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Complex Analysis of Human Movements based on the Identification of Amplitude-Time Characteristics of Electromyographic Patterns

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Keywords: digital signal processing, amplitude-time analysis, human movements, multi-channel electromyography, podography, electromyographic motion pattern.

I. INTRODUCTION

Human movements are the result of the coordinated work of functional mechanisms and processes. Such coordinated work develops during and as a result of constructing an action with the leading role of the higher parts of the central nervous system and ensures the consolidation of all body systems involved in its implementation [1-2].This complicated organization of the human motion system determines the demand of integrated analysis of movements based on the interpretation of both biomechanical and electrophysiological motion parameters. Biomechanical parameters describe the external spatio-temporal components, and electrophysiological parameters describe internal control mechanisms [3-4].

Existing methods and technical solutions for the study of human movements based on electrophysiological signals are used primarily in clinical practice to diagnose the functional state and diseases of the human musculoskeletal system [5-6]. Moreover, the list of movements in clinical practice is limited to simple and working movements (walking, grabbing, cyclic motion acts) [7-10]. In the field of sports, the use of biomechanical methods for analyzing human movements predominates. Such methods allow to estimate the technique of implementation sports exercises, but do not provide information about the physiological mechanisms of the motion act [11-13].Electrophysiological methods in sports are still not enough used, because they are mainly intended for laboratory use of rather complex and expensive neurophysiological systems, require highly qualified personnel and special methods for analyzing the obtained data [14-17].Diagnostic systems for the study of sports movements must have certain design and technical features: multichannel, compact, autonomous power, wireless data transfer[18-20]. In addition, the sport movements are characterized by a complicated structural and functional organization [21], which requires the development of new algorithms for the complex processing of biomechanical and electrophysiological data.

Each human movement corresponds to a certain spatio-temporal pattern, which characterize the direction, power and sequence of inclusion of muscles involved in performing the movement. Automated movements (walking, running, cycling, special and sports movements) are motion skills. They have a

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constant pattern of muscle involvement not only when the movement is repeated by one person, but also in different people. Selection from the aggregate of the muscles electrical activity data such combinations, which characterize a specific movement, make it possible to create the electromyographic pattern of human movement [22-24].

In this work, we propose the complex analysis of human movements based on the identification of amplitude-time characteristics of electromyographic patterns, and describe studies that confirm the effectiveness of the proposed approach.

II. RESEARCH METHODS AND DATA PROCESSING

a) *Subjects*

The study was carried out among participations of the basketball team at the Sports Complex of the Belarusian State University of Informatics and Radio Electronics (Minsk, Belarus). The study involved 42 people (7 women, 35 men) aged 17 to 25 years, of which 8 people are the professional sportsmen. The essence of the research were previously explained for all subjects. The subjects were in full health and did not report any feelings of pain when performing the tests.

The movement "jump up" was selected as a test for the study of person motion skills. This movement is a speed-strength exercise, andit' sused as a test movement for estimation of motion abilities in high-speed power sports, or as a training exercise to develop a muscle strength of legs, jumping ability and the ability to concentrate muscle efforts combining strength with speed [25-26].

The main muscles of the legs (*m. rectus femoris, m. biceps femoris, m. gastrocnemius lateralis, m. soleus*) were studied [27] (table 1) due to the specificity of the test movement.

Table1: The studied muscles and their functions

Musclename	Locationandfunction
m.rectusfemoris	It is located on the front of the thigh. Unbends the leg in the knee joint, flexes the hip in the hip joint.
m. bicepsfemoris	It is located on the back of the thigh. Flexes the leg in the knee joint, unbends the leg in the hip joint.
m. gastrocnemiuslateralis	It is located on the back of the shin. Flexes the foot, helps in the flexing of the leg in the knee joint.
m. soleus	It is located deep in the shin. Flexes the foot.

b) *Methods*

The method of multichannel interference electromyography was chosen for creation of the motion innervation structure. The method of podography was chosen for creation of the motion spatio-temporal structure.

The methods, which are used to create the motion innervation structure, should be associated with the registration of muscles control signals in the process of motion activity. The most convenient, simple and painless of these methods is multichannel interference electromyography, which allows studying the bioelectric activity of several muscles at the same time. The summary electromyogram (EMG) is formed as a result of interference of many motion unit signals located in the area of recording. The method of multichannel interference electromyography allows to estimate the participation of muscles in various movements, the sequence of their on and off, the integrated level of muscle activation, the correlation of muscle activity in different periods of motion skills formation [28-30].

Thus, the motion innervation structure can be represented by multichannel electromyographic signals of the studied muscles.

The spatio-temporal structure of movement allows to divide the motion activity into separate phases and then to research it in parts. In the presented paper, the method of podography was chosen for creation of the motion spatio-temporal structure. The method of podography (PDG) allows to record the time moments of contact of various parts of the foot with the ground, and to identifymotion phases [31-32].

Thus, the motion spatio-temporal structure can be represented by multichannel podographic signals of the studied movement.

The complex application of these methods (multichannel interference electromyography and podography) allows to create an electromyographic pattern of motion, which is an electrophysiological analogue of motion and is a combination of time, spatial and amplitude electromyographic characteristics of motion.

c) *Data collection*

Registration of electrophysiological and biomechanical signals were realized by the proprietary system "Mio Sport" [33]. The developed device includes a multi-channel electromyography system with synchronous registration multi-channel podographic signals, and a software for visualization and analysis of the results (Figure 1). The system allows real-time recording of 4EMG channels (minimum detection limit of 30 μ V, frequency range of 0.1–800 Hz), 4 PDG channels (time resolution of 3,125 ms), and data transmission via a wireless interface to a distance of up to 100 m [34–35].

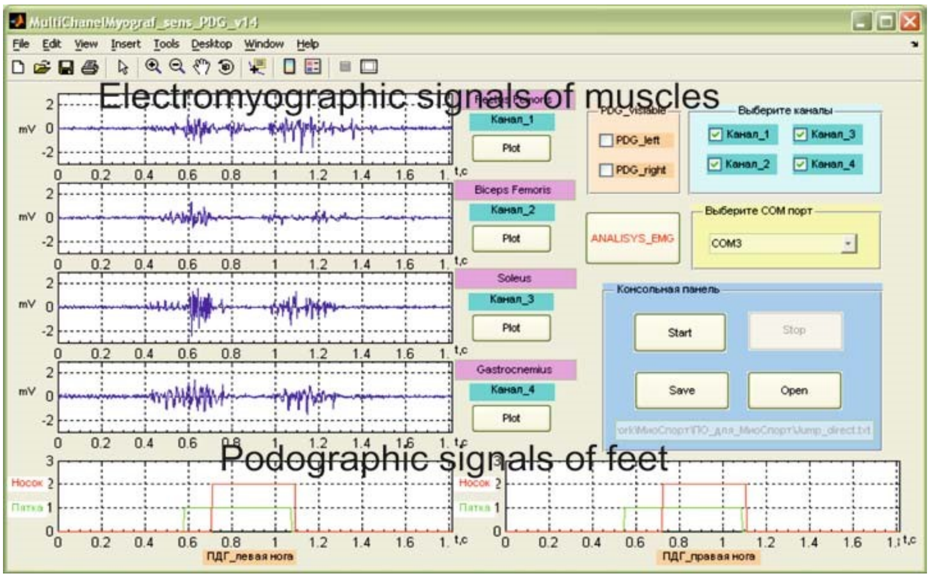


Figure 1: The software of the system "Mio Sport"

The registration of summary bioelectric activity of the muscles (electromyograms) was carried out using specialized surface medical adhesive electrodes. Fixation and positioning of electrodes on the studied muscles, orientation relative to motor fibers, the quality of skin surface preparation for recording of surface EMG were carried out in accordance with the recommendations of SENIAM [36].

The multi-channel podographic signals were recorded synchronously with EMG using the developed sensor electrodes [33–34] located on the soles of both feet. The dimensions of the podographic electrodes are small and do not disturb with the acting of exercises. The sensory manufacturing technology of PDG electrodes allows to study motions on the floor with any coating. The PDG electrodes are fixed to the heel and toe of each foot. Thus, it is possible to record the moments of separation and touching the ground by the heel and toe of each leg.

Figure 2 shows an example of the signals registration: the muscle electromyogram of *m. rectus femoris* of the right leg and two channels of the right foot podograms for the test move "jump up". The podograms of each leg are presented as two curves: with a smaller amplitude - the reaction of the heel, with a larger amplitude -the reaction of the toe. In this case, the zero level of the curves matches to the touching of the foot part with the ground, and the maximum amplitude of the curves matches to the lack of touching (Figure 2).

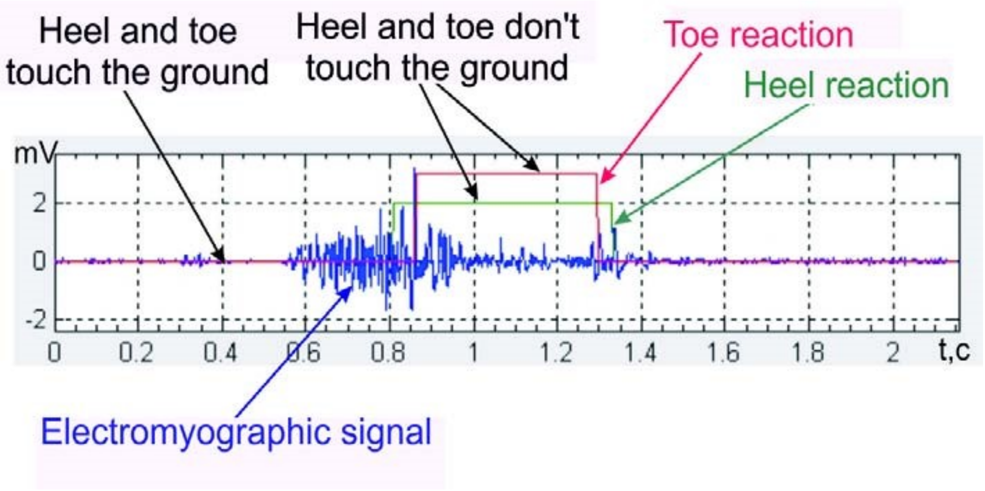


Figure 2: View of synchronously recorded EMG and PDG signals during the test movement

d) Data processing

The multichannel electrophysiological and biomechanical signals recorded during the motion are processed to create the electromyographic motion pattern according to the following algorithm:

1. The overlay of electrophysiological and biomechanical signals in the time domain.

The overlay of electrophysiological and biomechanical signals in the time domain is necessary for cooperative studying of the motion innervation and spatio-temporal structure. The time scales of signals are converted to a common basis according to their sampling frequencies, and then the signals are drawn in one graphic window.

In the presented work, the sampling frequency of the electromyographic signals is 1600 Hz for, and the sampling frequency of the podographic signals is 320 Hz. Accordingly, the minimum sampling recovery time interval for the correct displaying of electrophysiological and biomechanical signals is selected as 0.625 ms for the EMG signal, and 3.125 ms- for the PDG signal.

2. The filtration of multichannel electrophysiological signals.

As a result of the electrode system movement during the motion test, low-frequency components (motion artifacts) appear in the spectrum of the EMG signal, which leads to incorrect analysis of the EMG signal [37]. In the presented work, EMG signals are filtered using a fourth-order Chebyshev digital high-pass filter for removing of the motion artifacts from the useful signal spectrum. The cutoff frequency of the filter is 10 Hz.

3. Time rationing of multichannel electromyographic signals.

Time rationing of signals of multichannel electromyograms is necessary for unification of the EMG pattern of the same movement in different people.

The creation of a time motion structure using the method of podography is possible for such locomotion as walking, running, jumping. Thus, any such exercise will contain phases of movement, when one or both legs do not touch the ground. Those phases are chosen as the norm. Further, the signals of multichannel EMG are normalized according to the selected norm.

In the work, “jump up” was selected as a test motion. For this exercise, the phase of flight (Δt_flight) is taken as the norm. The time interval corresponding to the two phases of flight (2Δt_flight) is captured to the left of the moment the toe separate from the ground and to the right of the moment the toe touch with the ground (Figure 3).

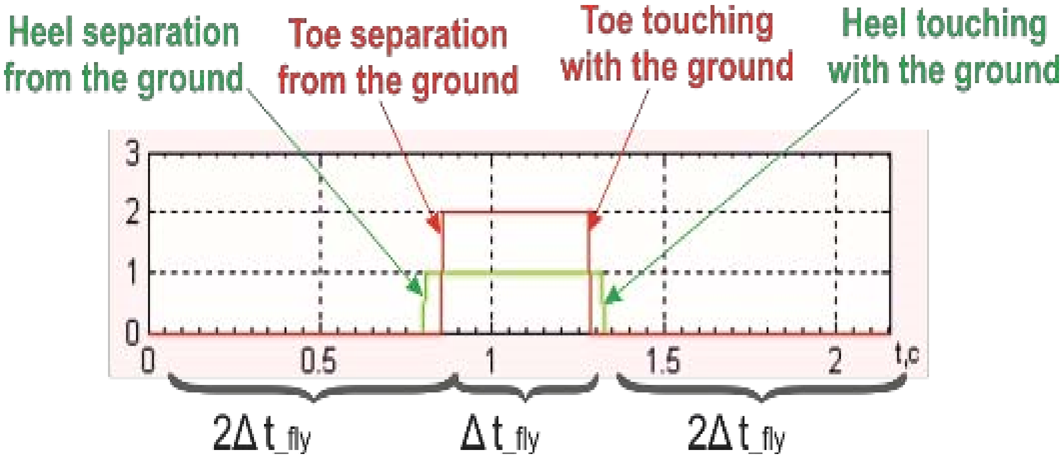


Figure 3: The time structure of the motion "jump up"

1. The detection of motion phases.

The phases of movement are detectedbased on the obtained time structure of the studied motion activity. The beginning and end of the movement can be determined based on the detection of the time interval of concentration of the EMG signal energy of the studied muscles. The detection criterion of this time interval is the concentration of the EMG signal energy of the studied muscles more than 95% of the initial EMG signals energy:

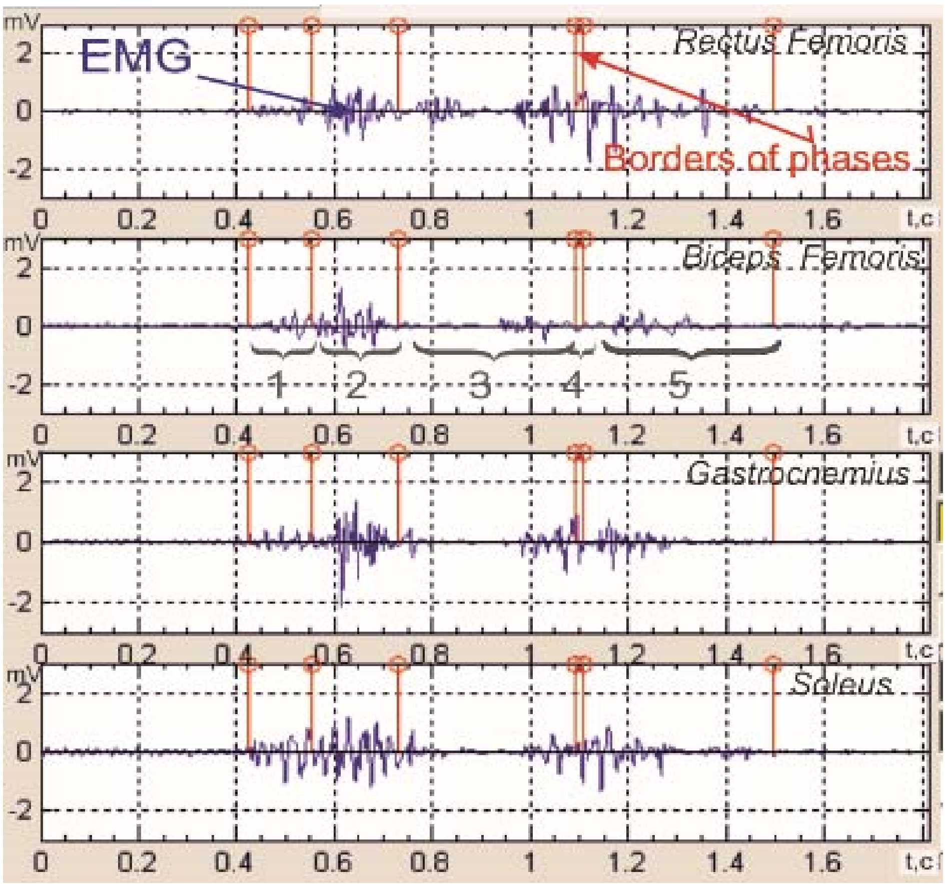
$$\sum_{m=1}^{M} E_{m,T} \geq 0,95 \sum_{m=1}^{M} E_m^{init} \qquad (1)$$

Where T – the time interval from the beginning to the end of the movement;

M – the number of studied muscles;
m – the muscle number;
$E_{m,T}$ - the EMG signal energy of the muscle $m$in the time interval T;
E_m^{init} - the initial EMG signal energy of the muscle m.

Thus, after processing of the multichannel electrophysiological and biomechanical signals in accordance with the described algorithm, the obtained data are the EMG pattern of the studied movement [38].

Figure 4 shows an example of the EMG pattern of the motion "jump up". The figure shows the normalized electromyograms of muscles *m. rectus femoris*, *m. biceps femoris*, *m. gastrocnemius lateralis* and *m. soleus* of the right leg, and markers of the movement phases borders corresponding to the time moments “start of the movement ", “heel separation from the ground", "toe separation from the ground", “toe touching with the ground", “heel touching with the ground", “heel touching with the ground" and "end of the movement". The following phases were detected for the test movement: the squatting phase (1) - from the motion beginning to the heel separation from the ground, the push phase (2) - from the heel separation from the ground to toe separation from the ground, the flight phase (3) - from toe separation from the ground to the toe touching with the ground, the touchdown phase (4) - from the toe touching with the ground to the heel touching with the ground, the rise phase (5) - from the heel touching with the ground to the movement end.



1 – the squatting phase, 2 – the push phase, 3 – the flight phase, 4 – the touchdown phase, 5 – the rise phase

Figure 4: The EMG pattern of the movement "jump up"

2. The amplitude-time analysis of electromyographic motion patterns.

The processing of registered electromyographic signals of muscles is carried out in the digital form. The initial analog electrical EMG signal of muscles is sampled in time and quantized in amplitude.

In the theory of digital signal processing, the energy of a digital signal is considered not as a physical quantity but as a means of comparing different signals. So, for the initial electrical signal, the load resistance is assumed R=1 [39]. Accordingly, the dimension of the received energy of the digital signal is not measured in Joules. However, the energy of the digital signal can be recalculated to a physical value if the load resistance is known [40].

The EMG signal energy E_m is calculated for each muscle *m*:

$$E_m = \sum_{i=1}^{n} E_{m,i} = \sum_{i=1}^{n} \frac{(x_{m,i})^2}{n}, \tag{2}$$

where $E_{m,i}$ - *i*-th discrete sample of the EMG signal energy of the muscle *m*;

$x_{m,i}$ - the amplitude of *i*- th discrete sample of the EMG signal of the muscle *m*;

n – the number of discrete samples of the EMG signal.

Similarly, the energy of the EMG signal of muscle *m* is calculated for each phase *f* of the studied motion $E_{m,f}$.

The using of the average, not summary energy of the EMG signal of muscles allows to take account of the frequency of sampling of the initial electromyographic signal, and, accordingly, to standardize the proposed method of integrated analysis of human motions in case of using technical systems of multichannel electromyography with different parameters of the sampling frequency of EMG signals.

In each phase of motion *f* for all muscles *m*, the fraction of the EMG signal energy $E^{\%}_{m,f}$ is calculated as a percentage of the total signal energy:

$$E^{\%}_{m,f} = \frac{E_{m,f}}{E_m} * \quad , (\%) \tag{3}$$

Where *f*– the number of the motion phase;

$E_{m,f}$ - the energy of the EMG signal of the muscle *m* in the phase *f*.

III. Results

The estimation of energy contribution of the muscles in the process of motion.

In order to identify types of motion skills, the estimation of the energy contribution of muscles during the motion "jump up" was carried out according to the following algorithm:

1. For each subject, the EMG pattern of the test motion was created in accordance with the above method.
2. The summary energy of the EMG motion pattern E_{Σ} was calculated as the sum of the EMG signal energies of all studied muscles:

$$E_{\Sigma} = \sum_{m=1}^{M} E_m \, , \tag{4}$$

3. For each muscle, the percentage of energy from the summary EMG energy of the motion pattern $E^{\%}_{m}$ was determined:

$$E^{\%}_{m} = \frac{E_m}{E_{\Sigma}} * \quad , \tag{5}$$

4. For each muscle, the mean value and standard deviation (RMS) of the energy fraction from the summary EMG energy of the motion pattern were calculated.

The percentage of the energy from the summary EMG energy of the motion pattern for each muscle is presented in Table 2.

Table 2: The percentage of the energy from the summary EMG energy of the motion pattern for the studied muscles

	m.rectusfemoris	m. bicepsfemoris	m. gastrocnemiuslateralis	m. soleus	m. gastrocnemius + m. soleus
Meanvalue of $E^{\%}_{m}$, %	38,82	4,33	28,62	28,23	56,85
RMS of $E^{\%}_{m}$, %	14,75	2,86	12,33	13,43	14,22

It was found out that among the studied muscles the following muscles mainly provide for the test movement: *m. rectus femoris muscles* (the share of EMG energy of the motion pattern is 38.82%±14.75%), *m. gastrocnemius lateralis* and *m. soleus* (the share of EMG energy of the motion pattern is 28.62%±12.33% and 28.23%±13.43%). The level of involvement of the muscle *m. biceps femoris* in the motion is not significant (the share of EMG energy of the motion pattern is 4.33%±2.86%).

In addition, the largest variation of the EMG energy fraction of the motion pattern is observed for the muscles *m. rectus femoris, m. gastrocnemius lateralis* and *m. soleus* (*m. rectus femoris* - ±14.75%, *m. gastrocnemius lateralis* - ±12.33%, *m. soleus* - ±13.43%).

Thus, the muscles *m. rectus femoris, m. gastrocnemius lateralis* and *m. soleus* are the leaders in the formation of the test motion and were chosen as the basis for the detection of jump types. The muscles *m. gastrocnemius lateralis* and *m. soleus* belong to the triceps of the shin and perform the same functions (shin and foot bending/unbending, shin rotation). Accordingly, they can be combined into one group for consideration of energy contribution of the muscles in the process of motion. For this muscle group (*m. gastrocnemius lateralis* + *m. soleus*), the share of EMG energy of the motion pattern is 56.85%±14.22% (see Table 2).

The point diagram of the percentage proportion of the EMG energy share of the test motion pattern for the muscle *m. rectus femoris* and the muscle group *m. gastrocnemius lateralis* + *m. soleus* was drawn (Fig. 5).

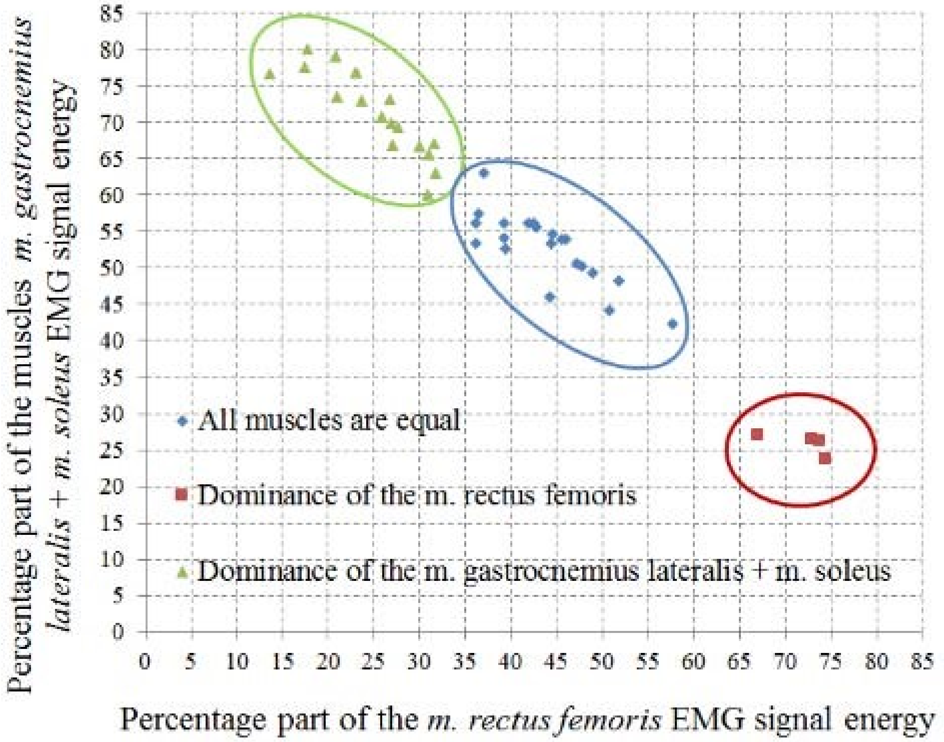
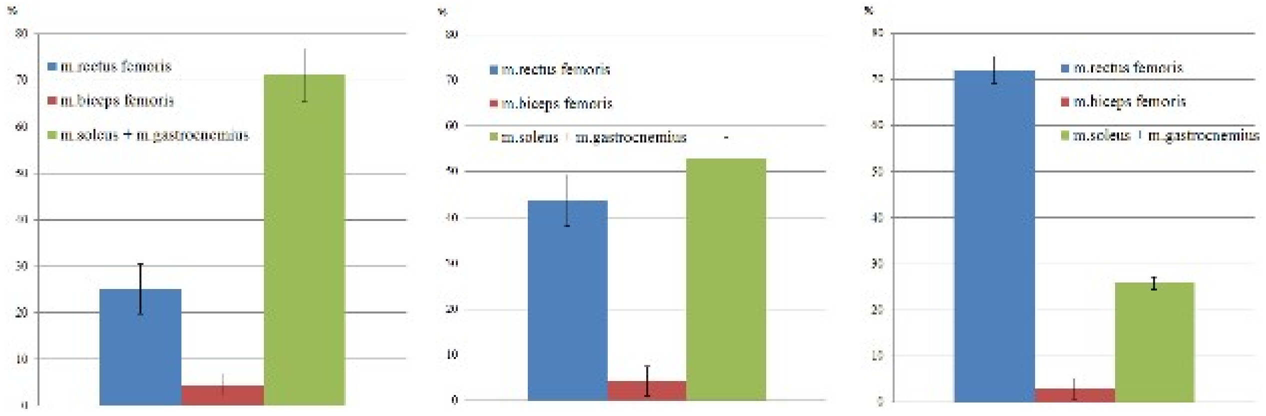


Figure 5: The point diagram of the percentage proportion of the EMG energy share of the test motion pattern for the muscle *m. rectus femoris* and the muscle group *m. gastrocnemius lateralis* + *m. soleus*

It was found that the data are clustered into 3 groups:

1. The group (17 people - 40.48% of the whole group), for which the muscles that mainly provide test motion are *m. gastrocnemius lateralis* and *m. soleus*. The share of EMG energy of the motion pattern for the muscular group *m. gastrocnemius lateralis* + *m. soleus* is 71.17%± 5.63%, for the muscle *m. rectus femoris* - 25.09%± 5.30%.
2. The group (21 persons - 50% of the whole group), for which the muscles *m. rectus femoris*, *m. gastrocnemius lateralis* and *m. soleus* are equal in the degree of involvement in the process of motion. The share of EMG energy of the motion pattern for the muscular group *m. gastrocnemius lateralis* + *m. soleus* is 52.78%± 4.69%, for the muscle *m. rectus femoris* - 43.81%± 5.58%.
3. The group (4 persons - 9.52% of the whole group), for which the muscle *m. rectus femoris* dominates in the process of the movement. The energy share of the EMG motion patternfor muscle group*m. gastrocnemius lateralis* + *m. soleus* is 25.79%±1.32%, for the muscle *m. rectus femoris* - 72.07%±2.94%.

Figure 6 shows the histograms of the percentage ratio of the EMG energy shares of the motion pattern for the studied muscles, corresponding to the above groups.



a b c

Figure 6: The histograms of the percentage ratio of the EMG energy shares of the motion pattern for the studied muscles: the muscles *m. gastrocnemius lateralis* and *m. soleus* mainly provide test motion (a); the muscles *m. rectus femoris, m. gastrocnemius lateralis* and *m. soleus* are equal in the degree of involvement in the process of motion (b); the muscle *m. rectus femoris* dominates in the process of the motion (c)

Thus, the percentage ratio of the EMG energy shares of the motion pattern for the studied muscles is different and allows to identify three types of motion skills for the jump: a) the muscles *m. gastrocnemius lateralis* and *m. soleus* mainly provide test motion (Fig. 6 a); b) the muscles *m. rectus femoris, m. gastrocnemius lateralis* and *m. soleus* are equal in the degree of involvement in the process of motion (Fig. 6 b); c) the muscle *m. rectus femoris* dominates in the process of the motion (Fig. 6 c). The EMG energy share of the motion pattern for the muscle *m. biceps femoris* does not exceed 5%.

The estimation of distribution of muscle efforts in the phases of motion.

The analysis of the distribution of muscle efforts in the phases of the test motion was carried out in order to identify the types of motion skills.

1. The analysis of the distribution of muscle efforts in the motion phases was carried out according to the following algorithm:
2. For each subject, the EMG pattern of the test motion was created in accordance with the above method.
3. The summary energy of the EMG motion pattern E_Σ was calculated as the sum of the EMG signal energies of all studied muscles (see formula 4).
4. The summary energy of the EMG signals of each phase E_f was calculated as the sum of the EMG signal energies of the muscles, concentrated in the phase *f*:

$$E_f = \sum_{m=1}^{M} E_{m,f}\ , \qquad (6)$$

5. For each phase, the percentage of energy from the summary EMG energy of the motion pattern $E_f^{\%}$ was determined:

$$E_f^{\%} = \frac{E_f}{E_\Sigma} * \qquad , \qquad (7)$$

6. For each phase, theme an value and standard deviation (RMS) of the energy fraction from the summary EMG energy of the motion pattern were calculated.

The percentage of the energy from the summary EMG energy of the motion pattern for each phase is presented in Table 3.

Table 3: The percentage of the energy from the summary EMG energy of the motion pattern for each phase

	The squatting phase	The pushphase	The flight phase	The touchdown phase	The risephase
Meanvalue of $E_f^{\%}$, %	20,20	50,94	15,91	4,14	8,81
RMS of $E_f^{\%}$, %	18,15	19,80	6,00	3,05	4,70

It was found that the largest variation of the EMG energy share of the test motion pattern is observed in the squatting phase and the push phase. The deviation of the EMG energy share of the motion pattern for the squatting phase is ±18.15%, for the push phase - ±19.80%. For the other phases (flight, touchdown and rise), this parameter does not exceed 6% of the summary EMG energy of the motion pattern. In addition, the sum of the EMG energy of the test motion pattern for the squatting and push phases is 71.14%±7.95%. Thus, these phases are determinative in the formation of test motion. Based on the above, the squatting and push phases were chosen as the basis for the identification of jump motion types.

The point diagram of the percentage proportion of the EMG energy share of the test motion pattern in the squatting phase and the push phase was drawn (Fig. 7).

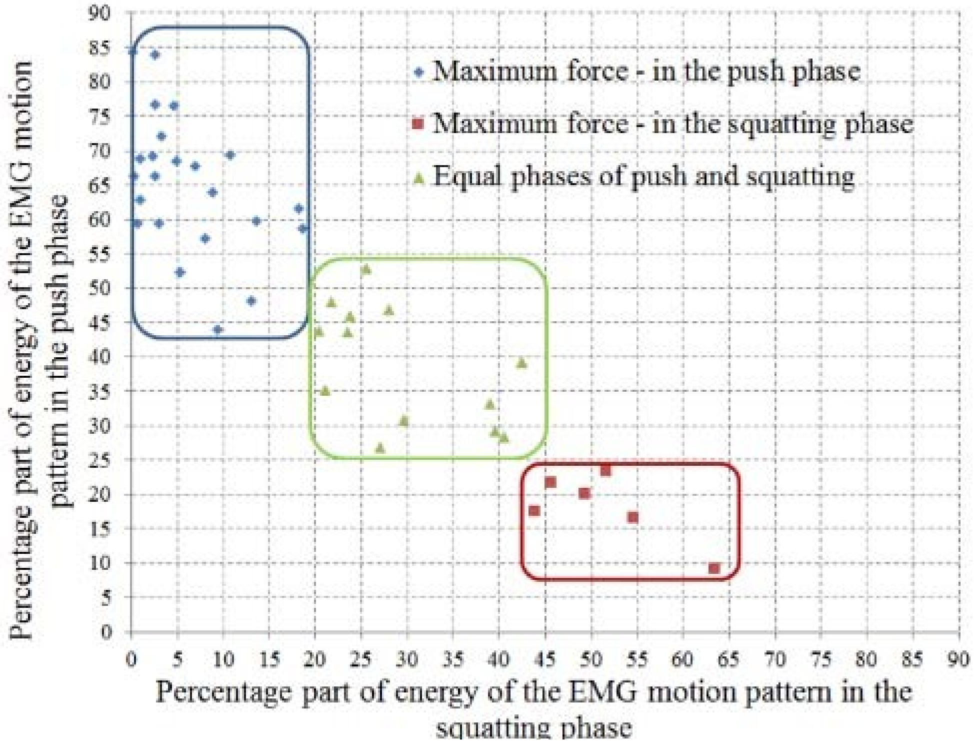
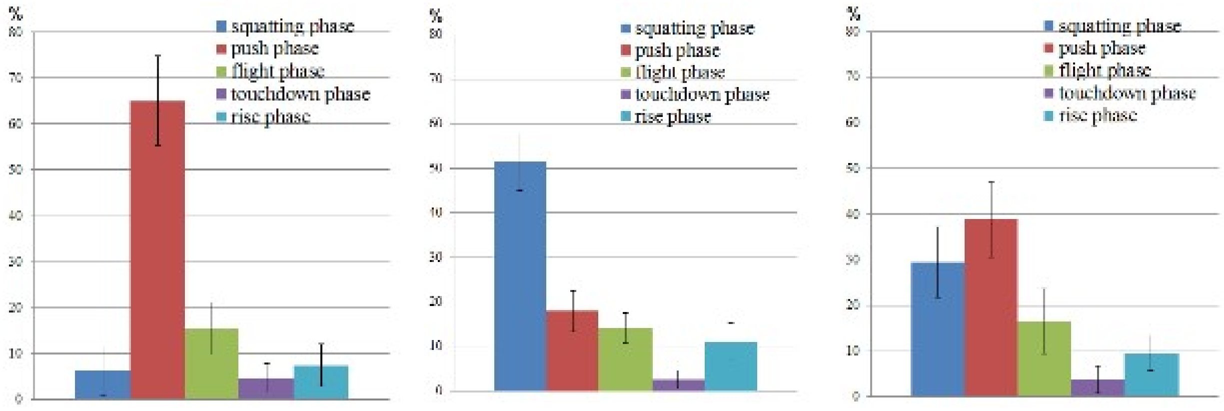


Figure 7: The point diagram of the percentage proportion of the EMG energy share of the test motion pattern inthe squatting phase and the push phase

It was found that the data are grouped into 3 groups (Figure 7):

1. The group (23 people - 54. 76% of the whole group), for which the maximum muscle effort is performed in the push phase: the share of EMG energy of the motion pattern in the squatting phase is 6.12%± 5. 45%, in the push phase - 65. 07%± 9. 82%.
2. The group (6 people - 14. 29% of the whole sampling), for which the maximum muscle effort is performed in the squatting phase: the share of EMG energy of the motion pattern in the squatting phase is 51. 47%± 6. 44%, in the push phase - 17. 90%± 4. 59%.
3. The group (13 people - 30, 95% of the whole group), for which the muscle efforts are equally distributed between squatting and push phases: the share of EMG energy of the motion pattern in the squatting phase is 29, 40%±7, 78%, in the push phase - 38, 74%±8, 29%.
4. Figure 8 shows the histograms of the percentage ratio of the EMG energy shares of the motion pattern by the phases, corresponding to the above groups.



a b c

Figure 8: The histograms of the percentage ratio of the EMG energy shares of the motion pattern by the phases: the maximum muscle effort is performed in the push phase (a); the maximum muscle effort is performed in the squatting phase (b); the muscle efforts are equally distributed between squatting and push phases (c)

Thus, the percentage ratio of the EMG energy shares of the motion pattern for the squatting and push phase is different and allows to identify three types of motion skills for the jump: a) the maximum muscle effort is in the push phase (Figure 8 a); b) the maximum muscle effort is in the squatting phase (Figure 8 b); c) the muscle efforts are equally distributed between squatting and push phases (Figure 8 c). The distribution of muscle efforts in the flight, touch-down, and rise phases does not change (the deviation of the EMG energy share of the motion pattern for these phases is less than 6%).

IV. DISCUSSING

The results of the research prove the effectiveness of the proposed complex analysis of human motion, which allows to classify the types of motion skills of the subjects on the following bases:

- by the energy contribution of the muscles in the process of motion;
- by the distribution of muscle efforts in the phases of motion.

The research of the energy contribution of the studied muscles during the test motion "jump up" was carried out. As a result of the analysis of the percentage ratio of EMG signal energy of the muscles during the test movement, three types of motion skills were identified:

a) 40.48% of all subjects: the muscles *m. gastrocnemius lateralis* and *m. soleus* mainly provide test motion (the share of EMG energy of the motion pattern for the muscular group *m. gastrocnemius lateralis* + *m. soleus* is 71.17%± 5.63%);
b) 50% of all subjects: the muscles *m. rectus femoris, m. gastrocnemius lateralis* and *m. soleus* are equal in the degree of involvement in the process of motion (the share of EMG energy of the motion pattern for the muscular group *m. gastrocnemius lateralis* + *m. soleus* is 52.78%± 4.69%, for the muscle *m. rectus femoris* - 43.81%± 5.58%);
c) 9.52% of all subjects: the muscle *m. rectus femoris* dominates in the process of the motion (the energy share of the EMG motion pattern for the muscle *m. rectus femoris* - 72.07%±2.94%).

The research of the distribution of muscle efforts in the phases of the test motion "jump up" was carried out. The percentage ratio of EMG energy of the motion pattern in the squatting and push phases is different and allows to identify three types of motion skills:

a) 54, 76% of all subjects: the maximum muscle effort is performed in the push phase (the share of EMG energy of the motion pattern in the push phase - 65. 07%± 9. 82%);
b) 14, 29% of all subjects: the maximum muscle effort is performed in the squatting phase (the share of EMG energy of the motion pattern in the squatting phase is 51. 47%± 6.44%,);
c) 30, 95% of all subjects: the muscle efforts are equally distributed between squatting and push phases (the share of EMG energy of the motion pattern in the squatting phase is 29, 40%±7, 78%, in the push phase - 38, 74%±8, 29%).

V. CONCLUSION

In the paper, the method of multichannel interference electromyography was chosen as a method of investigation of electrophysiological parameters of motion. The method of multichannel interference electromyography allows to estimate the participation of muscles in various movements, the sequence of their on and off, the integrated level of muscle activation, the correlation of muscle activity in different periods of motion skills formation. The method of podography was chosen to study the biomechanical motion parameters. The method of podography (PDG) allows to record the time moments of contact of various parts of the foot with the ground, and to identify motion phases. The complex application of these methods (multichannel interference electromyography and podography) allows to create an electromyographic pattern of motion, which is an electrophysiological analogue of motion and is a combination of time, spatial and amplitude electromyographic characteristics of motion.

In the paper, the algorithm of creation of an electromyographic motion pattern based on analysis of multichannel electrophysiological and biomechanical signals was proposed. The algorithm includes: 1) the overlay of electrophysiological and biomechanical signals in the time domain; 2) the filtration of multichannel electromyographic signals to remove motion artifacts and network interference from the spectrum of the useful signal; 3) the time rationing of multichannel electromyogrphic signals for unification of the EMG pattern of the same movement in different people; 4) the detection of motion phases.

In the paper, the method of complex estimation of human motion skills based on the analysis of electromyographic motion pattern was proposed. The analysis of multichannel electromyogrphic signals of muscles is made in the time domain, due to the need for comparison of the innervation motion structure with the spatial and time characteristics of the studied motion. The proposed method allows to calculate the energy contribution of the muscles in the process of motion and to calculate the distribution of muscle efforts in the phases of motion.

In the paper, the research of the motion skills was carried out on the example of the test movement "jump up”. The research of the energy contribution of the muscles during the test motion allowed to identify three types of motion skills: 1) the muscles *m. gastrocnemius lateralis* and *m. soleus* mainly provide test motion (40.48% of all subjects); the muscles *m. rectus femoris, m. gastrocnemius lateralis* and *m. soleus* are equal in the degree of involvement in the process of motion (50% of all subjects); the muscle *m. rectus femoris* dominates in the process of the motion (9.52% of all subjects).The research of the distribution of muscle efforts in the phases of the test motion allowed to identify three types of motion skills: the maximum muscle effort is performed in the push phase (54,76% of all subjects);the maximum muscle effort is performed in the squatting phase (14,29% of all subjects); the muscle efforts are equally distributed between squatting and push phases (30,95% of all subjects).The results of the research demonstrate the effectiveness of the proposed complex analysis of human motion.

The proposed approach to the analysis of human movements can be used to study human motion abilities in clinical and sports medicine (motion rehabilitation, clinical and sports biomechanics, prosthetics), training process (control of the sportsman's motion stereotype, prognosis of the children's motion talent) and special activity (effective training of special skills, professional selection).

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