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WEARABLE ROBOTIC SYSTEM FOR UPPER LIMB REHABILITATION

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Abstract: *Recovery, due to the large number of affected people, required the development of rehabilitation equipment in close connection with technology, increasing the number of robotic systems. The portable robotic system presented in this paper is an adaptive robotic equipment, which provides a customizable recovery program to the needs and pathology of the patients. After the presentation of the most important constructive-functional characteristics, the choice of actuators is justified and the integration of the EMG, thermotherapy and electrotherapy modules, is described. The use of the equipment is presented in detail, and several specific pathologies are analyzed.*

Key words: *robotic system, exoskeleton, upper limb, rehabilitation*

1. INTRODUCTION

The medical robots, as part of the family of service robots, include many applications such as: surgical robots, therapy assistance robots, robots for diagnosis and treatment, rehabilitation and assistive robots, exoskeletons, robotic orthoses and artificial limbs [1], [2], [3]. The main advantages offered by the robotic rehabilitation systems are: simultaneous treatment of several patients, thus reducing the patients' waiting time for the therapy; flexibility of the therapy programs and exercises, depending on the needs of each patient; assisting, facilitating and supplementing manual therapy performed by therapists; increasing the therapy time per patient; possibility of performing the rehabilitation exercises at home; possibility of assisting movements permanently, through portable robotic equipment [4], [5], [6].

The upper limbs are among the most important segments of the human body, with an essential role in the interaction with the external environment, being able to support daily activities, such as feeding, dressing, personal hygiene [7], [8]. Anatomical movements at the shoulder, elbow and wrist allow for hand positioning and orientation, while finger biomechanics allow for different grasping configurations, [9]. The functionality of the upper limb can be affected by multiple causes: stroke or other neurological conditions, degenerative or inflammatory rheumatic conditions, post-traumatic conditions and others. Based on the increasing demands of robotic rehabilitation systems as well as the complex functions of the upper limb, a wearable rehabilitation robotic system was studied and developed (Fig. 1) [10], addressing pathologies that use physical therapy, electrotherapy and thermotherapy as recovery procedures.

Fig.1. Wearable rehabilitation robotic system

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2. STRUCTURAL AND FUNCTIONAL CHARACTERISTICS

One of the main features of the proposed equipment is that it uses the patient's residual strength to perform daily activities and/or recovery exercises. The equipment can be used both in a hospital environment and at home. The equipment, whose components are highlighted in figure 2, is weighing only 1.8 kg, including the lumbar belt to which it is attached. It is positioned in the lower abdominal area of the patient where the center of gravity (COG) of the human body is also located, the patient being able to move, sit on a chair with a backrest, in the car, on the toilet bowl, or carry out their activities or exercises, the equipment not significantly affecting the COG.

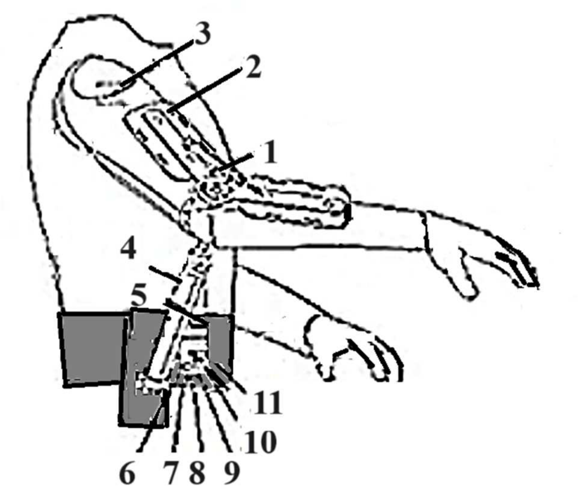
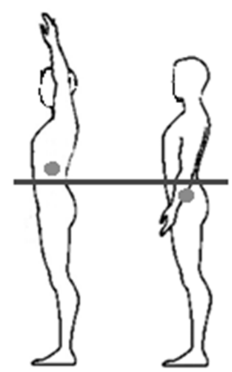


Fig.2 Pneumatic device components:
1– optional electric actuator 2 – elbow brace 3 - EMG electrodes 4 – pneumatic driven linear actuator exoskeleton 5 – pocket 6 – development board 7– pressure distributor 8 – battery 9- EMG module 10- CO2 tube

The COG of the body (Fig. 3) depends on the position of the body, but also on the relative positions of the segments. Therefore, any change affects the stresses to which the joints, tendons, muscles, articular cartilages, etc. are subjected. The body is more stable the larger is the support area and the closer the center of gravity is to the support surface [11], [12]. In patients with stroke or neurological conditions, ataxia may also occur, characterized by loss of balance, stumbling, falling, instability on stairs. That is why it is important that the patient's center of gravity is kept within normal limits, especially in these patients.

2.1. Choice of the actuators

In choosing the actuators, calculations were made regarding the required stroke and force.



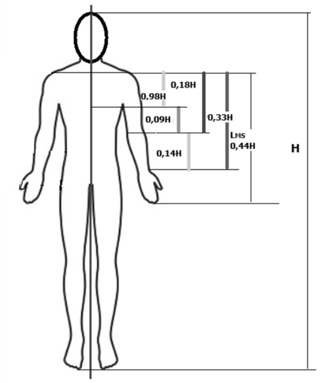


Fig. 3. Displacement of the COG according to body

Fig. 4. Anthropometric dimensions specific

The stroke of the actuator was calculated according to the anthropometric dimensions [13], as well as the specific movements performed by the upper limb [14], while calculating the force of the actuator, it was taken into account that the upper limb represents approximately 6.5% of the total body weight of a person [14]. According to Figure 4, the anthropometric dimensions of a male person with a height (H) of 1.75m are: shoulder - elbow distance is 0.188H = 329mm; wrist - elbow distance is 0.145*H = 253mm; elbow - chest level is 0.090*H = 157 mm; chest level – shoulder distance is 0.98*H = 171mm and wrist - shoulder distance is 0.333*H = 582 mm. Based on these values, the stroke of the actuator must be between 150-200mm.

The average weight of a man is 88.31 kilograms, which means that the average weight of the upper limb is 5.75kg. So the force of the actuator must be able to support this weight, to which is added the weight of the elbow orthosis and if there is also the actuator at the elbow level, and the limitations of mobility, depending on the condition spasticity, retractions, contracts, etc. Two types of actuators were tested: the electric actuator Micro Pen 150N, having the following characteristics [15]: rod stroke 150mm, total length 125mm closed / 275mm open, force 150N (maximum weight lifted), and the pneumatic MAL 16x200 actuator, having the following characteristics [16]: rod stroke 200mm, total length 111 mm closed / 311 mm open, working agent air, working pressure 0.1-0.9 MPa. A comparison between electrical and pneumatic actuation is given in Table 1. It results that is more efficient to use an electrically driven linear actuator.

Table 1

Comparison electrical vs. pneumatic actuation

ELECTRICAL ACTUATION	PNEUMATIC ACTUATION
- silent operation (40dB) - the amplitude of the generated movement is precise, the actuator acting as long as it receives a signal from the EMG sensor - reduced number of components - equipment weight 1.8 kg	- dependence to CO2 tube - acoustic discomfort – generated by the operation of the pressure distributor, - the amplitude of the movement does not have a very good precision, the volume of air that activates the actuator cannot be controlled very precisely - the CO2 tube, it is expensive and offers a limited number of movements (with a 16g tube you can achieve about 25 movements), thus requiring reserves of CO2 tubes - it is difficult for a disabled man to change his CO2 tube by himself increases the weight and volume of the equipment due to the CO2 tube, pressure regulator, pressure distributor, tubing required, thus equipment weight is 2.2 kg

2.2 EMG sensors

In order to sense the voluntary movement of the patient, EMG sensors (MyoWare type) were positioned on the muscles with gel electrodes, depending on the targeted movement. Thus the patient's voluntary movement is sensed, the signal is used to actuate the actuators. The pairs of muscles on which the EMG electrodes are placed are of the agonist-antagonist type. Thus, in the realization of the concrete movement, the muscles that contract are agonists, and those that relax are antagonists, but their action can be reversed depending on the muscle group and the movement that is initiated and that takes place in a controlled manner (figure 5).

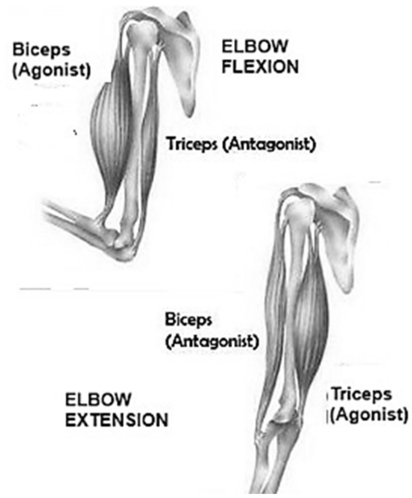


Fig. 5 Agonist-antagonist muscle pairs

The EMG electrodes, are placed as follows:
- for the flexion of the arm, on the anterior deltoid / pectoralis major the clavicular fibers;
- for the arm extension on the posterior deltoid / latissimus dorsi / pectoralis major sternal fibers;
- for the elbow flexion, on the biceps;
- for the elbow extension, on the triceps.

Also, for a better accuracy of the signal received by the EMG sensors on the targeted muscles, a MyoWare led shield will be used, with 10 light segments, which are activated depending on the amplitude of the received signal, thus making it possible to easily and accurately place the electrodes in the points that give the best EMG signal (figure 6). As a rule, finding these points is difficult and is done by groping, searching patiently and carefully in the distal area of the muscle, the points where the targeted contraction is most appropriate, [17]

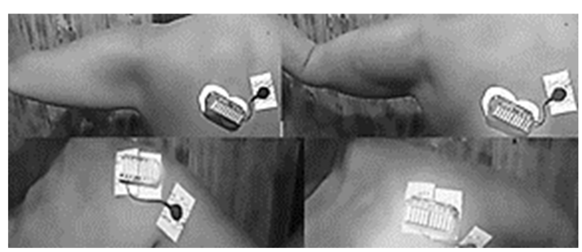


Fig. 6 Finding the best EMG signal point

If there is no EMG signal, the patient can perform auto passive mobilizations with the help of a switch, having the advantage of being able to dose their movement up to the limit of pain.

2.3 Thermotherapy

For the efficiency of the recovery and regaining the elasticity of the tissues, it is important to use the heating of the joints, as is presented in [19], [20], [21], at the temperature recommended by the medical doctor before the physical therapy sessions.

Thixotropy defines the resistance of a tissue to stretching. A high viscosity means a high resistance to stretching, which can lead to the tissue breaking if it is "forced" to stretch at a high speed.

The warm thermal factor is applied in subacute and chronic processes, it is also indicated that the warm applications precede the physical therapy procedures, precisely to allow muscle relaxation that favors the reduction of muscle recovery and to allow the performance of stretching exercises, specific to the reduction of retractions. The characteristic of joint pains is the limitation of normal movements of one or more joints.They can appear as a result of immobilization after fractures or dislocations, of prolonged immobilization in bed, or as a result of joint inactivity as a result of some conditions that do not allow their active mobilization. Muscle retraction is characterized by increased muscle resistance to stretch. The short waves have a residual heating effect, endothermy is produced, the heat is formed inside the tissues, so the body temperature remains high 48-72 hours after application, which makes the procedure superior to the other procedures, but they have a many contraindications, among which: they cannot be used in the case of classic robotic equipment, due to their metal components, and will not treat limbs with orthoses containing metal components, or regions with implants with intratissue metal parts (osteosynthesis materials) - rods, brooches, endoprostheses, etc., cardiac peace maker patients, because the procedure strongly heats the metals, [22].

The proposed system has the advantage that thermotherapy can be applied simultaneously with the exercises, while in the case of the classic methods applied in medical practice - paraffin and warm water, until the patient was able to perform the exercises, the effect of heating the tissues disappeared or was greatly attenuated. Among the pathologies that use warm applications, we mention: musculoskeletal conditions, arthrosis, discopathy, neuralgia, etc.

In classical method used in medical practice for applying thermotherapy with paraffin and warm water, until the patient was able to perform the exercises, the effect of heating the tissues disappeared or was greatly attenuated, but the proposed system has the advantage that thermotherapy can be applied simultaneously with the exercises, with the help of electrical resistances. The electrical resistances, mounted under the orthosis, can be activated/deactivated with the help of a temperature module, depending on the need by the patient or therapist.

In acute processes, the role of cryotherapy in recovery can also be discussed [23].

The effects of the hot factors are presented in Table 2.

Table 2

The effects of warm factors

The warm thermal factor	• effect of increasing elasticity - allows tissues to stretch with contractions; at 40-45 °C, the joint swelling decreases due to the decrease in the viscosity of the synovial fluid; • anti-algesic effect (heat applied for a longer duration decreases nerve sensitivity); • hyperemiant effect (vasodilator) – it is all the greater as the temperature increases, thus the circulation is activated which has a regenerative trophic effect, stimulating the metabolism by increasing the need for oxygen and tissue nutrient substrate; • anti-inflammatory, resorptive effect also due to the improvement of circulation, contributes to the reduction of edema; • decontracting, antispasmodic, muscle relaxant effect, they have a calming effect on the nervous system);

2.4 Electrotherapy

The described equipment also allows the application of electrotherapy procedures. The forms of currents [17], [22] used in these procedures are presented in table 3.

Table3

Type of currents used in rehabilitation procedures

The rectangular pulses	Represent the typical form of stimulation of skeletal muscle contraction, being indicated in muscle atony and atrophy of various causes but normo innervated, prolonged immobilization in bed of various causes, hypotonia, and muscle hypotrophy in the suffering of neighboring joints.

Exponential currents	They are indicated in the prevention and recovery of neurogenic muscle atrophies, i.e. in peripheral motor neuron lesions, having no effect in central motor neuron diseases and myopathies. The treatment is applied as early as possible, after the production of the peripheral motor neuron injury, before the establishment of muscle atrophic changes. After the introduction of exercise programs, one can continue with the selective stimulation of the affected muscles.
Functional electrical stimulation (FES)	This is a technique that uses electric current to excite the nerves of the extremities affected by paralysis or in other neurological conditions. Through FES, the aim is to coordinate the activation of the targeted muscle groups, so that the resulting movement corresponds to the normally voluntary one. FES is successfully used for gait correction in patients with stroke, multiple sclerosis, cerebral palsy, etc. and also for recovery of movement in the upper limbs. The benefits of using SEF are: • improving muscle tone and preventing muscle atrophy • reduction of spasticity • improving blood circulation and skin health • contributes to cortical remodelling.

The application of electrostimulation with the help of the equipment, is used for patients who only have F0 or F1 force, to perform the passive mobilizations, as follow:

a) stimulation of the contraction of normoinnervated muscles is carried out with rectangular currents. The patient can self-trigger the electric stimulus (intention of voluntary contraction) which simultaneously causes muscle contraction, thus realizing the recovery of the central motor image. Through this type of exercises, it is hoped that over time, progressively, the patient manages to regain control over the deficient movements.

b) in peripheral motor neuron disorders, the stimulation of totally denervated muscles is achieved with the help of exponential impulses. Tthe positioning of the affected locomotor segment is done in an anti-gravitational plane. The patient will be co-opted in carrying out the procedure, by the fact that he will have to follow and voluntarily control his movement, in a predetermined time interval (counting during the break); this is important for the restoration of motor movement engrams, necessary for the reacquisition of deficient movements.

The duration of the treatment is until the minimum F2 value is obtained on the muscle testing scale. After the introduction of physical therapy programs, the selective stimulation of the affected muscles can be continued. At the same time, it is recommended that before the electrostimulation session, a local heating procedure is done, which can be done in the case of the designed equipment, simultaneously with the exercises.

3. THE USE OF THE ROBOTIC SYSTEM

Kinesthetic memory or *Proprioception* is a sense involved in the coordination and control of movements, which tells us the position and movement of our body segments (joints) at the moment of an action. The information is received through sensors located in the nervous system and the body. Most of these receptors are located in muscles, joints and tendons. This is also the reason why kinesthetic exercises have an important role in recovery, especially in the recovery of coordination, being used in both physical and occupational therapy, [24].

The proposed equipment can be used both for coordination recovery and as a progressive or immobilization orthosis.

For coordination recovery exercises, certain equipment will be used, such as those in figure 7. The immobilizations are carried out in a functional position, so as not to restrict the movements of the neighbouring joints, such as the elbow or wrist joint.

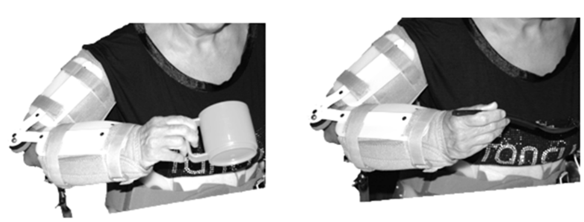


Fig. 7. Ways to recover the movement coordination

In the case of using the equipment as a

progressive elbow or glenohumeral orthosis, there is also the advantage that it does not require changing the orthosis; it will be used the electrical actuator to preserve the regained amplitudes, being able to mobilize the free articular segments so as to prevent atrophies and retractions inactivity. Compared to a cast appliance, the use of the equipment is much easier, more convenient and more efficient. The cast device is heavy, produces discomfort, the pressure exerted can lead to edema, eschar, necrosis, can generate skin irritations, leads to joint swelling after removing the cast, complex regional pain syndrome.

Muscle testing is a manual examination performed for the evaluation of muscle strength, which helps to establish: the diagnosis, the intervention program, the type of surgical intervention, the lesional level of the neurological condition and the functional prognosis. For the accuracy of the information, the muscle balance must always be preceded by the joint balance because it can be influenced by the functional state of a joint. In our country, a method developed by the National Foundation for Infantile Paralysis is used, that includes an evaluation scale from 0 to 5, whose characteristics are included in table 4, [25].

Table 4

The evaluation scale

Force 5 Normal	The muscle can perform the movement in its full amplitude, against an external force, equal in value to the normal force.
Force 4 good	The ability of the muscle to move the segment anti-gravitationally, over the entire amplitude, against an average resistance.
Force 3 acceptable	The ability of the muscle to fully mobilize the segment against gravity (without other counter-resistance), also indicates the functional minimum.
Force 2 mediocre	Allows the muscle to mobilize the segment, but with the complete elimination of gravity.
Force 1 skheched	Observing a slight tremor of the muscle, or sensing muscle contraction, by palpating the muscle.
Force 0 zero	The muscle does not perform any kind of contraction

So, based on this information, the patient's recovery program is established and with the proposed robotic system are constantly assised the movements and can be executed all types of mobilizations, presented in Table 5.

Table 5

Different types of mobilizations and their role in rehabilitation

Types of mobilizations	***The role of mobilizations in recovery***
Passive mobilization	• maintenance of normal joint amplitudes, prevention of relapses; • maintaining kinesthetic memory and stimulating the phenomenon of neuroplasticity, which is the property of the brain to change through learning; both components being favoured by repetitive exercises; • produce an activation of the circulation, achieving a pumping effect that contributes to the prevention or elimination of immobilization edema; • maintain tissue trophicity - increase the amount of oxygen and nutrients, favoring healing; • have an analgesic effect; • prevention of complex regional pain in the hand.
Passive-active mobilization	• make the transition to active mobilizations.
Active mobilization with or whithout resistance	• favours increasing muscle resistance, stretching the skin; • favours blood circulation and edema retraction; • improves muscle coordination; • improves the duration of muscle contraction.

In the case of forearm flexion/extension in patients who only have F0 or F1 force, passive mobilizations can be achieved by bringing the forearm into an anti-gravity position (at chest level) (Figure 9a), by means of the elbow orthosis, mobilized with the help of the actuator fixed between the lumbar support and the elbow orthosis, after which the patient can perform motorizations with the healthy contralateral limb, or passive mobilizations will be performed by applying the previously presented electrostimulation techniques.

If the F1 force is present (muscle contraction can be visualized/palpated), the EMG sensors sense the patient's voluntary movement and allow the joint segment to be mobilized by engaging the actuator(s), which are actuated as long as there is an EMG signal (figure 8).

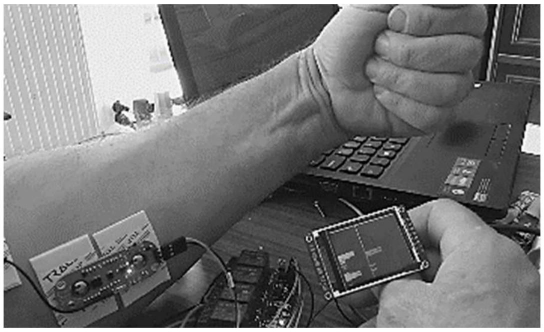


Fig. 8 Visualization of EMG signal

To achieve active mobilizations, if the patient has a mediocre F2 muscle strength, the designed equipment supports the arm and forearm in an anti-gravity position with the help of the elbow orthosis, a position from which the patient can perform horizontal abduction-adduction of the arm and flexion-extension of the forearm on the arm. This is possible due to the way the actuator is fixed on the elbow orthosis, through a spherical joint, which allows a varied range of movements (Figure 9b).

a) b)

Fig.9. a) Bringing the upper limb into the anti-gravity position; b) how to attach the actuator to the elbow brace

The types of mechanical joints, used to fix the actuator on the lumbar support, respectively on the elbow orthosis, allow the equipment to support all the desired/necessary movements. Also, the horizontal abduction and adduction movements (figure 10) who are performed in the horizontal plane around a vertical axis, as follows:

- horizontal adduction – brings the limb up to 135-140^0 in front of the chest;
- horizontal abduction – rearward facing at an angle of 30^0.

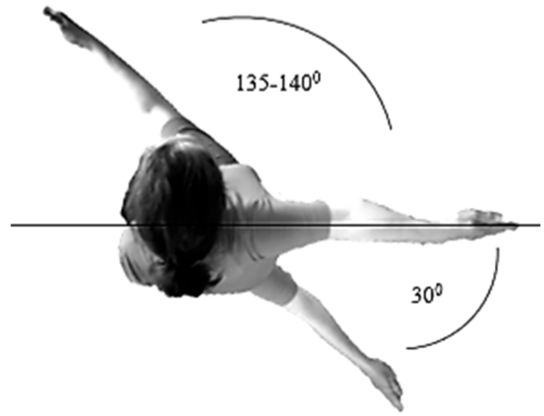


Fig.10. Horizontal abduction-adduction range of motion

The flexion-extension movements of the forearm on the arm are performed in the sagittal plane, transverse axis, having the following values: flexion – active 140^0 / passive 160^0, extension is the return movement from flexion - absolute 0^0, and in the presence of hyperlaxity, in women and children, we can have a hyperextension of the elbow 5-10^0.

Thus, from the anti-gravity position, the patient with an F2 force can actively mobilize his arm and forearm horizontally, being able to perform daily activities or recovery exercises that can also be scenarios in daily life: feeding, dressing, hygiene, etc. for the development of self-care skills and is helped by adjusting from the position of the trunk and head.

So, the equipment can be used in neurological conditions, post-traumatic, etc., and the patient using his affected limb for more time increases his strength, muscle endurance improves his kinesthetic memory, reduces recovery time and increases his self-esteem because he develops skills of self-care.

4. ANALYSIS OF DIFFERENT PATHOLOGIES

Next, some of the most common upper limb pathologies and how can be use the equipment in their recovery will be presented.

a. Recovery after stroke

The second leading cause of death and disability worldwide is stroke, [26]. The Eurostat statistics from the year regarding the repercussions of stroke on the population under

65 years old, placed Romania in an undesirable place 4, and at the world level, they even showed a significant increase in the number of young people between 25 and 44 years old affected by stroke, [27], [28]. According to a study published in 2018 in US Pharm, related to the population of the United States, it can be seen that the share of stroke in the annual incidence of neurological conditions is almost half of the cases, [29].

The spasticity developed in the upper limbs after stroke is present between 17-40% of cases, [30], [31], [32].

Functional recovery is also related to the ability of the neural tissue, which remained intact, to reorganize, taking place both in the affected hemisphere and in the contralateral one, which can also take over the deficient functions. The phenomenon of neuroplasticity, i.e. the way of reorganization of neural pathways has a decisive role in the process of functional recovery. The brain has the ability to change through learning. Repetitive therapy, being very important in regaining motor control, [33]. Thus, it is highlighted that the recovery is all the more effective the sooner it is instituted after the stroke, the progress being maximum in the first 3 months, and after the first 2 years, the disability remains irreversible.

The equipment can be used from the moment the patient is hemodynamically stable. In the initial acute stage, the first evolutionary stage, it is the flaccid/hemiplegic stage in which both voluntary movement and muscle tone are missing. Passive, then passive-active mobilizations are made.

Auto mobilization / auto passive mobilization is also recommended, as a method of protection against tissue overload, as it is easier for the patient to bear, as he can easily limit his movement, depending on the pain threshold, knowing that pain is a significant barrier in recovery. In the medium and chronic stage, active and active movements with resistance will be performed.

Also in the case of these patients, post-stroke hemiplegics, there is an increased risk of subluxation of the humeral head. In the case of other portable robotic equipment, which are of the backpack type, the shoulders are pulled, increasing the risk of subluxation of the humeral head, but in the case of the designed equipment, the load on the scapulohumeral joint is reduced, thus preventing the occurrence of subluxation of the humeral head, the upper limb being supported in a functional position from which the patient can perform daily activities or exercises, which can be scenarios from daily activities: feeding, care, hygiene, etc.

In post-stroke patients, ataxia is also common, the characteristics of which have been mentioned in relation to the importance of maintaining the body's center of gravity within physiological limits.

Also, by the possibility of permanent use of the affected limb, supported by the robotic equipment, as well through the possibility of realizing all the types of mobilizations specific to the pathology, the installation of the unilateral neglect syndrome is also avoided, because as rule, post-stroke patients forget about the affected hemi body and do not use it. [34].

b. Recovery in scapulohumeral periarthritis

This is a degenerative rheumatic condition that appears after 40 years leading to limitation of movement, the periarticular structures being affected ligaments, tendons, bursae, joint capsule.

The clinical forms of manifestation are:

- simple painful shoulder - includes various degenerative processes of the tendons accompanied by pain when moving;
- acute hyperalgic shoulder - inflammation at the level of the tendons and the subacromial and deltoid bursae, manifested by great pain and difficulty in movement;
- mixed shoulder - represents the association between a painful shoulder of tendinous origin and a limitation of movements due to antalgic muscle contracture;
- the blocked (frozen) shoulder – it is due to the inflammatory lesions of the gleno-humeral capsule and due to the aggravation, its fibrosis also occurs;
- pseudo paralytic shoulder - due to the partial or total rupture of the rotator cuff, the pain is very great, and in the case of total rupture, movements in the shoulder joint are impossible.

The treatment can be preventive, conservative (physical procedures, physical therapy) or surgical.

Depending on the diagnosis and the evolutionary stage, the robotic equipment, can be customized for: immobilizations, active-passive or, active mobilizations, also if necessary, with the possibility of thermotherapy application too.

So the equipment can be used in all pathologies that use Kinetotherapy, Thermotherapy and Electrotherapy as recovery methods.

5. CONCLUSIONS

The multitude of studies and research on the rehabilitation of the upper limb is based on the fact that it is an essential element in ensuring a good quality of life, in increasing the autonomy and mobility of people suffering from disorders at this level. Thus, the robotic systems must provide functional support, in the recovery of motor functions.

The design of the proposed robotic equipment took into account the following:

- the possibility of being adapted to a large number of pathologies, to different stages of damage and to the specific needs of each patient;
- its use should be simple, requiring a minimum training of the patient and the belongings, thus allowing its use including at home, not requiring the assistance of patients by a qualified medical staff and thus increasing the recovery time; thus reducing the pressure on the medical staff, making it possible to treat several people simultaneously;
- have a low weight and dimensions that do not inconvenience the patient, do not restrict the functionality of the free joints in the neighbouring areas and thus do not cause discomfort during therapy/activities;
- to maintain the involvement and motivation of the patient in recovery, having a positive impact on the quality of life: it increases the patient's self-esteem. He / she no longer feels a burden to those around him, develops self-care skills (feeding, dressing, hygiene, etc.) and increases his / her independence in carrying out daily activities or other activities;
- to provide visual feedback - it favours neuroplasticity and improvement of voluntary control;
- to be used in the recovery of patients with severe motor deficits, being able to be applied from the earlier phase of recovery;
- allows, as necessary, the simultaneous application of thermotherapy and electro-therapy procedures with the exercises;
- at the same time, solutions were sought, so that it could be made in variants that would allow its purchase by the widest category of patients.

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SISTEM ROBOTIZAT PORTABIL PENTRU RECUPERAREA MEMBRULUI SUPERIOR

Rezumat: Recuperarea, datorită numărului mare de persoane afectate, a necesitat dezvoltarea unor echipamente de reabilitare în strânsă legătură cu tehnologia, ponderea echipamentelor robotizate fiind în creștere. Sistemul robotizat portabil prezentat în această lucrare face parte din categoria echipamentelor robotizate adaptabile, care oferă un program de recuperare personalizabil la nevoile și patologia pacienților. După prezentarea celor mai importante caracteristici constructiv-funcționale, se justifica alegerea actuatorilor și este descrisa integrarea modulelor EMG, pentru termoterapie si pentru electroterapie. Este descrisă în detaliu utilizarea echipamentului, fiind analizate câteva patologii specifice.

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