Electromyographic complex with goniometric tracking of the degree of muscle

Tatyana V. Zhemchuzhkina*[a], Tatyana V. Nosova[a], Denys O. Kostin[a], Olena Yu. Prisych[a], Irina K. Palii[b], Viktor P. Kovalskiy[c], Konrad Gromaszek[d], Saltanat Amirgaliyeva[e], Ainur Kozbakova[e]

[a]Kharkiv National University of Radio Electronics, 14 Nauki Ave., 61166 Kharkiv, Ukraine; [b]National Pirogov Memorial Medical University, Pyrohova St, 56, 21018 Vinnytsia, Ukraine; [c]Kyiv National University of Construction and Architecture, Povitroflots'kyi Ave, 31, 03680 Kyiv, Ukraina; [d]Lublin University of Technology, ul. Nadbystrzycka 38A, 20-618 Lublin, Poland; [e]Institute of Information and Computational Technologies CS MES RK, 28 Shevchenko str., 050010 Almaty, Kazakhstan

ABSTRACT

The focus of this research is on the upgrade of the electromyographic system of diagnosing back pain. Back pain is a common ailment that affects people of different classes and differs in its intensity. The evaluation of the condition of the back muscles is carried out according to the results of an electromyographic examination during physical exercise. Electromyographic results are strongly correlated with the degree of tension and flexion of the muscle. The quality of the physical exercise by the patient can be determined by the presence of pain or fear of pain. In this regard, it is proposed to supplement the electromyographic complex with blocks of control of the level of pain, degree of flexion of the back muscles, and sound stimulus to maintain maximal back flexion.

Keywords: electromyography, low back pain, back flexion, muscle tension, goniometric measurement, ultrasonic distance measurer

1. INTRODUCTION

Pain is the most common reason for seeking medical help. In particular, back pain of varying intensity in a given period of life is noted by 80-100% of individuals in the population. Regarding this syndrome, patients most often (compared with other pain syndromes) turn to neurologists. In 80–90% of patients with adequate therapy, acute back pain regresses within 2–3 months. However, in about 5% of patients, the pain syndrome lasts longer, the disease acquires a remitting nature, leading to disability [1].

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Pain in the lumbar spine can be caused by various diseases, for the diagnosis of which various methods can be used. Choice of the method depends on the anamnesis, the nature of the pain, as well as a number of other factors that describe the general functional state of the body. There are studies that indicate that patients who suffer from chronic lower back pain are characterized by higher fatigability of the extensor muscles, and in the presence of certain diseases (e.g. discogenic radiculopathy) local muscular atrophy can occur. For this reason, back extensor muscle endurance tests can play an important role in evaluating paraspinal muscle dysfunction [2,17].

*s. tatyana.nosova@nure.ua; phone +380930301076.

Photonics Applications in Astronomy, Communications, Industry, and High Energy Physics Experiments 2021
edited by Ryszard S. Romaniuk, Andrzej Smolarz, Waldemar Wojcik, Proc. of SPIE
Vol. 12040, 1204008 · © 2021 SPIE · 0277-786X · doi: 10.1117/12.2603991

2. EXPERIMENTAL

Pain is the most common reason for seeking medical help. In particular, back pain of varying intensity in a given period of life is noted by 80-100% of individuals in the population. Regarding this syndrome, patients most often (compared with other pain syndromes) turn to neurologists. In 80–90% of patients with adequate therapy, acute back pain regresses within 2–3 months. However, in about 5% of patients, the pain syndrome lasts longer, the disease acquires a remitting nature, leading to disability [1].

2.1 Electromyographic method

Most often to determine the causes of nonradicular pain, as well as pain in the presence of trauma and neoplastic processes in the anamnesis, it is recommended to use magnetic resonance imaging methods. However, in the presence of radicular pain, one of the key diagnostic methods is electromyography (EMG).

It is known that during a long isometric contraction, the EMG signal shape will change, which leads to a shift in the spectrum. Thus, the average and median frequencies will decrease during contraction as a sign of myoelectric manifestation of muscle fatigue [3,18].

Surface electromyography is widely used to study the neuromuscular mechanisms associated with muscle fatigue during endurance tests. Stable isometric muscle contraction causes changes in the spectral parameters of EMG, namely a decrease in the median frequency of the power spectral density. The reliability of this procedure for assessing muscle fatigue has been established in both healthy and patients with severe pain [2]. It is advisable to use the EMG method, since it allows assessing the state of muscle tissue in the study of the causes of pain in the lumbar spine.

The indisputable advantage of the spectral analysis of the EMG signal is that it allows evaluating the function of the back muscles objectively and non-invasively, as well as observing the dynamic characteristics of muscle tension. The advantages of the EMG method can also be attributed to the fact that the indicators of the frequency analysis are informative both at the minimum tension and at a more significant one, which reduces the influence of the patient's motivation factor. In addition, this makes it possible to examine patients with pain syndromes.

There are various that indicate the dependence of indicators of the level of fatigue on the position of the body in which the results of EMG were obtained. To assess the level of fatigue, some authors propose to use Sorensen test, as well as the Roman chair (Fig. 1) [2,19,20].

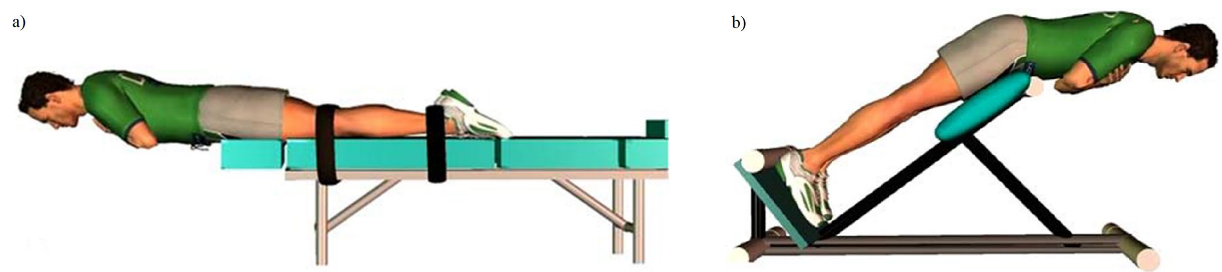

Figure 1. Test positioning of the study subjects during Sorensen (a) and 45° Roman chair (b) back endurance testing [2].

In this study, the authors investigated changes in EMG depending on the position of the body during exercise. The study identified that muscle fatigue during EMG using the Roman chair occurs later through the distribution of load between the paraspinal muscles and the hip flexor muscles [2,21,22].

Other researchers have proposed a recording of EMG in a sitting position using a device for training and extension of the back. In this position, the pelvis, lower back at the level of the L3-L4 vertebrae, hips and knees were firmly fixed. The seat is individually adjustable for each person. The resistance pad, which the patient pressed, was at the level of the scapula. The display in front of the object continuously displayed the torque in newtonmeter (Nm) as feedback (Fig. 2). In this case, electrical activity was recorded from the muscles of the extensor back at the level of the first (L1) and fifth (L5) lumbar vertebrae on the right and left [3,23,24].

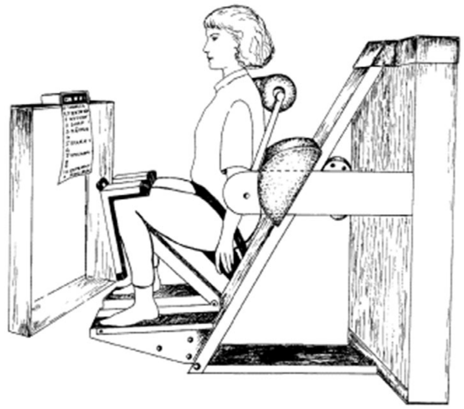

Figure 2. EMG recording in a sitting position using a monitoring device [3].

In the process of obtaining data, the patient performed an isometric extension of the torso against the resistance of the pad. The patient performed isometric contraction with a low level of torque in order to learn how to maintain a constant torque using a visual feedback system. Then, the value for the maximum contraction of the three tests with one minute break was determined. The average of the two highest values was used as the maximum contraction value. The main test consisted of recording EMG signals during an isometric fatiguing 45-second contraction at 80% maximum contraction followed by a recovery process that was measured by recording EMG signals for 5-second contractions at 80% maximum contraction performed 1, 2, 3 and 5 minutes after the end of the fatiguing contraction.

The main disadvantage of the methods that study muscle fatigue is the fact that there are no available tools that could determine if the measured maximum force matches the true maximum force. Incorrect determination of the maximum contraction leads to a decrease in the load level. Since local fatigue is load dependent, this leads to a lower frequency reduction. Some authors in a comparative analysis of control groups and patients with pain found lower activity of the back muscles in patients with pain during coordination and strength exercises.

Possible reasons for patients with pain not reaching the maximum load can be divided into physiological and psychological. According to the fear avoidance model, patients with back pain tend not to increase physical activity because they are afraid that this will aggravate their pain. Although simply waiting for pain cannot cause pain, it can affect measurement results, especially at the start of a series of studies. In this case, the sensation of pain also affects the measurement results. It is proved that self-efficacy is the best predictor of isokinetic indicators in patients with lower back pain, followed by estimates of pain and temporary disability, while anthropometric variables have a fairly low prognostic value. It was found that both of these variables affect productivity and should be taken into account when interpreting research results [4,5,25].

2.2 Electromyographic complex

In the pathophysiology laboratory of the Sytenko Institute of Spine and Joint Pathology, National Academy of Medical Sciences of Ukraine, doctors diagnose vertebrological diseases such as kyphosis, scoliosis, and functional pains of the musculoskeletal system. To diagnose the condition of patients, they used EMG signals, obtained by examining the long extensor of the trunk at the level of the lumbar spine (L4-L5 vertebrae) with the so-called "boat" method, when the patient bends back in the lumbar region in lying position, thereby straining the muscles under study (Fig. 3) [6,26].

Figure 3. Test "Boat" method.

As an apparatus for recording signals, the electroneuromyograph ‘Neyro-MWP-8’ was used. It is an 8-channel electroneuromyograph with functions of studying visual, auditory, somatosensory and cognitive (P300, MMN, CNV) evoked brain potentials.

However, currently there are difficulties in studying the signals obtained this way. The patient can change the height of the back deflection during the recording of the EMG signal, due to which the tension of the studied muscles changes. Patients are examined before and after surgery, and the presence of pain or fear of pain during the procedure may interfere with an objective assessment of the quality of treatment.

In [7,8,9], an electromyographic complex with control of the patient's pain level during the exercise was proposed [10,27,28].

In this complex, information from the patient is delivered to the 8-channel neuroelectromyograph ‘Neyro-MWP-8’ (electromyograph, elecrtroencephalograph). To detect fluctuations in the height of the deflection of the patient's back in the lumbar spine, an optocoupler is used. The information from the electromyography and elecrtroencephalograph is exported to the database of the web server. The PCs are connected to a local area network (LAN). The information can also be exported to the database from other devices or entered manually with the client application, to analyse the dependencies of various indicators on the diagnostic result.

In this paper, it is proposed to simplify the back deflection control module, proposed as an optocoupler in [9], and add a software module for objectifying EMG studies. The block diagram of an advanced electromyographic system is shown in Fig. 4.

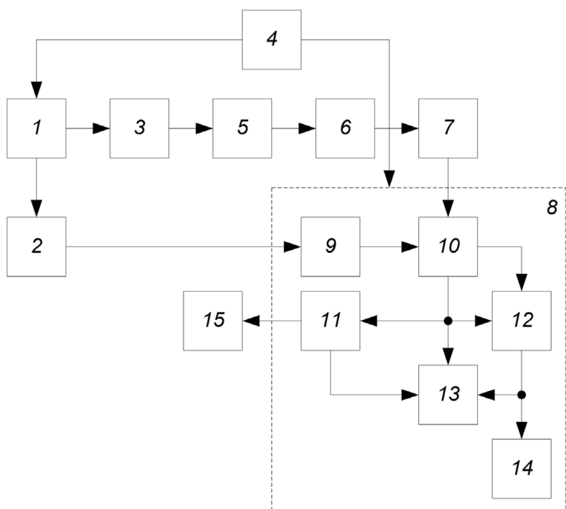

Figure 4. Block diagram of the electromyographic system. 1 – patient; 2 – back deflection control unit; 3 – electrodes (EEG, EMG); 4 – doctor; 5 – switch; 6 – biopotential amplifier; 7 – analog to digital converter; 8 – personal computer; 9 – back deflection control module; 10 – patient data recording module; 11 – EMG objectification module; 12 – module for data processing and analysis; 13 – visualization unit, 14 – data storage module, 15 – audio output device.

The developed block diagram consists of biological and technical subsystems. The composition of the biological subsystem includes a doctor and a patient who interact with each other directly, as well as using medical equipment during the study [29,30].

The technical subsystem consists of hardware and software. The hardware includes medical equipment and a personal computer. The input signal, which carries information about the electrical activity of the muscles (EMG) and brain (EEG), comes from the patient by applying surface electrodes, after which the signal is amplified by the biopotential amplifier and transmitted to a personal computer (PC), after passing through the analog to digital converter (ADC) [31-34].

In this system, there is a parallel registration of two EMG signals – on the right and left sides of the patient’s lower back, as well as EEG signals for parallel control of the pain level by EEG indicators[11-13]. To obtain multi-channel data from a patient, a switch is used. After amplification of the signals, they are input to the ADC. It is proposed to use a computer sound card as an ADC. In the system, it is advisable to use built-in sound cards with the ability to connect an EMG device using the microphone input of a PC sound card. The signal received from the patient is transmitted to the program modules on the PC using the MatLab environment [14 - 16].

The back deflection control unit records the angle of the back deflection by the patient in real time.

To register fluctuations in the height of the deflection of the patient's back in the "boat" position, it is proposed to use a non-contact device to conduct goniometric tracking of the moment of the onset of the pain threshold during exercise. Registration of back deflection is necessary to maintain the same load while receiving an EMG signal from the muscles of the lumbar back in the "boat" position, since with a decrease in the height of deflection, the patient's muscles relax, and this can affect the characteristics of the studied signal.

During the study, when the subject performs the "boat" exercise (Fig. 1), electromyographic surface electrodes in the region of L4-L5 vertebrae and electroencephalograph electrodes are connected to him, and the goniometric measuring device is fixed motionless on a separate console bracket (Fig. 5).

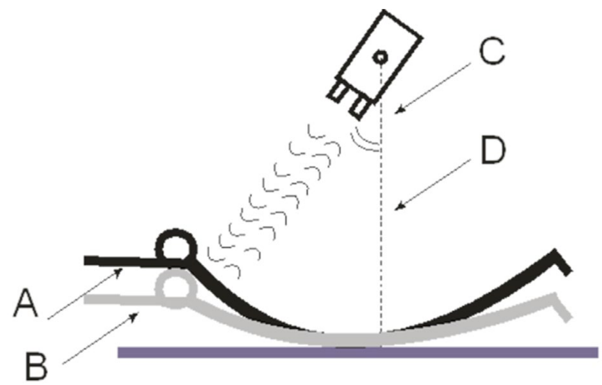

Figure 5. Illustration of measurement. The initial position of the patient (A); deviation from the starting position due to fatigue (B); the angle by which the measuring device is turned relative to the perpendicular to the basis (C); axis with a given height (the height of the position of center point of the device) (D).

The basis of the measuring prototype for recording fluctuations in the height of the deflection of the patient's back in the "boat" position is an electronic distance measurer with an ultrasonic sensor HC-SR04 (a working prototype of the measuring device is shown in Fig. 6).

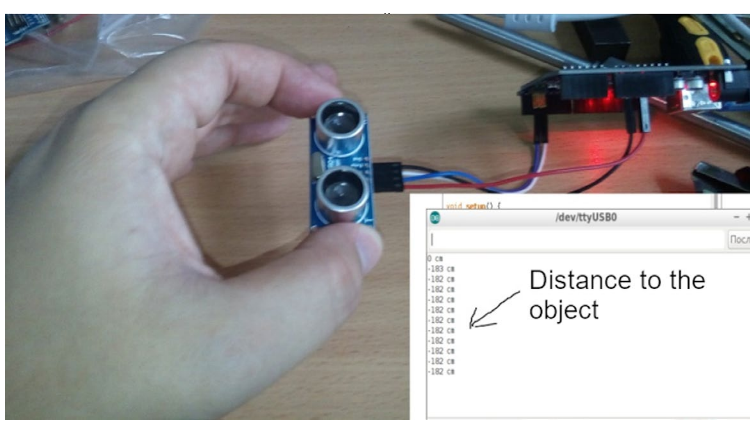

Figure 6. Device prototype testing.

Technical characteristics of the ultrasonic sensor HC-SR04 (Fig. 6):

- Dimensions 43mm×20mm×15mm;
- Supply voltage: 5 V;
- Consumption in silence mode: 2 mA;
- Operating consumption: 15 mA;
- Range of distances: 2–400 cm;
- Effective viewing angle: 15°;
- Operating viewing angle: 30°.

The ultrasonic distance measurer is designed to determine the distance to objects within a radius of four meters. The module is based on the principle of echolocation. The module sends an ultrasonic signal and receives its reflection from the object. By measuring the time between sending and receiving an impulse, the distance to the object can be calculated

3. RESULTS AND DISCUSSION

Center The software part of technical subsystem consists of a module for recording data obtained during the study, an objectification module for EMG studies of patients with back pain, a module for monitoring back deflection in EMG studies, and a data processing and analysis module [9].

The data recording module allows collecting EMG and EEG signals in real time and adding the patient data necessary for further research.

The objectification module allows assessing the condition of the muscles of the patient's back when exposed to the load, using data obtained from the EMG signal from the patient.

The back deflection control module is connected to the back deflection control unit and allows tracking the angle of deflection of the lower back by the patient in the "boat" position simultaneously with the control of muscle tension.

The essence of the objectification module for EMG research is that when receiving a signal at a load (in the "boat" position), an additional monitoring device that holds the patient in a certain load is not used, but an audio signal is used. This signal is used as a marker, upon hearing which, the patient will know that it is not necessary to relax, but rather maintain maximum tension. At the same time, the program calculates the maximum muscle tension, and also detects a decrease in tension. In this case, the decay ranges are allocated within 80% and 60% of the maximum tension. Simultaneously with the level of muscle tension, the angle of deflection of the back is controlled.

A portable speaker is used as an audio output device.

In parallel analysis of EMG and EEG signals, the real level of pain is determined by EEG indicators, muscle tension strength as a percentage of the maximum effort, and a non-contact meter determines the position of the body at this moment when performing static loads. Such an implementation of the method makes it possible in real time to control the quality of the exercise and the patient's objective indicators, which will allow a more detailed analysis of changes in the patient's condition before and after surgery, excluding subjective assessments of the level of pain, fatigue and quality of the exercise.

After completion of the study, it is proposed to visualize and save the results, on the basis of which the doctor should assess the state of the muscles for the study period, and conduct a comparative analysis during the repeated study (for example, to evaluate the effectiveness of treatment).

CONCLUSION

An electromyographic complex is proposed for EMG recording in a "boat" position with control of the degree of back muscle flexion with ultrasonic distance measurer with parallel registration of the EEG signal to control the level of pain during exercise and sound signal for control of maintaining tension of the back muscles as a percentage of the maximum tension. The system will allow objectivizing evaluation of the results of electromyography with parallel control of the level of pain and level of flexion of the back muscles to assess the degree of dysfunction of the back muscles and the quality of the performed therapeutic and surgical activities.

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