

Normative values for Glazer Protocol in the evaluation of pelvic floor muscle bioelectrical activity

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Abstract

The aim of the study was to evaluate pelvic floor muscle bioelectrical activity in healthy, young, and nulliparous women, and to present normative values for all phases and parameters measured with the Glazer Protocol.

In this study, 96 healthy, young, nulliparous women (age 22–27 years; 168.6 ± 5.1 cm; 57.1 ± 11.8 kg) were tested. The bioelectrical activity of the pelvic floor muscles was collected using an endovaginal electrode with the Glazer Protocol, which included the following series of muscles contractions and relaxations: pre-baseline rest, phasic contractions, tonic contractions, isometric contractions for muscle endurance evaluation, and post-baseline rest.

The following normative values of the bioelectrical signal for all phases of the Glazer Protocol were calculated: mean, minimal, and maximal values, 95% confidence interval, standard deviation, 95% standard deviation confidence interval, variance, coefficient of variation, and standard error of measurement. Average Mean Amplitude (μV) was as follows: pre-baseline rest (6.26 ± 3.33 μV), phasic contractions (49.76 ± 26.44 μV), tonic contractions (37.05 ± 25.99 μV), endurance contraction (16.10 ± 6.68 μV), and post-baseline rest (6.93 ± 3.99 μV).

This study was the first in which normative values for all phases of the Glazer Protocol were reported. This protocol is very often used in electromyography devices as a tool for pelvic floor muscle assessment. Due to the fact that the interpretation of the pelvic floor muscle evaluation is complex and difficult, the authors believe that the normative values proposed in this study allow for comprehensive interpretation of this test (both qualitatively and quantitatively) and provide a reference point for parameters measured in women with different pelvic floor dysfunctions.

Abbreviations: FFT = Fast Fourier Transform, PFM = pelvic floor muscles, sEMG = surface electromyography.

Keywords: Glazer Protocol, normative values, pelvic floor muscles, sEMG

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1. Introduction

The main function of pelvic floor muscles (PFM) is to provide continence and trunk stability.^[1–3] Dysfunctions of PFM may be multifactorial and such symptoms as urinary incontinence, lower back pain, or weakness of spinal stability may appear.^[2,3] This problem affects both women and men, and the incidence is so great that pelvic floor dysfunctions are now considered a “hidden epidemic”.^[4] It is estimated that approximately 21% to 26% of women suffer from various pelvic floor dysfunctions, with the highest incidence regarding urinary incontinence.^[5]

Assessment of PFM dysfunction with surface electromyography (sEMG) is considered an objective and non-invasive diagnostic method.^[6,7] sEMG is also used for biofeedback in monitoring the real-time bioelectrical activity of muscles during the rehabilitation of pelvic floor disorders.^[4,5,7,8] This is commonly performed with the Glazer Protocol.^[4,9,10] Intrapelvic sEMG assessment using the Glazer Protocol includes the following series of muscle contractions and relaxations: pre-baseline rest, phasic contractions, tonic contractions, isometric contraction for muscle endurance evaluation, and post-baseline rest. The sEMG signal analysis comprises average sEMG amplitude, recruitment and recovery latencies, changes in spectral frequency, and sEMG amplitude variability.^[9]

As reported by some authors, the evaluation of pelvic floor muscle disorders, e.g., urinary incontinence, pelvic pain, or

sexual disorders with sEMG, may very clearly demonstrate the number and type of deficits in the functioning of those muscles, and thus, help with the selection of proper therapeutic method.^[7,11,12] Analysis of the test results is usually based on qualitative assessment of the sEMG signal parameters because there are no normative data to which the quantitative values of the signal from the individual phases of the Glazer Protocol can be compared.

There is a lack of studies reporting some referential values of pelvic floor muscle activity in healthy women. In the majority of available research, there is of changes within the sEMG signal due to some treatment intervention,^[13,14] comparing pelvic floor muscle activity in different measurement conditions^[15,16] or different study groups.^[17] Some authors also described the reliability of pelvic floor muscle sEMG, but only during maximal isometric contraction and/or resting state.^[18,19] Therefore, there is a need to determine normative values of sEMG signal for each of the phases and parameters assessed via the Glazer Protocol. This would allow for broader application of this assessment method while facilitating its clinical interpretation. The report on PFM assessment using the Glazer Protocol is commonly generated by software of surface electromyography devices, thus, it seems necessary to determine the normative range of amplitude, timing, and frequency of the sEMG signal measured intravaginally. In this study, the authors undertake this issue for the first time. The aim of the study was to evaluate pelvic floor muscle bioelectrical activity in healthy, young, and nulliparous women, and to present normative values for all phases and parameters measured using the Glazer Protocol.

2. Materials and methods

2.1. Participants

In this study, 96 healthy, young Caucasian, nulliparous women (age 22–27 years; 168.6 ± 5.1 cm; 57.1 ± 11.8 kg) were examined. All of the women were of Polish nationality. They were recreationally active but did not engage in regular physical training. They did not have any symptoms of urinary incontinence nor did they experience any spinal pain within 6 months prior to enrolment in the study. They were informed in detail about the research protocol and gave their written informed consent to participate in the study. Approval of the Ethical Committee at Józef Piłsudski University of Physical Education in Warsaw was obtained for this study (SKE 01–34/2017)

3. Procedures

3.1. sEMG measurement

Data on bioelectrical activity of the PFM was collected using the Life - Care Vaginal Probe endovaginal electrode (Everyway Medical Instruments Co., Ltd., Taiwan). The signal was registered with 16-bit accuracy at a sampling rate of 1500 Hz using the Noraxon G2 TeleMyo 2400 unit (Noraxon USA, Inc., Scottsdale, AZ). The sEMG signal was processed using MyoResearch XP software (Noraxon USA, Inc., Scottsdale, AZ)^[6,20]

sEMG data was filtered using the built-in hardware 1st order high-pass filter set to 10 Hz +/- 10% cut-off. The raw sEMG data were visually checked for artefacts. The sEMG signal was

rectified and then, the root mean squared (RMS) value was determined over a 200-ms window.^[6,20] Then mean and peak amplitude values, time before and after peak were calculated.^[20,21] The median and mean frequency were calculated using the FFT (Fast Fourier Transform) method. The unfiltered raw sEMG signal was analyzed using the stepwise regression model in 1000 ms increments over 60-second static contraction. The mean and median frequency were calculated for each 1-second step. The mean and median frequency values were estimated as the difference between the average first 3rd- and last 3rd-period values^[6].

PFM activity was recorded in supine position, the participant having a pillow underneath her head. The hips and knees were gently flexed, supported by a pillow under the knees, and the lumbar spine was in a neutral position. After electrode application, the subjects performed a short trial of phasic, tonic, and endurance contractions to become better familiarised with the testing procedures. After 10 minutes of rest in supine position, measurements were performed. During this time, the participants were verbally instructed to perform the PFM contraction without the use of abdominal, gluteal or hip adductor muscles. All testing procedures were conducted during a single laboratory session.

The Glazer Protocol consists of 5 activities^[10]:

1. One 60-second rest (pre-baseline) - the women were instructed to feel the pelvic floor in resting position.
2. Five 2-second phasic (flick) contractions with a 2-second rest in-between - the women were instructed to contract the PFM as quickly as possible, and then quickly and fully relax the PFM immediately after contraction.
3. Five 10-second tonic contractions with a 10-second rest in-between - the women were instructed to contract the PFM as strongly as possible, maintain the contraction for 10 seconds, and then fully relax the PFM after contraction, remaining relaxed for 10 seconds.
4. One 60-second endurance contraction - the women were instructed to contract the PFM at such a level as to hold it for 60 seconds.
5. One 60-second rest (post-baseline) - the women were instructed to feel the pelvic floor in resting position.

The following sEMG signal parameters were calculated for the Glazer Protocol^[10]:

1. One 60-second rest (pre-baseline)
 - Average Mean Amplitude (μ V)
 - Mean Amplitude Variability (%)
2. Five 2-second phasic (flick) contractions with a 2-second rest in-between
 - Average Peak Amplitude (μ V) - the result was the mean value from 5 contractions
 - Time Before Peak (s) - the result was the mean value from 5 contractions
 - Time After Peak (s) - the result was the mean value from 5 contractions
3. Five 10-second tonic contractions, with a 10-second rest in-between
 - Average Mean Amplitude (μ V) - the result was the mean value from 5 contractions
 - Average Peak Amplitude (μ V) - the result was the mean value from 5 contractions
 - Time Before Peak (s) - the result was the mean value from 5 contractions

- Time After Peak (s) - the result was the mean value from 5 contractions
4. One 60-second endurance contraction
 - Median Frequency (Hz)
 - Mean Frequency (Hz)
 - Average Mean Amplitude (μV)
 - Mean Amplitude Variability (%)
 5. One 60-second rest (post-baseline)
 - Average Mean Amplitude (μV)
 - Mean Amplitude Variability (%)

3.2. Statistical analysis

Statistical analysis was performed using the STATISTICA 12.0 software package. The following descriptive statistics for all phases of the Glazer Protocol were calculated: mean, minimal, and maximal value, 95% confidence interval, standard deviation, 95% standard deviation confidence interval, variance, coefficient of variation, and standard error of measurement. The first author of this study is certified in performing methods of statistical analysis.

4. Results

The total sample size was 96 women who performed PFM activity, which was measured using the Glazer Protocol. All parameters describing the mean value of the bioelectrical signal and its variability are presented in Table 1.

5. Discussion

This study was the first in which normative values for all phases of the Glazer Protocol were reported. This tool is the most popular when evaluating pelvic floor muscle bioelectrical activity. The presented values of the sEMG signal amplitude, frequency, and muscle activation as well as deactivation time, may serve

clinicians as a reference point allowing for quick and specific interpretation of PFM assessment. To date, PFM activity has been evaluated mainly qualitatively, focusing on signal line shape, the amount of signal amplitude from rest, and contraction phases, or the duration and quality of the sEMG signal during endurance contraction. The changes in PFM function due to treatment were compared between baseline and after treatment measurements,^[10,12,22] but there are only a few studies which have reported such changes quantitatively. Moreover, in some of the studies on sEMG, it has been suggested that the bioelectrical signal amplitude should not be compared between measurements without normalization due to high signal variability.^[23,24] This is probably the reason why there are no studies reporting typical values of the sEMG signal recorded from PFM. However, considering all the weaknesses and limitations of this approach, we have obtained normative values among a large group of young, healthy, and nulliparous women. Therefore, those sEMG values may be considered as typical for healthy pelvic floor muscles, being a reference for any PFM dysfunctions.

In current literature, the normative values of muscle bioelectrical activity have been described by some authors but mainly for the lower limbs and were evaluated with regard to clinical gait analysis.^[25,26] Although sEMG evaluation of PFM dysfunctions in women has been undertaken by some authors, little data exists on normative sEMG muscle activity. Typically, in healthy women, PFM activity is only measured for the purpose of comparison with pathological conditions.^[27]

Analysis using sEMG may help clinicians identify muscle imbalance and monitor patterns of muscle activity appearing in musculoskeletal disorders.^[28] sEMG signal amplitude evaluates the value (increased, decreased, absent) and timing patterns (early, late or asynchronous) of muscle activity.^[29] Frequency domain analysis of the sEMG signal is performed in order to study muscle fatigue. It has been reported that elevated amplitude during resting/baseline activity implies that a muscle has insufficient possibilities for rest.^[30] The dynamic phase of muscle

Table 1
Values of pelvic floor muscles bioelectrical activity at all phases of Glazer Protocol.

	Mean	-95% CI	95% CI	Min	Max	Variance	SD	-95%SDCI	95%SDCI	CV	SE
Rest pre-baseline											
Average Mean Amplitude (μV)	6.26	5.58	6.93	1.12	14.50	11.15	3.33	2.92	3.89	53.34	0.34
Mean Amplitude Variability (%)	10.63	9.89	11.36	3.56	22.40	13.28	3.64	3.19	4.24	34.28	0.37
Phasic (flick) contractions											
Average Peak Amplitude (μV)	49.76	44.40	55.12	9.79	101.00	699.29	26.44	23.15	30.82	53.13	2.69
Time Before Peak (s)	0.29	0.27	0.31	0.13	0.64	0.01	0.10	0.09	0.12	36.50	0.01
Time After Peak (s)	0.36	0.33	0.40	0.09	0.79	0.02	0.17	0.14	0.19	46.62	0.01
Tonic contractions											
Average Mean Amplitude (μV)	37.05	31.78	42.31	4.77	114.00	675.57	25.99	22.76	30.29	70.14	2.65
Average Peak Amplitude (μV)	43.94	37.98	49.90	5.29	125.00	864.99	29.41	25.75	34.28	66.92	3.00
Time Before Peak (s)	1.40	1.12	1.68	0.15	5.95	1.91	1.38	1.21	1.614	98.35	0.14
Time After Peak (s)	0.70	0.61	0.80	0.02	1.93	0.22	0.47	0.41	0.55	67.55	0.04
Endurance contraction											
Median Frequency (Hz)	61.50	58.68	64.32	37.50	100.00	193.32	13.90	12.17	16.20	22.60	1.41
Mean Frequency (Hz)	78.34	75.11	81.57	49.80	120.00	254.17	15.94	13.96	18.58	20.34	1.62
Average Mean Amplitude (μV)	16.10	14.75	17.46	5.15	33.00	44.64	6.68	5.85	7.78	41.48	0.68
Mean Amplitude Variability (%)	17.53	16.48	18.59	7.31	28.10	27.00	5.19	4.55	6.05	29.62	0.53
Rest post-baseline											
Average Mean Amplitude (μV)	6.93	6.12	7.74	1.30	17.30	15.95	3.99	3.49	4.65	57.59	0.40
Mean Amplitude Variability (%)	14.65	12.33	16.97	2.09	64.50	130.58	11.42	10.00	13.31	77.97	1.16

% = percent; μV = microvolt; CI = confidence interval; CV = coefficient of variation; Hz = hertz; s = second; SD = standard deviation; SDCI = standard deviation confidence interval; SE = standard error of measurement.

contraction describes their functional activity. The ability to prompt recruitment is described by onset time, whereas offset time represents the ability of prompt muscle deactivation after contraction.^[29]

There are many studies in which PFM activity has been monitored via intrapelvic sEMG electrodes.^[12,22,31,32] It has been reported that in women with urinary incontinence, a weakening of PFM strength as well as decreased endurance occur in comparison to women without pelvic floor dysfunctions.^[31–33] Thompson et al^[31,32,25] observed a group of women with incontinence at a lower amplitude of PFM bioelectric activity and with a simultaneously greater amplitude in the abdominal and thorax muscles.^[31] In the evaluation of PFM related functional disorders, e.g., urinary incontinence, pelvic pain, or sexual disorders, some authors have observed left-sided shifts in sEMG median frequency.^[4,10] Glazer et al^[34] reported significantly lower sEMG amplitude for subjects with urinary incontinence as compared to their continent counterparts. They also noted that Parous women obtain lower values of sEMG amplitude than those nulliparous, while postmenopausal women were weaker than their premenopausal counterparts. Bocardi et al^[35] evaluated the influence of age on sEMG activity of the PFM in healthy, nulliparous women aged 18 to 69, but they did not find significant differences between varying age groups. On the other hand, Auke et al^[36] observed significant correlations between lower bioelectrical activity of the PFM and age, even in continent women.

Some researchers have described changes in the PFM under the influence of therapy.^[4,12,22] Rett et al^[22] observed a significant increase in sEMG amplitude throughout the intervention. Furthermore, Dannecker et al^[12] noted a 50% increase in the amplitude of the sEMG signal measured during 10 seconds of maximal PFM contraction in incontinent women after 3 to 6 months of training. Due to the fact that interpretation of PFM assessment is complex and difficult, the authors believe that the normative values proposed in this study, which were created on the basis of a group comprising young, nulliparous women without pelvic floor dysfunctions, will significantly facilitate the interpretation of such evaluation, providing a reference point for parameters measured in women with different pelvic floor dysfunctions.

The Glazer Protocol allows for comprehensive PFM assessment during various types of contractions. There are many studies in which the assessment of the PFM activity was performed only in selected contraction types (most often during rest and maximal contraction).^[7,12,22] The authors reported sEMG signal values only from these contractions,^[7,12,22] whereas there are only a few articles in which values from all phases of the Glazer Protocol are presented.^[10,34] Even Glazer et al^[10] have only presented case studies and reported sEMG values only for individual patients. However, there is a lack of research reporting sEMG signal values among a larger group, implementing the full Glazer Protocol in PFM evaluation. Zang et al^[7] evaluated bioelectrical activity of PFM in women with stress urinary incontinence and in age-matched controls. The testing session consisted of 4 5-second contractions preceded by 10-second relaxation periods. In a different study, the test included only maximal muscle contractions held for 10 seconds.^[12] As suggested by Glazer et al,^[10,34] this protocol allows to gain much more bioelectric information from sEMG signal analysis, rather than traditional sEMG assessment which includes only PFM maximal contraction and relaxation. Furthermore, because the Glazer Protocol is often implemented in software of surface electromyography devices as a standard protocol for PFM

assessment, there is a need to develop standards and normative values for individual phases of this protocol. In order to allow for comprehensive interpretation of this test (both qualitative and quantitative), it is necessary to compare the test results to reference data.

In some studies, it has been underlined that among women representing different age groups, vast differences tended to occur between individuals.^[35] However, in many studies using sEMG in the diagnosis of PFM dysfunctions, the non-normalized amplitude of the bioelectric signal was analyzed. This may be a source of bias, leading to incorrect conclusions.^[23,24] It is commonly known that the value of sEMG signal amplitude is influenced by many factors such as surface electrode placement, skin preparation, size, shape and position of the anal or vaginal electrode, hydration of the subject, and diurnal variation in muscle bioelectrical activity.^[6,20] Therefore, according to the current standards regarding the conditions and methodology for measuring bioelectrical muscle activity, any comparisons related to the size of bioelectrical muscle activity expressed in amplitude (μV) without signal normalization can only be made within the same muscle – that is, between performed measurements without changing the electrodes.^[6,24]

There are some limitations of this study that need to be addressed. Because the study population consisted of only young, healthy, nulliparous women without any symptoms of urinary incontinence, future studies should also include women with PFM dysfunctions. Also, there is a need to present reference data for PFM activity in different age groups, including parous women.

6. Conclusions

In this study, the authors were the first to report normative values for all phases of the Glazer Protocol, which is very often used in electromyography devices as a PFM assessment tool. Due to the interpretation of the PFM evaluation being complex and difficult, the authors believe that the normative values proposed in this study allow for comprehensive interpretation of this test (both qualitatively and quantitatively) and provide a reference point for parameters measured in women with different pelvic floor dysfunctions.

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