Evaluation of the electrode system pressure force influence on neuro muscular activity signals

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Introduction

Full or partial functional loss of upper limb due to amputation or some diseases has a great influence on human ability to do routine tasks.

Active prosthesis and orthosis helps a disabled person to get back after losing the function of a limb. Nowadays there are plenty of different prosthesis for upper and lower limbs. Therefore, an amputee can make a choice according to the desired model's functions and price. Unfortunately, it is more difficult to choose an active orthosis due to limited number of models.

Modern prosthesis and orthosis should correspond to different requirements, such as limb's function substitution and its aesthetic appearance. In particular, active devices with a function of bioelectrical control mostly meet these requirements. It has an external power source and it can be manipulated via biological signals registered by electrode systems.

However, the main disadvantage of using bioelectrical active devices at present is the complexity of their control. Due to the fact that the number of electrode systems is often limited, problems of recognizing precise movements are arising, which leads to the impossibility of using small objects.

Most modern bioelectrical active devices are controlled by signals of surface electromyogram. Such signals of neuromuscular activity, as signals of bioelectrical impedance and myotonic signals, are used in practice much less often. Despite the lower popularity these signals are quite informative, and in some cases may exceed the electromyogram informativity for management tasks.

The aim of the study is to analyze the neuromuscular signals such as electromyogram, bioelectrical impedance and myotonic signals during performing isometric hand grasping with different electrode system pressing force.

Methods

Electromyography

Electromyography (surface) is a non-invasive method for evaluating the activity of skeletal muscle tissue by recording the bioelectric potential. [1]

The advantage of the method is its non-invasiveness and ease of implementation. The disadvantage is the small amplitude and complexity of the interpretation of the signal due to its interference nature, caused by the influence of signals from neighboring muscles.

Myotonic method

The method allows recording the mechanical stresses resulting from muscle contraction. Tension is transferred to the skin, resulting in an effect on the attached sensor. To record these oscillations, special transducers are used: force sensors, accelerometers [2] [3]. The disadvantage of the method is that the signal depends on the sensor pressure of the on the surface of the skin, which can be the cause of the occurrence of artifacts during the action.

Bioimpedance

The bioimpedance signals represent the current level and changes of the impedance of the biological object. The value of tissue impedance $|Z|$ consists of two components: $|Z|=|Zo|+|Z(t)|$, constant - $|Zo|$ and changing over time function - $|z(t)|$. To measure the instantaneous impedance value high frequency alternating current passing through the biological object and the voltage drop is recording on the area. [4,5] The range of alternating current frequencies used in bioimpedance studies is from 1 kHz to 500 kHz, in industrial devices optimum is 30-100 kHz. [4] In experiments was used alternating current with amplitude 1 mA and frequency 100 kHz (at the given frequency the active component of the tissue impedance predominates).

With a muscle contraction, a change in the impedance occurs. The change in such parameters as the thickness of the skin-fat layer, the cross section of muscles, the conductivities and the pressing force of the electrode system lead to a bioimpedance value change during various actions performance. [6]

Research

Experiment

For comparison of different types of biosignals, 4 measurements were made on volunteers with a medium build and an average coverage of the forearm at the place where the electrode system was 34 cm. The signals were recorded using a single electrode system that was located on the surface flexor muscles of the fingers, in place, used to position the electrode systems in modern forearm bioelectric prostheses. Before the installation of the electrode system, the place was scrubbed (by Nuprep Skin Prep Gel) and lubricated with an electrode contact gel (by Geltek Uniagel). An example of the electrode system location is shown in Figure 1.

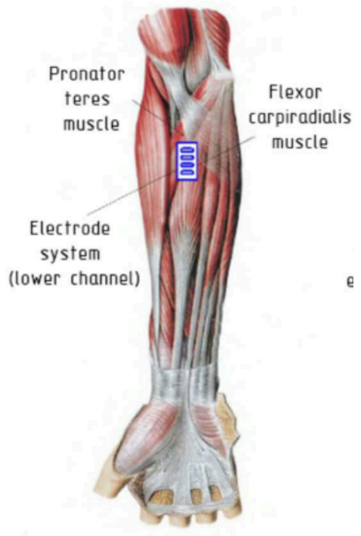

Figure 1: Electrode system placement

The electrode system consisted of reusable electrodes arranged according to the tetrapolar lead-out system (two current electrodes along the edges and two measuring electrodes in the middle) with an inter-electrode distance equal to 10 mm. Such lead system makes it possible to reduce the polarization effect in bioimpedance measurements. The electromyogram was recorded from the same electrode system, from the measuring electrodes. The sampling frequency of the signals was 1 kHz.

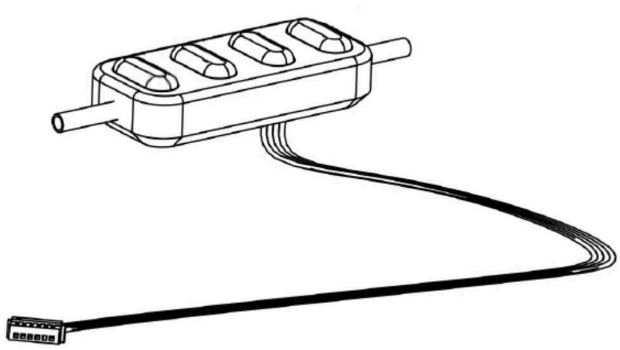

Figure 2: View of electrode system

Myotonic signal was recorded by means of two Honeywell FSG15N1A force sensors (resolution to 1.0g force, maximum overforce 5.5kg, linearity 0.5%, repeatability 0.2%, response time 1ms), which allow recording signals with high accuracy. The force sensors were placed under the electrode system closer to the edges in a special platform in such a way that the electrode system presses on them (Figure 3: 1 - electrode system, 2 - force sensor, 3 - platform, transparent view).

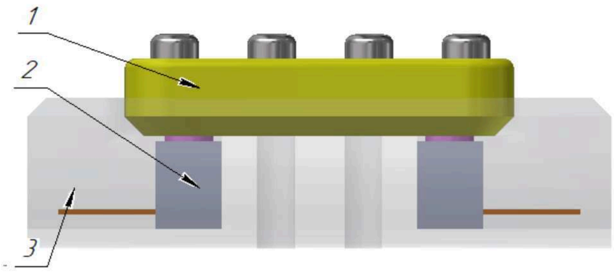

Figure 3: Myotonic signal recording system

During each study, bioimpedance signal, electromyogram and myotonic signal were simultaneously recorded. Network interference was filtered by digital band-stop filter (rejection frequency 50 Hz, 3 dB level on 50±5 Hz, sampling frequency 1 kHz) in recording device. During the experiment, the pressing of the electrode system was successively changed by the control mechanism expanding, a non-stretchable Velcro tape as a belt was used (Figure 4). The mechanism moved apart at a distance of 0cm, 1cm, 2cm.

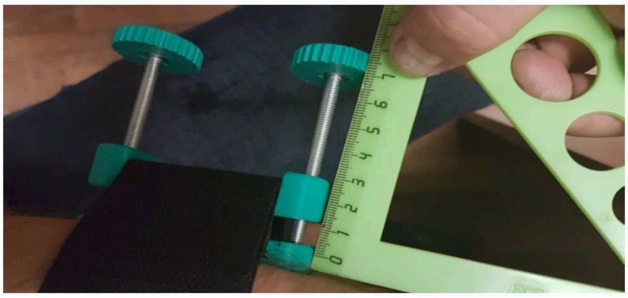

Figure 4: Electrode system pressing control mechanism

To register the force of isometric compression, the special stand was designed (Figure 5: 1,2 - handles, 3 – guideways, 4 - force sensor), which included two parallel force sensors based on the tensoresistors arranged according to the Winston bridge scheme (resolution to 50g force, maximum overforce 20kg, repeatability 0.2%, response time 1ms). The time of each study from the series was 1 minute, during which the following actions were performed: 0-5s - the volunteer does not compress the stand (state without load), 5-10s - the volunteer compresses the stand (load state). The compression force increased iteratively in the framework of one study. During the experiment, the brush was located in a neutral position (between pronation and supination).

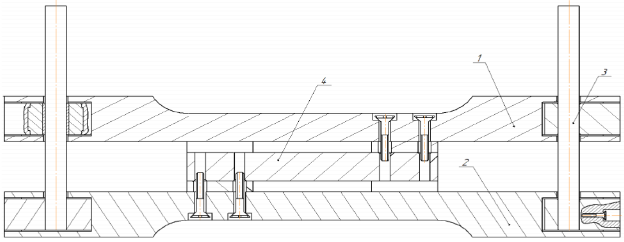

Figure 5: Isometric hand grasp force measuring stand

The force sensors were calibrated by installing laboratory weights of 10 g to 2.5 kg to the center of the electrode system assembled with the platform and to the center of the stand handle. Thanks to the use of two sensors in each case, it became possible to detect skews, however, when conducting studies, skews were not observed and the skew data were not presented in the work. Thus, the average values of the ADC from two sensors were recorded in the experiment and recalculated into force values (daN).

A sample of the recorded signals during one set of measurements depending on the different degrees of compression (which was realized by sliding mechanism) over a particular period of time is shown on Figure 6. An unprocessed electromyogram signal is difficult to analyze. Therefore, it was processed by moving average method with a window length equaled to 100 ms and filtered by a digital Equiripple FIR low pass filter with a cutoff frequency 5 Hz.[8]

Based on the data obtained, a regression analysis was performed, based on which regression curves were plotted with a confidence interval of 95% (Figure 7). As a result of the regression analysis and a least-squares analysis it was obtained, that a straight line is the most accurate for an experimental data interpretation.

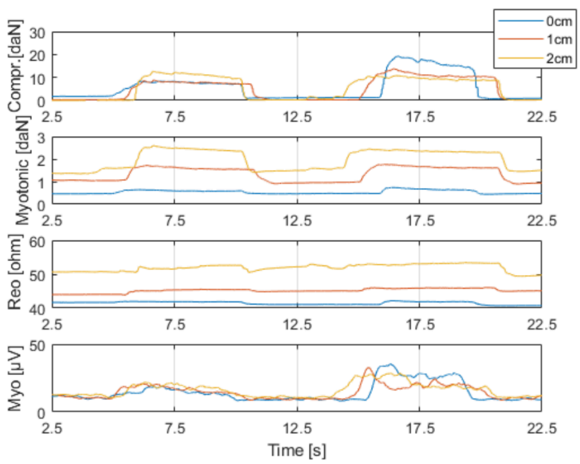

Figure 6: A sample of the recorded signals during one set of measurements

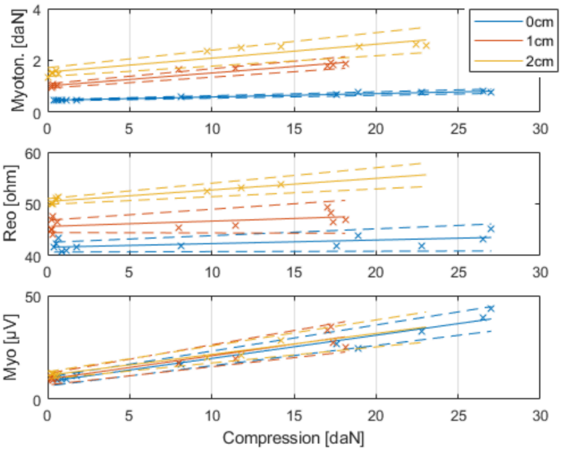

Figure 7: Regression curves with confidence intervals of 95%, based on experimental data

Dependences of regression lines parameters on the electrode system pressure for myotonic signal are shown on Figure 8, Figure 9. Similar dependences for electromyogram and bioimpedance signals are not shown due to its less informative.

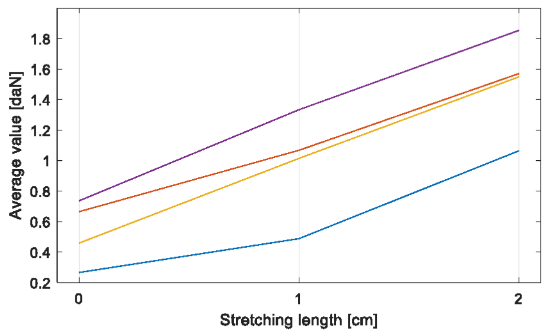

Figure 8: Dependence of the myotonic signal mean value in the condition without load on the electrode system pressure on skin

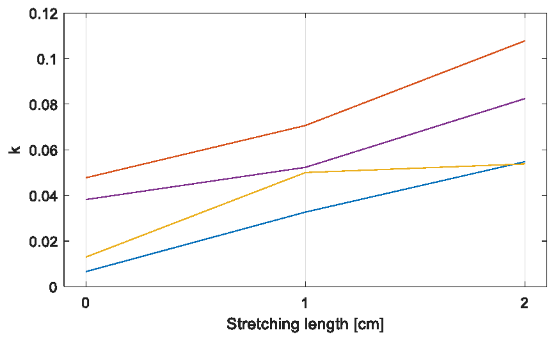

Figure 9: Dependence of the angular coefficient of the regression straight myotonic signal as a function of the electrode system pressing on skin

Discussion

To conduct the investigation, the special stand for measuring isometric hand grasping force with a mechanism for controlling the electrode system pressing force was designed.

Because of using two tension sensors, the grasping force was measured more accurately with an error less than 100g. Moreover, it is possible now to register system imbalances. Guideways usage makes it possible to customize the stand for functioning with different grasping degree.

In spite of widely spread electromyogram usage as a control signal in bioelectrical devices, it was observed, that myotonic method was not less informative type of signal and it could be used as an alternative. The disadvantages of the method are electrode system thickness increase due to force sensor addition and calibration necessity in case of particular force value measurements. Because of myotonic method it is also possible to regulate the electrode system pressure on skin.

Conclusions

As a result of the conducted investigation it can be concluded, that myotonic method is the most accurate among described neuromuscular registering methods. Due to the electrode system pressure on skin increase, signal huge increment was observed with the same grasping force change. However, myotonic signal scatter and amplitude mean value also were increased in the condition without load.

Also, it was determined that increase of electrode system pressure on skin didn't have huge influence on the electromyography and bioelectrical impedance signals. In case of electrode system overpressure, imbalances in the system may appear. It causes additional problems in high quality signal registration.

Therefore, the conducted investigation has shown, that electrode system location is not the only factor which must be taken into account while designing bioelectrical control of different devices. Moreover, the problem of necessary contact providing between an electrode system and skin must also be considered because it should not exceed acceptable pressure value.

References

[1] Seward B. Electrical Impedance Myography: Background, Current State, and Future Directions/ Seward B. Rutkove//NIH Public Access, –2010.-C. 1-20.

[2] Barry, D.T., Cole, N.M., 1990. Muscle sounds are emitted at the resonant frequencies of skeletal muscle. IEEE Trans. Biomed. Eng. 37, 525–531

[3] Morufu Olusola Ibitoye. Mechanomyography and muscle function assessment: A review of current state and prospects/ Morufu Olusola Ibitoye, Nur Azah Hamzaid, Jorge M. Zuniga, Ahmad Khairi Abdul Wahab// Clinical Biomechanics. –2014. –№ 29. –C. 691– 704.

[4] V.I. Polishuk, L.G. Terehova, Technique and methodology rheography and reopletizmography, (Medicine, Moscow, 1983).

[5] R.M. Rangayan, Analysis of biomedical signals, (FIZMATLIT, Moscow, 2007).

[6] T. Zagar and D. Krizaj "Electrical impedance of relaxed and contracted skeletal muscle", Hermann Scharfetter, Robert Merva (Eds.): ICEBI 2007, IFMBE Proceedings 17 (2007).

[7] A.N. Briko, A.V. Kobelev, S.I. Shchukin " Determining committed action type by dual-channel phase rheogram portrait for bioelectric forearm prosthetics", Proceedings of the 12th Russian-German-Conference on Biomedical Engineering (2016).

[8] M.V. Markova, A.N. Briko, A.V. Kobelev, S.I. Shchukin "Evaluation of informative parameters of the EMG signal for controlling of prosthetic arm in real time", Proceedings of the 11th German-Russian-Conference on Biomedical Engineering (2015).

[9] Y.L. Slavucky, Physiological aspects of bioelectric control of prostheses (Medicine, Moscow, 1982).