Bioelectrical activity of the pelvic floor muscles after 6-week biofeedback training in nulliparous continent women

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Purpose: The aim of the study was to evaluate the effects of a 6-week sEMG-biofeedback-assisted pelvic floor muscle training program on pelvic floor muscle activity in young continent women. *Methods*: Pelvic floor muscle activity was recorded using a vaginal probe during five experimental trials. Biofeedback training was continued for 6 weeks, 3 times a week. Muscle strenghtening and endurance exercises were performed alternately. SEMG (surface electromyography) measurements were recorded on four different occasions: before training started, after the third week of training, after the sixth week of training, and one month after training ended. *Results*: A 6-week sEMG-biofeedback-assisted pelvic floor muscle training program significantly decreased the resting activity of the pelvic floor muscles in supine lying and standing. The ability to relax the pelvic floor muscles after a sustained 60-second contraction improved significantly after the 6-week training in both positions. SEMG-biofeedback training program did not seem to affect the activity of the pelvic floor muscles or muscle fatigue during voluntary pelvic floor muscle contractions. *Conclusions*: SEMG-biofeedback-assisted pelvic floor muscle training might be recommended for physiotherapists to improve the effectiveness of their relaxation techniques.

Key words: *pelvic floor, electromyography, biofeedback, healthy volunteers, prevention*

1. Introduction

Pelvic floor muscles (PFM) have several functions and, among them, to maintain location of the pelvic viscera and control continence [2]. They must counteract any increase in intra-abdominal pressure and vertical ground reaction forces during physical exercise and everyday activities [22] to prevent involuntary leakage of urine. Pelvic floor muscles are characterized by synchronous and harmonic contractions [13] and prolonged tension (except for micturition and defecation) [23]. Both layers of the pelvic floor muscles (superficial and deep) work as a functional unit [5].

Weakening of pelvic floor muscles and the resultant loss of urinary bladder and bladder neck support lead to stress urinary incontinence [2]. Involuntary leakage of urine significantly decreases the quality of life [21]. Stress urinary incontinence affects women during and after menopause [12], after vaginal delivery [6], hysterectomy [16], sportswomen [11], but also – more and more frequently – young healthy women [22]. Hence, early implementation of effective preventive strategies is essential, including pelvic floor muscle training.

Due to specific location of the pelvic floor muscles, they are difficult to identify; hence, a lot of women are unable to contract the muscles correctly, especially at the start of the training program. Bø and

Sherburn [5] observed that activation of inadequate muscle groups and incorrect breathing patterns were the most common mistakes when exercising. It has been shown that supervised training protocol is more effective than oral instruction alone [7]. Biofeedback training with electromyography (EMG) recordings is often applied when teaching voluntary contraction and relaxation of the pelvic floor muscles.

The function of the pelvic floor muscles is associated with age, parity and mode of delivery, BMI and intense physical training [10]. Considering the number of risk factors for stress urinary incontinence and high prevalence of this disorder among women, the importance of preventive interventions should be emphasized. Bioelectrical activity of the pelvic floor muscles decreases with age [3] and so does the function of these muscles [24], commonly resulting in urinary incontinence. Hence, pelvic floor muscle training should be implemented in the population of young and healthy women.

Regular exercises of the striated muscles of the pelvic floor may result in adaptive changes characteristic of other muscles of the same type. The aim of the study was to evaluate the effects of a 6-week sEMG-biofeedback-assisted pelvic floor muscle training program on pelvic floor muscle activity in young continent women.

2. Material and methods

Subjects

Twenty-three continent women aged 19–28 (mean age 24.1 ± 2.3 years) were invited to participate in the study. Two of them were excluded from the group since they did not meet the inclusion criteria, and so ultimately 21 healthy nulliparous women entered the study. The mean body mass was 58.3 kg and the mean height was 163.5 cm. Exclusion criteria included a history of SUI, pregnancy, childbirth(s), pelvic surgery, diabetes, hypertension, neurological abnormalities, urinary tract infection, elevated temperature, practicing professional sport, spinal pain and Body Mass Index over 30 kg/m^2. All participants gave consent to participate in this study prior to the experiment, which was approved by an ethics committee of the Institutional Review Board.

sEMG measurements

The measurements were performed under standard testing conditions, the same for all subjects.

PFM sEMG (surface electromyography) was recorded using Myo Trace 400 (Noraxon U.S.A. Inc.) with a preamplifier (band pass filter 20 Hz–500 Hz, Common Mode Rejection Ratio of >100 dB at 60 Hz, input impedance >100 MΩ, amplifier gain 500). A 16-bit analog to digital (A/D) converter with an anti-aliasing filter set to 500 Hz frequency was also used.

Pelvic floor sEMG activity was recorded using a small diameter vaginal probe with two metal sensors (Everyway Medical Instruments Co). The probe was inserted using a small amount of antiallergic lubricant with the sensors positioned laterally in the vagina. After cleansing the skin site with an alcohol swab, round self-adhesive electrodes (silver/silver chloride) were applied to the skin over the examined muscle in accordance with SENIAM recommendations [15]. The reference surface electrode was placed over the right anterior superior iliac spine. No visible contractions of the hip adductor, rectus abdominis or gluteus muscles were allowed. In order to exclude the undesirable contractions of these muscles, the next two bipolar self-adhesive electrodes were located on the right side along muscle fibres of the rectus abdominis, hip adductor muscle and gluteus maximus.

Prior to measurements, the participants were asked to urinate a full void. All subjects were instructed on the correct contraction of pelvic floor muscles and could observe sEMG signals on the computer monitor but only during the instruction session.

The experiment consisted of two phases: (1) the MVC procedure to recruit pelvic floor muscles and (2) five trials designed to determine pelvic floor muscle activity (see below). During the first phase, each participant was instructed to perform maximal voluntary contractions (MVC) of pelvic floor muscles as forcefully as possible for about 5 seconds. Three attempts were made with 60-second rests between each contraction to reduce the effect of muscle fatigue. During MVCs verbal encouragement was provided. MVC was used as a reference value. The maximal voluntary contractions of pelvic floor muscles were performed in supine lying position with the hip and knee positioned at 30° and 90° of flexion, respectively. The position was controlled with the goniometer.

Following the MVC procedure, sEMG signal was recorded during each trial [14]:
– a 10-second baseline sEMG recording. Parameters measured were: mean amplitude (% MVC), area (% s) (mathematical integral under the EMG amplitude for a certain period);
– 5 repeated short (quick flick) contractions with a 5-second pause between each contraction. Parameters measured: average peak (% MVC) (aver-

age value of all five local peaks, calculated when the amplitude exceeds the threshold level predetermined as 50% between minimum and maximum amplitudes in each particular trial), average mean (% MVC) (mean amplitude value of the active sEMG portions, calculated when the amplitude exceeds the threshold level predetermined as 50% between minimum and maximum amplitudes in each particular trial), average time before peak (s) (the average duration needed to let the signal increase to the local peak), area (% s) (see above);

– 5 repetitions of 10-second voluntary contractions with 10 seconds of rest in between. Parameters measured: average peak (% MVC) (see above), average mean (% MVC) (see above), area (% s) (see above);

– a sustained 60-second contraction. The magnitude of external forces or loading is not sufficient to initially estimate forces generated by the pelvic floor muscle. The only way to ensure correct performance of the task is to use the maximal contraction and provide verbal encouragement to maintain the contraction. Therefore the instruction "Pull up and in, and squeeze around the probe as strongly as you can until you hear the command *Now relax*". Verbal feedback was given during the trial. The initial subperiod (3 seconds) in which the voluntary contraction had not yet begun (time lapse between the instruction to contract the PMF and actual initiation of the contraction), was excluded from analysis. Percentage changes in the mean and median frequency and mean amplitude were calculated using the formula for the difference of two subperiods. Five 1-second intervals of both subperiods yielded five values of the variables under analysis.. The mean amplitude and mean and median frequency of the sEMG signal were analysed [25]. Relative changes of the values were analysed with respect to body positions assumed during the examination;

– a 10-s relaxation (resting tone) immediately after the 60-s contraction. Parameters measured: mean amplitude (% MVC), area (% s) (see above).

SEMG recordings were performed in 2 positions, i.e., supine lying and standing [3]. The order of the testing positions was randomly assigned with 5-minute breaks between each trial.

SEMG measurements were recorded on four different occasions: before training started (measurement 1), after the third week of training (measurement 2), after the sixth week of training (measurement 3), and one month after training ended (measurement 4).

The raw sEMG data were full wave rectified. Root mean square values were calculated using a 100 ms sliding window.

sEMG biofeedback training

During the first phase, each participant was instructed to perform MVC of pelvic floor muscles as forcefully as possible for about 5 seconds. Three attempts were made with 60-second rests between each contraction to reduce the effect of muscle fatigue. MVCs were used as reference values for the training.

The lengths of the on/off times (contraction/relaxation) of pelvic floor muscles exercises was 3/3 s and 3/6 s (alternately). During 3/3s and 3/6s on/off muscle activity, the muscles worked at 60% and 80% of the maximal voluntary contraction (MVC), respectively. Biofeedback training was continued for 6 weeks, 3 times a week (18 training sessions altogether).

Muscle strenghtening and endurance exercises were performed alternately. To increase muscle strength, the participants performed 3 sessions of 10 contractions weekly during the first three weeks of the training program; at week 4, the number of sessions increased to 4 per week. Endurance training consisted of 3 sessions of 15 contractions (i.e., 45 contractions) weekly for the first three weeks; at week 4, the number of sessions increased to 4 per week (60 contractions altogether).

Statistical analysis

Statistical analysis was performed using Statistica program (StatSoft version 10). The Friedman two-way ANOVA by ranks was used when the same parameter was measured several times ($k >= 2$) under different conditions on the same subjects. The Bonferroni posthoc test, which reveals which means are significantly different from each other, was also performed. The significance level was set at $p < 0.05$.

In order to assess the magnitude of sEMG signal amplitude changes in consecutive measurements, we decided to compare the values of percentage change which provide information on the changes in a parameter on measurements 2, 3 and 4 compared to measurement 1.

3. Results

Baseline sEMG recording

The analysis of the mean normalized amplitude and area in supine lying revealed statistically signifi-

cant differences between measurements 1, 2, 3 and 4 (Table 1). The Bonferroni post-hoc test showed statistically significant differences between measurements 1 and 2, 1 and 3, and 1 and 4, with sEMG signal amplitude decreasing throughout the examination.

Statistically significant differences in the mean normalized sEMG amplitude in standing were observed between measurements 1, 2, 3, and 4 (Table 1). The post-hoc revealed statistically significant differences between measurements 1 and 3 as well as 1 and 4.
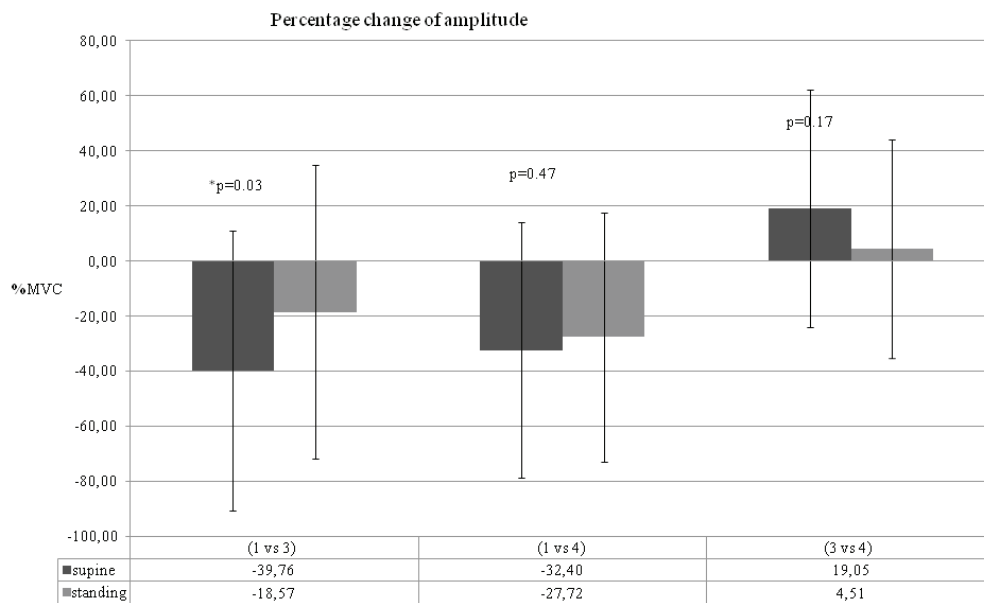
Similar to supine lying, sEMG signal amplitude decreased during the examination. Significant differences in the area were found between measurements 1 and 3, and 1 and 4.

The analysis of the baseline test results revealed statistically significant differences between supine lying and standing. The negative value of the percentage change in PFMs activity was greater in supine lying compared to standing (1 vs. 3) (Fig. 1). No statistically significant differences were seen between

Table 1. Comparison of the normalized amplitude (%MVC)
for pelvic floor muscles in supine lying and standing during the baseline sEMG recording
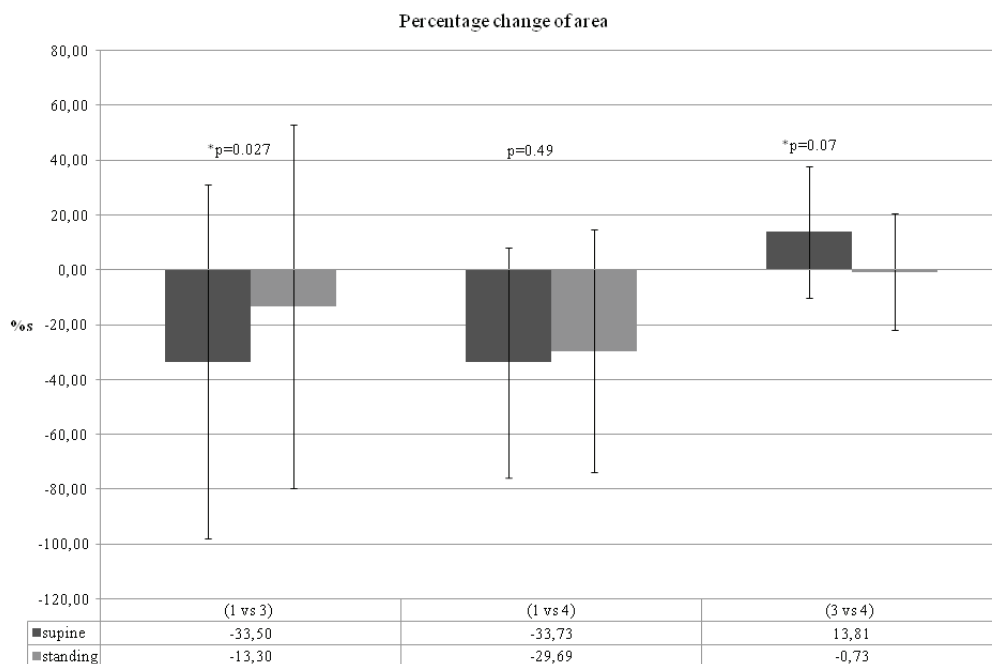
Trial	n	Supine				Standing			
		Mean amplitude %MVC	SD	Mean area %s	SD	Mean amplitude %MVC	SD	Mean area %s	SD
1	19	20.75	16.59	207.46	165.91	32.10	20.74	320.95	207.40
2	19	10.92	6.68	109.18	66.77	22.73	15.71	227.82	156.59
3	19	8.73	5.57	95.23	63.20	19.42	10.79	206.28	129.89
4	19	10.43	7.73	104.27	67.05	19.52	12.44	192.95	126.12
p*(trial 1,2,3,4)		**$p = 0.000$**		**$p = 0.000$**		**$p = 0.007$**		**$p = 0.004$**	
p(trial 1 vs. 2)		**0.005**		**0.0059**		0.086		0.11	
p(trial 1 vs. 3)		**0.00055**		**0.0014**		**0.01**		**0.03**	
p(trial 1 vs. 4)		**0.003**		**0.0036**		**0.011**		**0.012**	
p(trial 2 vs. 3)		0.86		0.96		0.83		0.95	
p(trial 2 vs. 4)		1		1		0.84		0.82	
p(trial 3 vs. 4)		0.93		0.99		1		0.99	

p* – Friedman's ANOVA,
p – Bonferroni's post hoc test.

Percentage change of amplitude

	(1 vs 3)	(1 vs 4)	(3 vs 4)
■supine	-39,76	-32,40	19,05
■standing	-18,57	-27,72	4,51

Wilcoxon test
*statistically significantly different

Fig. 1. Supine lying and standing positions – percentage changes in baseline amplitude

Wilcoxon test
*statistically significantly different

Fig. 2. Supine lying and standing positions – percentage changes in baseline area

supine lying and standing positions regarding percentage change between measurements 1 and 4, and 3 and 4.

Statistically significant differences in the area parameter were seen between supine lying and standing positions regarding percentage change between measurements 1 and 3, and 3 and 4 (Fig. 2).
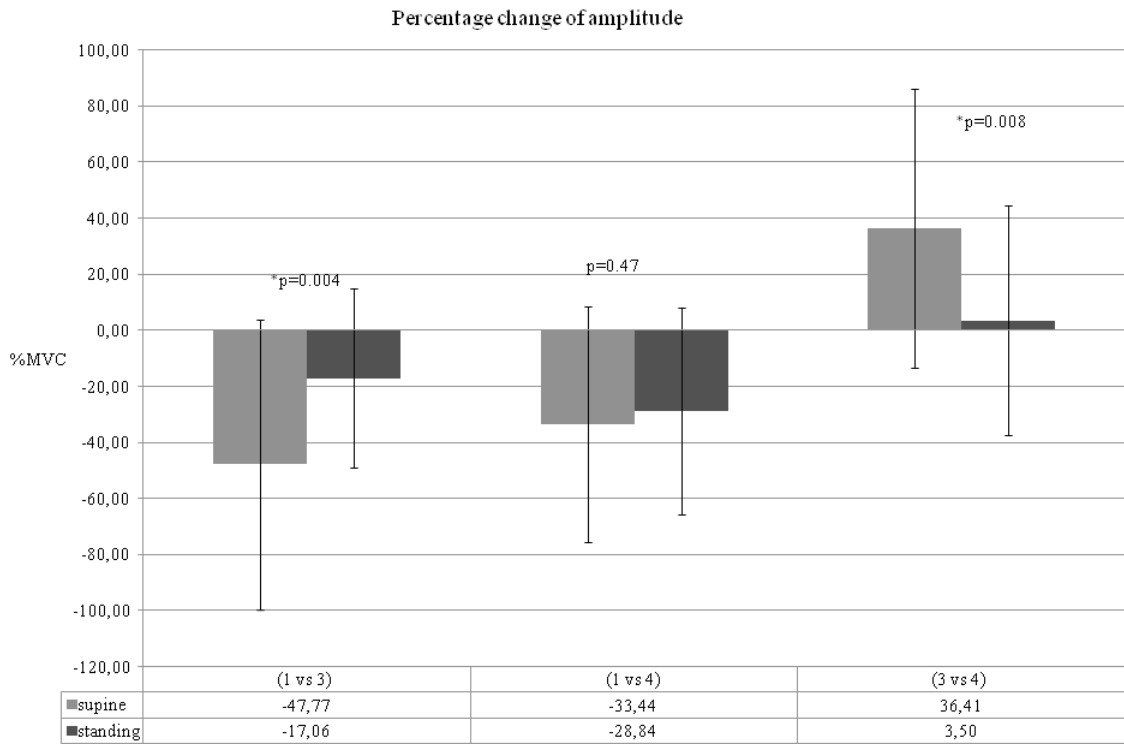
Short (quick flick) contractions

Average peak, average time before peak, average mean amplitude and mean area did not differ significantly during the voluntary contractions of the PFMs in supine and standing positions.

Table 2. Comparison of the normalized amplitude (%MVC)
for pelvic floor muscles in the lying and standing positions during 10-second relaxation
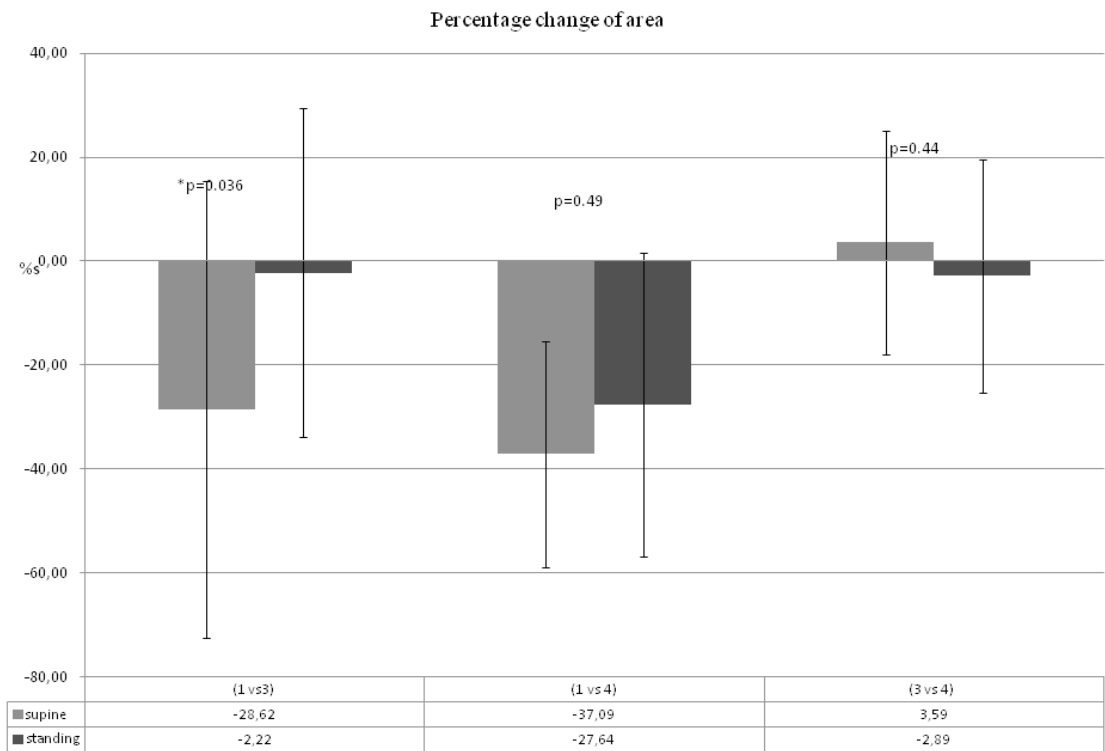
Measurement	n	Supine				Standing			
		Mean area %s	SD	Mean amplitude %MVC	SD	Mean area %s	SD	Mean amplitude %MVC	SD
1	19	196.49	141.13	20.00	13.89	297.23	196.09	30.04	19.61
2	19	137.40	85.09	13.74	9.51	226.58	148.32	22.66	14.83
3	19	98.25	66.31	7.04	3.29	205.37	130.26	16.86	9.71
4	19	96.16	59.32	9.81	5.92	179.09	116.80	17.57	11.95
$p*$(1.2.3.4)		**$p = 0.015$**		**$p = 0.001$**		$p = 0.104$		**$p = 0.036$**	
p(1 vs. 2)		0.11		0.067		0.42		0.31	
p(1 vs. 3)		**0.0019**		**0.00017**		0.2		**0.015**	
p(1 vs. 4)		**0.0015**		**0.00086**		0.05		**0.024**	
p(2 vs. 3)		0.43		**0.043**		0.97		0.52	
p(2 vs. 4)		0.38		0.39		0.73		0.63	
p(3 vs. 4)		0.99		0.68		0.94		0.99	

$p*$ – Friedman ANOVA,
p – Bonferroni post-hoc test.

Fig. 3. Supine lying and standing positions – percentage changes in resting amplitude

Fig. 4. Supine lying and standing positions – percentage changes in resting area

5 repetitions of 10-second voluntary contractions with 10 seconds of rest in-between

No significant differences were found in average peak amplitudes (normalized to the MVC) and mean sEMG amplitudes (normalized to the MVC) of the pelvic floor muscles between any measurements in both lying and standing positions.

Sustained 60-s contraction

Relative changes of the median and mean frequency were negative in particular measurements for both study positions indicating a downward trend. No differences in relative changes in mean and median frequency of the sEMG signal and mean amplitude of the PFMs were found between measurements performed in the two study positions.

Resting tone

The mean normalized amplitude and area of the sEMG signal were the lowest in the third measurement in supine lying (significantly lower compared to measurements 1 and 2) (Table 2). Statistically significant differences were also revealed in the mean values of the normalized amplitude between measurements 1 and 4 in the supine position.

In the standing position, significant differences in the mean normalized amplitudes were observed between measurements 1 and 3, and 1 and 4.

A comparison of negative percentage change in normalized sEMG signal amplitude and area demonstrated differences between the lying and standing positions as well as between measurements 1 and 3, and 3 and 4. Differences in the values of percentage change were not statistically significant between measurements 1 and 4 (Figs. 3, 4).

4. Discussion

Feedback is an important element of motor learning. Repeated and incorrect contractions of the pelvic floor muscles may lead to permanent extension, weakening and impairment of their contractile function. Consequent stretching of the fibrous connective tissue of the fascia and ligaments might increase the risk for future pelvic organ prolapsing [4]. EMG-biofeedback assisted pelvic floor muscle training promotes and accelerates the process of movement re-education, provides information regarding the performance of a movement task and sustains motivation for exercising.

Baseline activity of the pelvic floor muscles was evaluated during a 10-second trial, which is long enough to obtain adequate information [23].

Lauper et al. [17] compared the pelvic floor muscle response of a healthy control group with that of a postpartum group. They found that in healthy women aged 18–40 years, the mean rest activation level of the pelvic floor muscles was 30.1% MVC during standing. Similar resting activity in standing position (32.1% MVC) was noted in our study.

Our analyses revealed that the resting activity of the pelvic floor muscles decreased significantly after 6 weeks of the training program compared to the baseline levels in both standing and supine lying. Interestingly, this tendency seemed to persist throughout a longer period of time – the results of the analysis still showed a significantly lower bioelectrical muscle activity one month after training cessation compared to baseline.

The investigations of Slieker-ten Hove et al. [24] revealed that only 51.3% of their study population were able to relax pelvic floor muscles voluntarily after voluntary contraction. The ability to properly relax these muscles is of considerable importance, and especially during micturition and defecation. Complete relaxation after voluntary and involuntary contractions of the pelvic floor muscles allows the termination of urethral, vaginal, and anal closure [24]. Overactivity of the pelvic floor muscles may cause voiding problems, obstructed defecation and dyspareunia [20].

Burti et al. [9] also observed a significant decrease from the baseline rest tone amplitude after a 60- and 10-second contraction of the pelvic floor muscles in 26 continent women. The authors suggest that the decrease in EMG rest amplitude after a 60-second contraction resulted from fatigue.

Difficulties in comparing changes in sEMG signal amplitude are predominantly due to differences in the methods of data collection and analysis. The majority of researchers do not normalize electromyograms [3], [9], although the sEMG from an isometric maximal voluntary contraction should be used as a normalization reference value [8], and especially when measurements are carried out at time intervals.

A sudden increase in intra-abdominal pressure from coughing or sneezing should be counteracted by a quick and intense contraction of the pelvic floor muscles. Madill et al. [18] observed that relative time to peak pelvic floor muscle contraction was lower in incontinent women. Slieker-ten Hove et al. [24] reported that only half of the women (48.5%) performed an effective pelvic floor muscle contraction during

coughing. Therefore effective increase of the speed of pelvic floor muscle contractions is an important strategy for prevention of urinary incontinence. However, we did not observe significant differences in the parameters of short (quick flick) contractions after a 6-week training program.

A 60-second contraction did not result in pelvic floor muscles fatigue in our young continent study participants. Nevertheless, the issue requires further investigations. Fatigue during sustained voluntary contraction is evidenced by a power-spectrum shift to lower frequencies with a simultaneous increase in sEMG signal amplitude. A 450-second contraction of the biceps brachii at 25 % MVC resulted in a decrease of median and mean frequency and an increase in mean amplitude thus confirming the development of muscle fatigue [25]. Our results reveal a similar (but not so strong) tendency; therefore we cannot confirm muscular fatigue.

Pelvic floor muscle fatigue was investigated by several authors but the assessment method was not electromyography [9], [22].

In our study, normalized amplitude of the pelvic floor muscle sEMG signal during voluntary contractions did not change significantly following EMG-biofeedback-assisted pelvic floor muscle training program; neither did it show differences between the supine and standing positions. Similar results were reported by Madill and McLean [19], who examined continent women, and did not find significant differences in the activity of pelvic floor muscle contractions in supine, sitting and standing positions. The authors conclude that, in young and healthy women, gravitational forces do not significantly affect PFM's activation capacity and functional strength.

Devising a resistance training program requires the consideration of exercise mode as well as training frequency, intensity, and duration [1]. Beneficial adaptive changes also require periodization of the training volume, load and intensity. The lack of statistically significant differences between bioelectrical activity of the pelvic floor muscles before and after the 6-week sEMG-biofeedback-assisted training program might be due to insufficient training load.

Changes in sEMG signal amplitude were greater in supine lying; in this position gravity acts on the posterior abdominal wall and not directly on the pelvic floor which favours lower resting activity of the muscles. Standing is associated with changes in intra-abdominal pressure, which, in turn, results in an involuntary contraction of the PFM [20]. Our results indicate that supine lying facilitated muscle relaxation.

The major limitation of our study was the small number of participants. Also, we could not compare the results with incontinent women as no comparison group had been formed.

5. Conclusions

Our findings seem to indicate that a 6-week sEMG-biofeedback-assisted program training improves the ability of the pelvic floor muscles to relax after a sustained 60-second contraction and significantly decreases the activity of the pelvic floor muscles at rest. Therefore, sEMG-biofeedback training might be recommended for physiotherapists to improve the effectiveness of their relaxation techniques and rehabilitation programs. However, considering the importance of effective interventions to prevent stress urinary incontinence in women, we would like to emphasize the need for further research in this area.

Acknowledgement

Conflict of interest

The authors declare that they have no conflict of interest.

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