limitations of research equipment, which was able to evaluate simultaneously PFM and three pairs of other muscles.

Promising results of the study encourage to continue undertaken research. The new projects will take into account the results presented in this study as well as additional aspects that may also affect the increase in the bioelectrical activity of PFM. This study presents basic research. However, the evaluation of selected muscles in the tested positions in patients with pelvic floor insufficiency will be a continuation of the research conducted by the authors.

## Conclusion

In the study, we evaluated the relationship between the activity of PFM and various lower limb positions. The results showed that in the supine position, the PFM achieved the lowest resting activity and the highest functional activity. Therefore, the supine position can be recommended for the diagnosis and therapy of weakened PFM and SUI. In the assessed positions, we did not observe that the synergist muscles (AM, RA, GM) influence PFM activity. Thus, the obtained PFM activity may be treated as a result measured in isolated conditions. It seems, however, that other muscles, such as the transverse abdominal muscles and abdominal oblique muscles, play a great supporting role for the PFM, which will be investigated in further studies.

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## Disclosure

The authors report no conflicts of interest in this work.

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