UDC 616-7:004.896

AUTOMATED DEVICES FOR POST-STROKE REHABILITATION

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Annotation. The study and analysis of the potential of robotic devices in creating conditions for high-quality support in the rehabilitation process for individuals with upper limb mobility limitations was investigated.

Key words: upper limb mobility limitations, biomechanical systems, CRAB

Introduction. Rehabilitation of people with upper limb mobility limitations is one of the most important tasks in the field of medicine. The possibility of full recovery and socialization of patients necessitates the provision of healthcare institutions with special developments that automate the stages of rehabilitation, partially replace medical personnel, and allow rehabilitation procedures to be carried out for an extended period without the constant presence of a healthcare professional. Every year in the Republic of Belarus, over 750 thousand people sustain injuries, and in 2021 alone, more than 30,000 people experienced a stroke; these two facts are the main causes of loss of hand motor skills. The attempt to create a method for high-quality rehabilitation motivates our interest in the scientific research topic «Automated Devices for Post-Stroke Rehabilitation». The relevance of our research is driven by the need to address the rehabilitation challenges for individuals with upper limb mobility impairments. The subject of this research is biomechanical systems. The object of the research is the CRAB, Capturing Rehabilitation Anthropomorphic Block. The aim of this project is to study and analyze the potential of robotic devices in creating conditions for high-quality support in the rehabilitation process for individuals with upper limb mobility limitations. The hypothesis is that CRAB, the gripping rehabilitation anthropomorphic block, can become a competitive development for stimulating the musculoskeletal system of the human hand. The theoretical significance of the work lies in our attempt to design CRAB, the capturing rehabilitation anthropomorphic block. The practical significance of the work lies in our proposal and description of the benefits for utilizing CRAB.

Main part. Modern technologies allow for the development of a model for a human hand simulator and a system for its integration with a "brain-computer" interface. The simulator should be connected to the human hand, providing independent movement seamlessly. The difficulty in its development lies in considering the specific load on the musculoskeletal system of the patient and ensuring complete alignment with the natural movement of the patient hand. According to the research conducted by the Northwestern University (Chicago), Louis Stokes Cleveland VA Medical Center (Virginia), Myomo, Inc. – a medical robotics company (New York), and Case Western Reserve University (Cleveland), a combined therapy approach (combining the use of a myoelectric upper limb orthosis for 1.5 hours twice a week for 9 weeks with medication support), followed by 9 weeks of using the orthosis at home, resulted in a very positive recovery outcome [2].

Human hand model. The dimensions of the hand simulator are based on NASA research [4]. Figure 1 represents the model of the interaction of the joints of the hand and fingers.

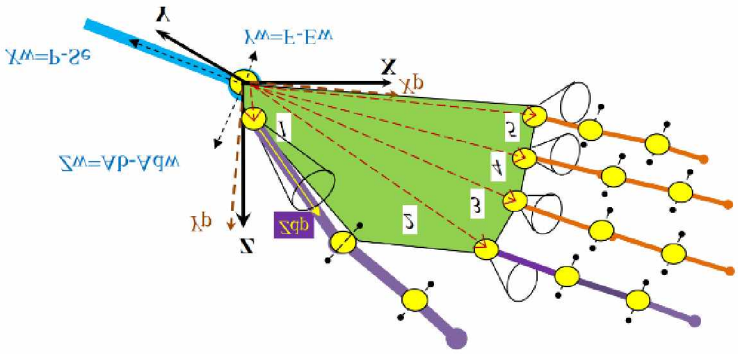

Figure 1 – Model of the dynamics of the human hand and fingers

Positioning vectors 1, 2, 3, 4, 5 with the phalanges of the fingers in the coordinate system.

Xp, Yp – The edge of the palm and the plane of the hexagon of the wrist.

FE и Ab Ad – Flexion-extension and abduction-adduction axes;

FE – Axes of the phalangeal joint hinges;

Zdp – Additional axis for rotational mobility required for the grasping movement of the thumb. In the coordinate system Xp, Yp, the coordinates of the finger joints will be defined, which have limited mobility in the coordinate system Xw, Yw, Zw. The movements of the finger phalanges are defined by angles and planes. In these coordinate systems, each joint of the device has ranges of permissible movements and directions, which are based on NASA research [4].

Functional diagram of the exciting rehabilitation anthropomorphic block CRAB. To ensure comfort and durability of the device, we propose using polyvinyl chloride (PVC plastic) for creating the covering bracelet to which the actuators are attached. This material will provide decent freedom of movement due to its flexible properties. The inner lining and straps use polyester. More precise measurement is achieved using a strain gauge sensor embedded in each finger strap; the degree of strap stretching is measured and converted by the sensor into a signal establishing the force for the actuators. The forearm bracelet carries a battery and sensors for information processing and actuator control. The bracelet itself uses the same materials as the wrist bracelet. To reduce the device's weight, EMG sensors are integrated directly into the fabric of the bracelet by applying a silver coating to the fibers. The sensors are located on the inner side of the bracelet around the forearm. This technology eliminates the need for usual sticky sensors, which caused a variety of inconveniences. The driving force for the finger mechanism is provided by a structure of pneumatic actuators. A compressor, along with a computer, is installed in a miniature backpack on the patient's back. The compressor supplies compressed air to the wrist bracelet, where a system of solenoid pneumatic valves is located, regulating the operation of the actuators. The rotary pneumatic actuator moves a gear rack connected to a flexible metal plate along the fingers, causing them to move.

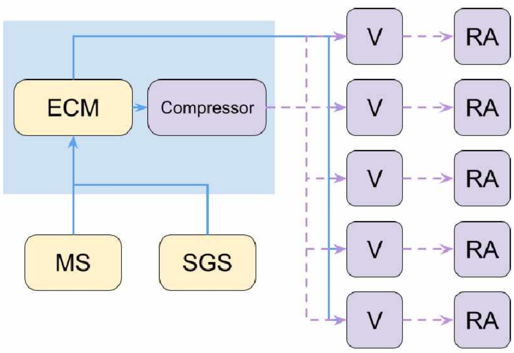

Figure 2 – Functional diagram of the functioning of the structure of pneumatic actuators, where MS is a myoelectric sensor, SGS is a strain gauge sensor, V is a valve, RA is a rotary actuator

Conclusion. In the research work, we formulated requirements for a biomechanical hand trainer – movements should be generated based on signals from the human nervous system about the desired movement of the hand. The study and analysis of materials on the topic of our research lead to the following conclusions: CRAB (Capturing Rehabilitation Anthropomorphic Block) is an automated manipulator for the hand, whose main function is to provide additional force when the user performs certain movements. It will be more cost-effective compared to foreign counterparts, as the estimated cost will be less than 1500 Belarusian rubles.

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