Development of the structure of a robotic complex for the rehabilitation of a patient with amputation of the lower limbs

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***Abstract*—The object of the study is the motor activity of patients with various pathologies of the lower extremities in the process of prosthetics. The subject of the study is the methods and means of monitoring the motor activity of patients with amputation of the lower extremities. To solve the tasks set in the work, a clinical analysis of gait was used in terms of temporal, spatial, kinematic, dynamic and energy parameters. The structure of the robotic complex is proposed, which makes it possible to increase the efficiency of adjusting the parameters of the prosthesis by organizing biofeedback, taking into account the individual characteristics of the patient. The use of the structure of the rehabilitation robotic complex proposed by the authors will reduce mechanical loads in the process of finishing operations when creating a lower limb prosthesis. The location of the mass-dimensional blocks of robotic mechanisms in a stationary instrument rack ensures the natural gait of the patient.**

Keywords—amputation of human lower limbs, bionic prosthesis, electrode sensors, electromyographic signal, robotic mechanism

I. Introduction

The level of comprehensive rehabilitation and the quality of life of a patient with lower limb amputations are largely determined by the quality of prosthetics. An ill-fitting prosthesis puts you at risk for a number of medical complications, including further amputation, skin conditions, and usually excessive pain in both legs. Faced with these problems, many amputees decide to greatly reduce or even stop using the prosthesis while remaining essentially immobile. In turn, a well-chosen prosthesis helps a person return to a normal life in society: study, work, and even play sports.

Currently, when assessing clinical indicators, the organoleptic method of examination is mainly used. The movement function is not convenient for observation or research with the help of the senses; specific equipment is required, the imported versions of which are very expensive. In addition, this area belongs to high technologies and the sale of such equipment to Russia is subject to sanctions and is not available to Russian medicine.

The aim of the study is to develop a rehabilitation complex that will improve the effectiveness of the rehabilitation of a patient with amputation of his lower extremities.

II. Materials And Methods

Lower limb prosthetics is a system of medical, technical and organizational measures aimed at restoring lost forms or functions of an amputated limb. The rehabilitation effectiveness of lower limb prosthetics depends on the following factors [1]:

- the level of amputation or congenital pathology of the limb according to the type of stump;

- size, shape and functional state of the stump;

- reasons for amputation;

- functionality of the prosthesis;

- materials used;

- the quality of the prosthesis;

- the degree of training and development of the prosthesis by a disabled person;

- general somatic condition of a person;

- preservation of the second limb.

The main goal of prosthetics is to restore the contraction functions of lost or truncated muscles and kinesthetic sensations lost as a result of amputation of a part of the limb and to ensure that walking is as anthropomorphic as possible.

Walking is a type of motor activity that does not require special training, but is characterized by high loads, as it requires the muscles and life support systems to transfer body weight [2]. The entire musculoskeletal system is involved in the formation of a person's step. During amputation of a part of the lower limb, the symmetry is violated, both geometric and static, dynamic [3], and kinesthetic, and the stronger, the higher the level of amputation or the more significant violations in the musculoskeletal and nervous system of the limbs as a result of the disease.

In the rehabilitation of patients with amputation of the lower extremities, it is customary to analyze the temporal characteristics of the step, the angles in the hip, knee, and ankle joints when walking, and force reactions when interacting with the supporting surface [4]. In recent years, due to the advent of bionic prostheses, biopotentials are recorded at the locations of motor neurons during walking or during other motor tests. In order to eliminate the effect of signal filtering noise, its rms value S is used:

$$S = \sqrt{\frac{1}{N}\sum_{i=1}^{N} U_i^2}, \qquad (1)$$

where U_i is the EMG signal amplitude, N is the window size.

III. Results

The authors propose a robotic complex for the rehabilitation of disabled people with lower limb amputation (Fig. 1).

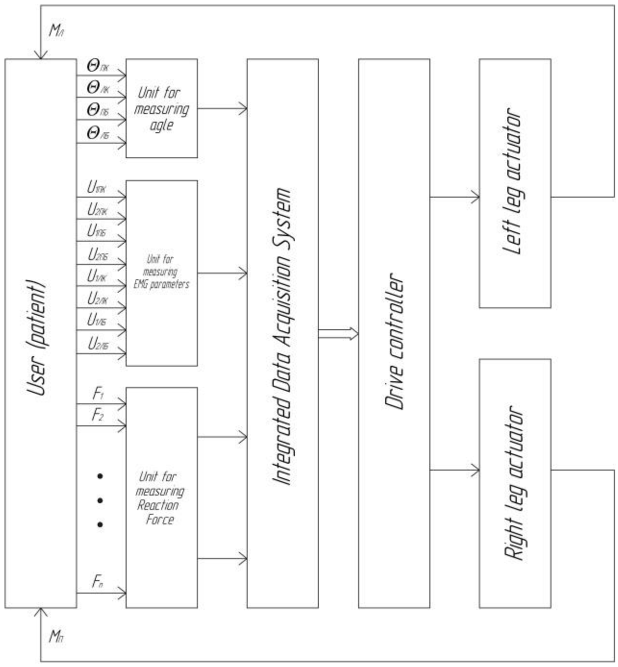

Fig. 1. Structural diagram of a robotic complex for the rehabilitation of disabled people with lower limb amputation

It includes: an instrument rack, a treadmill equipped with a ramp and railing for patient safety, and a personal computer. In the process of monitoring the patient's motor activity using the proposed complex, it is possible to study the temporal and kinematic parameters of walking, the dynamic parameters of the force interaction of the lower extremities with the supporting surface, and to record an electromyogram.

The block diagram of the complex contains a node for measuring the angles of rotation of the hip and knee joints, respectively, of the right and left legs, a node for measuring the parameters of the EMG signal, a node for measuring the reaction force, an integrated system for collecting data on the measured parameters, a drive controller and actuators of the right and left legs.

Primary measuring transducers (PMT) of angles are attached with the help of cuffs to the lower extremities of a person. PMT for measuring the reaction force is made in the form of strain gauge insoles.

Surface electrodes for EMG recording are attached at the locations of motor units and fixed in any way possible. In order to reduce interference, the normalizing amplifiers are located in close proximity to the PMT and electrodes. The instrument rack contains power supplies, blocks for processing signals from sensors and electrodes, as well as a drive controller. Actuating mechanisms are made in the form of rigid links attached with the help of cuffs to the lower limbs of the user.

The system works as follows. The patient is placed on the treadmill of the robotic complex and sensors, electrodes and actuators are fixed on it. The operator turns on the treadmill; the controller of the complex applies force, and the patient begins to move. PMT measures the articular angles, the biopotentials of muscle activity are taken from the electrodes. The EMG signals enter the EMG parameters measurement unit, where they are amplified and filtered. Then the filtered signal enters the integrated data acquisition system for further processing. The integrated data acquisition system also receives data from units for measuring angles and reaction forces. The integrated data acquisition system processes the received signals and sends a signal to the drive controller that controls the actuators

IV. Conclusions

The feedback implemented in the robotic complex allows the control system to carry out rehabilitation more efficiently by selecting and replacing the appropriate drives to support the ankle, knee and hip joints of a patient in need of help. The introduction of the proposed complex into rehabilitation practice will free amputees from wearing heavy blocks such as batteries and signal processing units, which will bring their gait closer to natural.

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