Romanova, N. A. (2025). Electromyographic signal as feedback for pelvic floor muscle rehabilitation and training. *Actual Issues of Modern Science. The Proceedings of the European Institute for Innovation Development International Conference*, *36*, 145–153. Ostrava–Ragusa. (WoS)

DOI: 10.61726/7877.2025.76.41.001

The paper is published in Web of Science, Crossref, ICI Copernicus, BASE, Zenodo, OpenAIRE, OJS, LORY, Academic Resource Index ResearchBib, J-Gate, ISI International Scientific Indexing, ADL, JournalsPedia, Scilit, EBSCO, Mendeley, and WebArchive databases.

Natalia A. Romanova, Doctoral Student in Physiotherapy, IP Romanova Natalia. Moscow, Russia.
E-mail: Nr0718040@gmail.com
ORCID 0009-0003-6832-9558

ELECTROMYOGRAPHIC SIGNAL AS FEEDBACK FOR PELVIC FLOOR MUSCLE REHABILITATION AND TRAINING

Abstract: In the present world, most people are engaged in routine office work. This factor contributes to high inactivity in the musculoskeletal system and the body. Disorders of the muscular structure and pelvic ligaments may also be caused by dyssynergic defecation, surgical intervention, degenerative disease, pregnancy and childbirth in women, muscle relaxants, narcotics, and similar factors. Therefore, developing physiotherapy methods and a fitness training plan is a highly relevant task today. The novelty of this research lies in developing a new approach to rehabilitating and training pelvic floor muscles using the electromyographic signal as biofeedback. The study object is the rehabilitation and training of pelvic floor muscles. The study subject is the method of rehabilitation and training of pelvic floor muscles using the EMG signal. The study aims to develop a physiotherapy method and a fitness training plan. The author applied general scientific methods such as analysis, experimentation, observation, and classification to achieve the purpose and address the study objectives. The study draws upon the works of foreign and Russian researchers in rehabilitation and physiotherapy of the pelvic floor muscles, processing and classification of electromyographic signals, and the evaluation and analysis of muscular activity. Within the framework of this study, a method of pelvic floor muscle training using biofeedback was proposed. The article presents the method of pelvic floor muscle training with biofeedback, illustrating what an EMG signal looks like and describing exercises based on electromyography. A 10-day training plan is provided. The method of assessing the patient's condition before and after the training is also described. The author concludes that the proposed method contributes to a positive change in the shape of the EMG signal. The paper presents EMG signals recorded before and after training, clearly showing significant changes in the shape and stability of muscle activity levels.

Keywords: physiotherapy, rehabilitation, electromyography, pelvic floor muscles.

Abbreviations:

EMG is electromyography,

RMS is root mean square.

Introduction

Phylogenetically, the pelvic floor represents a relatively ancient group of skeletal muscles, which, as humans adopted an upright posture, acquired several new vital roles or underwent adaptation of previously existing functions. The functional tasks of the pelvic floor include: supporting the contents of the abdominal cavity in a vertical position; participating in both voluntary and reflexive contraction of the urethra; narrowing the transverse diameter of the vagina and the urogenital opening; contributing to sexual functions; and ensuring the function of the terminal section of the digestive tract (*Jozwik et al., 2013*).

Pelvic floor dysfunction and pelvic organ prolapse are currently significant issues—even early manifestations of pelvic floor dysfunction can lead to a decline in sexual quality of life, reduced activity, and eventually to social isolation and decreased self-esteem. One of the most popular conservative methods for treating pelvic floor dysfunction is pelvic floor muscle training. Pelvic floor muscle training is among the most widely used and promising conservative approaches to correcting pelvic floor dysfunction (*Samsonova et al., 2023*; *Rusina et al., 2024*; *Dobrokhotova et al., 2018*). Researchers also note that the skeletal muscles comprising the pelvic floor can be "trained" and "overtrained" to maintain pelvic floor function (*Woodley & Hay-Smith, 2021*).

Such training aims to improve the strength, endurance, and coordination of the pelvic floor muscles and to enhance support of the proximal urethra and the bladder neck (*Madokoro & Miaki, 2019*). Therefore, pelvic floor muscle training may be beneficial in the prevention of urogenital, reproductive, and sexual system disorders. Objective assessment of pelvic muscle activity is crucial for evaluating the condition and determining appropriate rehabilitation and treatment strategies (*Hay-Smith et al., 2024*).

Many researchers argue for integrating electromyography (EMG) recording alongside clinical examination and observation (*Dornowski et al., 2018*; *Dannecker et al., 2005*). The use of biofeedback based on surface EMG has proven helpful in facilitating the identification of pelvic floor muscle dysfunction symptoms (*Wang et al., 2024*; *Auchincloss et al., 2009*). Thus, the EMG signal can be used to classify the state of pelvic floor muscles and to provide feedback for designing targeted training programmes for their development.

It is worth noting that the EMG signal is complex; however, it directly correlates with muscle activity (*Chen et al., 2025*). This correlation makes surface EMG a valuable tool for diagnosing and training various muscle groups (*Richaud et al., 2024*).

This study will examine different methods of pelvic floor muscle training and investigate their effects on the development and stabilisation of pelvic floor muscle condition. The EMG signal will serve as the primary measure of muscle activity.

The study's novelty lies in its development of a new approach to pelvic floor muscle rehabilitation and training, using the EMG signal as feedback.

The study object is the rehabilitation and training of pelvic floor muscles.

The study subject is the pelvic floor muscle rehabilitation and training method using the EMG signal.

The study aims to develop physiotherapy methods and a fitness training programme.

To achieve this aim, the following objectives were set:

- study existing methods and approaches to physiotherapy and pelvic floor muscle rehabilitation;
- explore and identify key characteristics of the EMG signal;
- assess the electromyographic activity of the muscles before physiotherapy;

– conduct training using EMG and evaluate the electromyographic activity of the muscles after physiotherapy.

Methods and Materials

The following research methods were employed in the course of the study:

1. Analysis. The study includes an analysis of existing methods in the field of physiotherapy. An overview of EMG is provided, along with a breakdown of its features and properties. The primary methods used in pelvic floor physiotherapy are as follows:

- Biofeedback therapy is recommended for addressing urinary and faecal incontinence, vaginal wall prolapse, chronic pelvic pain, and sexual dysfunction.
- Electrical stimulation, aimed at restoring the pelvic floor following childbirth.
- Low-load exercises.
- Manual therapy.

2. Experiment. An experiment was conducted under specially created conditions to study electromyographic activity. The proposed method was tested on a 32-year-old female patient of average build with a usually developed musculoskeletal system. The experiment involved a series of training sessions using the proposed methods and EMG signals, comparing EMG signals recorded before and after the training programme.

3. Observation. Information about the condition of the subject's muscles was obtained through observation and the recording of significant changes. Prior to each training session, the trainer carried out a non-invasive visual inspection of the vestibular vaginal mucosa using a camera. The balance between the anterior and posterior pelvic floor muscles was assessed.

4. Classification. The study identified features of the electromyographic signal that allow for its classification. Signal classification was performed using time-frequency domain characteristics. Key features such as zero-crossing, RMS variation, and amplitude power were identified.

The study drew upon several key sources, including the monograph by J.V. Basmajian *Muscles Alive: Their Functions Revealed by Electromyography*, which is considered foundational in electromyographic research. The book examines various muscles, describes measurement methods, and explores the nature of EMG signal generation.

The work by C. Auchincloss, T. Richaud, and Y. Wang explores the reliability of surface EMG recorded from pelvic floor muscles. This study is widely cited and supports the use of surface EMG in physiotherapy.

Jozwik Maciej provides a review of the anatomy and function of the female pelvic floor, with a focus on the effects of vaginal childbirth. The work surveys scientific findings on pelvic floor muscles and their condition post-delivery.

Another widely referenced publication is the narrative review by S.J. Woodley and E.J.C. Hay-Smith, "Narrative Review of Pelvic Floor Muscle Training for Childbearing Women—Why, When, What, and How", which discusses various changes to the pelvic floor during pregnancy and outlines training methods to prepare for childbirth.

Results

EMG Signal

This paragraph briefly describes what EMG is and how it can be used for pelvic floor muscle training. Surface EMG signals are one of the primary sources of neural signals (*Basmajian & De Luca, 1962*). Various EMG signal processing algorithms decode the user's action and generate a control signal for external devices or software.

Figure 1 (*1*) presents examples of EMG signals in the case of a relaxed muscle and during muscle activity. The graph in Figure 1 (*1*) shows that the onset of muscle activity significantly increases the number of slope sign changes and the amplitude magnitude. At the same time, the number of zero crossings and the mean absolute value change only slightly (*Unanyan & Belov, 2019*). Therefore, one can derive a curve directly correlating with muscle activity using such characteristics as slope sign changes and amplitude. Figure 2 (*2*) illustrates the muscle state after EMG signal processing.

Assessment of EMG Values and Pelvic Floor Muscle Training

During the initial assessment, evaluating the overall condition of the pelvic floor muscles and the mucosal tissues is essential. This is conducted through an invasive examination using a camera, during which the condition of the mucosa at the vaginal introitus and the balance between the anterior and posterior muscle groups are assessed. This information enables the development of an appropriate training plan. Additionally, the assessment results help determine the patient's overall condition and rule out any potential adverse effects of physical exercise.

The next stage involves assessing the myo activity of the pelvic floor muscles. It is important to note that numerous factors can influence the EMG signal. For this procedure, it is assumed that the equipment filters the EMG signal and shields it from external magnetic fields and environmental interference. The patient must adhere to the following behavioural criteria:

1. The body must be relaxed.
2. The abdomen should be drawn in for proper function.
3. The legs and gluteal muscles should remain relaxed.
4. The upper thoracoabdominal diaphragm should maintain calm, steady breathing.

At this stage, the patient's myo activity is tested. The trainer instructs the patient to engage the anterior and posterior muscle groups and evaluates the EMG signal during this engagement. The patient is then asked to perform a light contraction of the muscles and maintain this activity level for seven minutes. During this time, the trainer observes the patient's general body state and corrects their behaviour, for example, addressing irregular breathing or tension in the legs and gluteal region—to ensure proper technique during the exercise. The EMG signal pattern during the static exercise is illustrated in Figure 3 (*3*). The aim is to teach the patient to activate the pelvic floor muscles without engaging other muscles or organs. A successful outcome is the patient acquiring the ability to use the pelvic floor muscles while keeping the rest of the body completely relaxed.

Once acceptable results have been achieved with the patient, a basic training routine is established. It consists of two exercises: one static and one dynamic. The static exercise involves tensing the muscles and maintaining the tension for a specific period, followed by relaxation. In this case, the patient is required to apply mild tension and hold it for 10 minutes. After that, the dynamic exercise is worth performing. The dynamic exercise involves tensing the muscles for 7 seconds and relaxation for 5 to 10 seconds. The dynamic exercise starts with ten repetitions of muscle tension; increasing the number of tension cycles by two in each subsequent session is recommended until the patient reaches 20 repetitions per exercise. Figure 4 (*4*) shows the EMG signal behaviour during the dynamic exercise.

Figure 4 shows that a threshold of 15 units has been selected, above which the patient must maintain the EMG signal during exertion. This threshold is individually tailored for each patient and can be adjusted during training. Next, a static exercise is repeated, during which the patient aims to engage primarily the posterior muscle groups; the contraction duration is five minutes. Ultimately, the training consists of the following sequence: static–dynamic–static exercise. It is recommended to perform 10 repetitions daily for 10 days.

Approbation

This training method was tested on a 32-year-old female patient of average build. After 10 days of training, the following changes were observed through video analysis:

1. Changes in the structure of the mucous membrane (small cracks and tears were eliminated).
2. The anterior and posterior muscles were toned.
3. Blood circulation improved.
4. The patient had varicose veins around the cervix, and after the training, a positive trend in the treatment of varicose veins was noted.
5. Changes in EMG.

One of the key results was the change in the EMG pattern. Over 10 days, the patient learned how to contract her muscles properly and, as a result, gained control over them. Figure 5 (*5*) clearly shows that the amplitude of the EMG noise significantly decreased. The patient can now "glide" at a certain level of load. In this case, the patient was required to maintain a signal at levels 9–10.

Comparing Figures 3 (*4*) and 5 (*5*), it can be concluded that the quality of the EMG signal has significantly improved. The amplitude of noise caused by the vibration of the muscle tissue has notably decreased. This suggests that the patient has significantly improved the physical condition of the pelvic floor muscles.

Discussion

During the work, it was found that the proposed method allows for positive dynamics in the development of the pelvic floor muscles. Biofeedback significantly accelerates the process of recovery, rehabilitation, or maintenance of pelvic floor muscles.

It is worth noting that the EMG signal, used as biofeedback, is highly susceptible to external influences, such as:

1. Electronic device noise.
2. Environmental noise, such as various parasitic electromagnetic fields.
3. Entering saturation mode.
4. Natural instability of the signal.

All these factors significantly complicate the training process and the use of the EMG signal. Additionally, the patient's psychosomatic state plays a crucial role. This issue was avoided in the experiment described in the work. However, the overwhelming majority of patients, influenced by their perceptions of the condition of the muscle or body as a whole, significantly reduce the effectiveness of the training.

It is worth noting that the training's results were less productive than the author had anticipated. Unfortunately, this was caused by an unoptimised training plan formulated for the patient.

In the future, it is planned to continue the research on the pelvic floor muscles and address the following questions:

How do dynamic and static training regimes affect the pelvic floor muscles and EMG signals in the long term?

How can EMG signals be displayed for the patient to increase the productivity of the training?

Can EMG signals be used to detect fatigue and dysfunction of individual fibres or the muscle as a whole?

Conclusion

Thus, the article discusses the method of pelvic floor muscle training using biological feedback. It demonstrates the appearance of the EMG signal and describes exercises involving electromyography. A 10-day training plan is provided. The method for assessing the patient's condition before and after the training is outlined. The graph shown in Figure 5 illustrates the positive impact of this training method on the pelvic floor muscles. After completing the 10-day training programme, the patient learned to work the front and back muscles separately. The condition of the mucosa at the vaginal vestibule significantly improved. The stability of the electromyographic signal during static exercises also greatly improved.

Conflict of Interest

The author declares that there is no conflict of interest.

Appendix

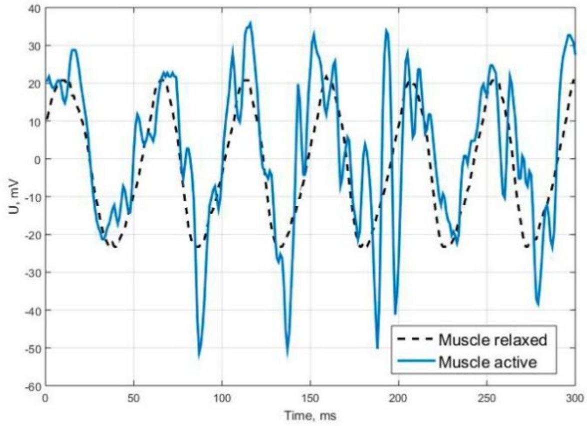

Figure 1. The form of EMG signal

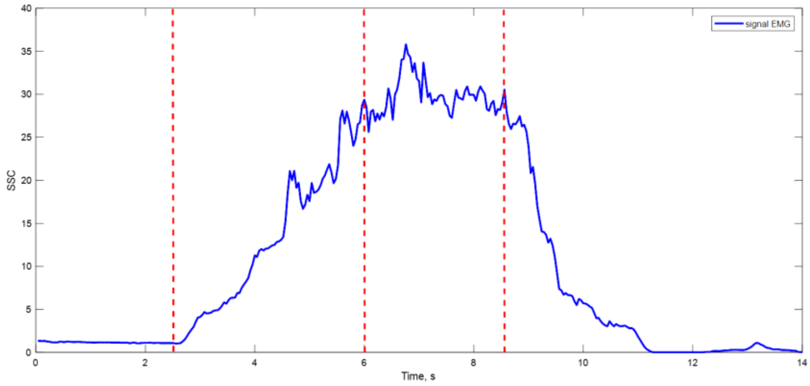

Figure 2. Changes in EMG characteristics during muscle activity: 0–2.5 sec.—muscle is relaxed, 2.5–6 sec.—gradual contraction, 6–8.5 sec.—sustained muscle activity, 8.5–14 sec.—relaxation.

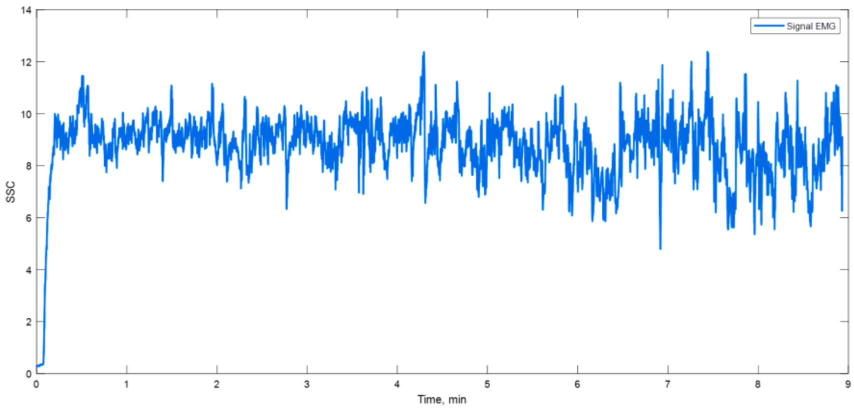

Figure 3. Static exercise

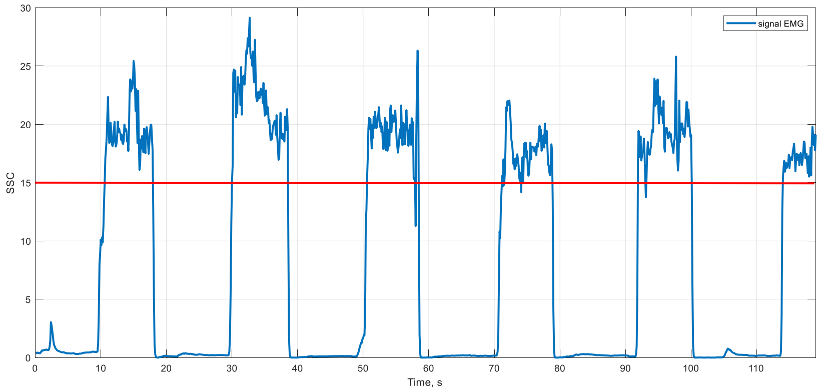

Figure 4. Static exercise

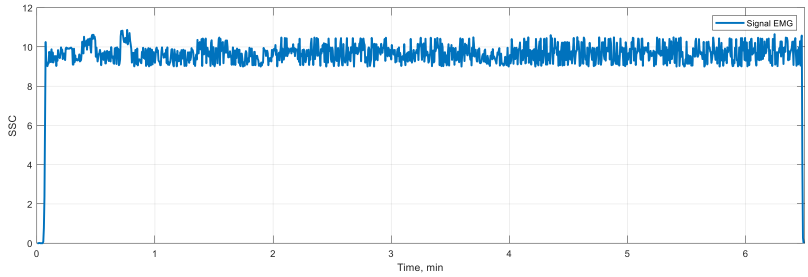

Figure 5. The view of EMG after 10-days training

References:

Auchincloss, C., & Mclean, L., (2009). The reliability of surface EMG recorded from the pelvic floor muscles. *Journal of Neuroscience Methods*, *183*, 85–96. https://doi.org/10.1016/j.jneumeth.2009.05.027

Basmajian, J. V., & De Luca, C. J. (1962). *Muscles alive: Their functions revealed by electromyography*. Baltimore: Williams & Wilkins.

Chen, C., Li, Dongxuan, & Xia, Miaojuan. (2025). A motor unit action potential-based method for surface electromyography decomposition. *Journal of NeuroEngineering and Rehabilitation*, *22*. https://doi.org/10.1186/s12984-025-01595-y

Dobrokhotova, Y. E., Nagieva, T., & Slobodyanyuk, B. A. (2018). A new approach to postpartum rehabilitation of patients with pelvic floor dysfunction. *Obstetrics and Gynecology*, 78–82. (In Russ.). https://doi.org/10.18565/aig.2018.7.78-82

Dornowski, M., Sawicki, P., Vereshchaka, I., Piernicka, M., Błudnicka, M., Worska, A., & Szumilewicz, A. (2018). Training-related changes of EMG activity of the pelvic floor muscles in women with urinary incontinence problems. *Neurophysiology*, *50*. https://doi.org/10.1007/s11062-018-9740-4

Dannecker, C., Wolf, V., Raab, R., Hepp, H., & Anthuber, C. (2005). EMG-biofeedback assisted pelvic floor muscle training is an effective therapy of stress urinary or mixed incontinence: a 7-year experience with 390 patients. *Arch Gynecol Obstet*, *273*(2), 93–97. https://doi.org/10.1007/s00404-005-0011-4

Hay-Smith, E., Starzec-Proserpio, M., Moller, B., Aldabe, D., Pazzoto Cacciari, L., & Pitangui, A., Vesentini, G., Woodley, S., Dumoulin, C., Frawley, H., Jorge, C., Morin, M., Wallace, S., & Weatherall, M. (2024). Comparisons of approaches to pelvic floor muscle training for urinary incontinence in women. *The Cochrane Database of Systematic Reviews*, *12*. CD009508. https://doi.org/10.1002/14651858.CD009508.pub2

Jozwik, M., Jóźwik, M., Adamkiewicz, M., Szymanowski, P., & Jóźwik, M. (2013). An updated overview on the anatomy and function of the female pelvic floor, with emphasis on the effect of vaginal delivery. *Medycyna Wieku Rozwojowego*, *17*, 18–30. (In Pol.)

Madokoro, S, & Miaki, H. (2019). Relationship between transversus abdominis muscle thickness and urinary incontinence in females at 2 months postpartum. *Journal of Physical Therapy Science*, *31*(1), 108–111. https://doi.org/10.1589/jpts.31.108

Richaud, T., Lacaze, K., Fassio, A., Nicolas, P., Ourliac, M., Hennart, B., Ina, J., Sonnery-Cottet, B., & Cavaignac, E. (2024). How biofeedback with surface EMG can contribute to the diagnosis and treatment of AMI in the knee. *Video Journal of Sports Medicine*, *4*. https://doi.org/10.1177/26350254241241084

Rusina, E., Zhevlakova, M., Shelayeva, E., & Yarmolinskaya, M. (2024). Differentiated approach to the choice of therapy for stress urinary incontinence in women with pelvic floor dysfunction. *Journal of Obstetrics and Women's Diseases*, *73*, 63–76. https://doi.org/10.17816/JOWD629472

Samsonova, I., Gaifulin, R., Toktar, L., Orazov, M., Kamarova, Z., Li, K., & Pak, V. (2023). Pelvic floor muscle training as a method of prevention and treatment of pelvic floor dysfunction and genital prolapse. *RUDN Journal of Medicine*, *27*, 39–45. https://doi.org/10.22363/2313-0245-2023-27-1-39-45

Unanyan, N. N., & Belov, A. A. (2019). Signal-Based Approach to EMG-Sensor Fault Detection in Upper Limb Prosthetics. *The 20th International Carpathian Control Conference (ICCC)*, 1–6.

Wang, Y., Wang, J., & Li, W. (2024). Basic vs electromyographic biofeedback–assisted pelvic floor muscle training for the improvement of sexual function after total hysterectomy: a prospective study. *Sexual Medicine*, *12*, qfae034. https://doi.org/10.1093/sexmed/qfae034

Woodley, S. J., & Hay-Smith, E. J. C. (2021). Narrative review of pelvic floor muscle training for childbearing women-why, when, what, and how. *International Urogynecology Journal*, *32*(7), 1977–1988. PMID: 33950309. https://doi.org/10.1007/s00192-021-04804-z