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PREDEFINED ASSESSMENT TOOLS IN ROBOT ASSISTED PHYSICAL THERAPY AFTER STROKE

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Abstract: *Stroke is a major cause of death and a major cause of disability. Evidences in brain neurobiology suggest that early rehabilitation, at a right dose, improves recovery after stroke. The paper discusses the suitability of predefined assessment tools and gonio- respectively dynamometry for robot assisted rehabilitation. Fugl-Meyer assessment test, Action Research Arm Test and Motor Activity Log Test were compared with gonio- and dynamometry. Goniometry and dynamometry seems to be an objective evaluator-independent method at least equal with the previously presented predefined assessment tools.*

Key words: *stroke, goniometry, dynamometry, robotic rehabilitation.*

1. Introduction

Stroke is the third most common cause of death and a major cause of disability. It is defined as the sudden onset of a focal neurological deficit lasting more than 24 hours, for which other than vascular causes have been excluded (World Health Organization 2001). The areas of brain damage determine the effects of stroke [5].

Main, relevant symptoms presented by stroke patients are paralysis/paresis, dysarthria (problems of articulation in speech), hypertonia (increased muscle tone), hypotonia (decreased muscle tone), spasticity (velocity-dependent stretch reflex hyperactivity, fatigue, unilateral neglect (failure to respond to stimuli presented on the hemiplegic side) etc. Hemiplegia - the paralysis of muscles on one side of the body affecting arm, trunk, face and leg, contralateral to the side of the lesion in the brain - is the most common impairment, causing limitations of daily activities, and a decrease in the quality of life.

Secondary musculoskeletal impairments, such as contractures, subluxation of the shoulder, swelling of the extremities can occur if passive mobilization is not started as soon as possible after the onset of the stroke. Contracture is a clinical term, used to describe a decrease in passive range of motion at a joint. This might be the result either of loss in muscle length or peri-articular connective tissue, or increased stiffness in these structures. The most detrimental effect on daily activity is when muscles shorten under the circumstances when full range of motion is needed for the everyday tasks.

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In countries with a low or middle income, only a few patients with cerebrovascular disease benefit from an organized rehabilitation program, therefore the burden of chronic deficits is in increase. Affordable effective rehabilitation techniques would have a major impact [2].

According to the majority of the protocols, early rehabilitation is needed after stroke. Brain neurobiology suggests that early training at the right dose will help recovery [1]. The latter is a complex procedure, consisting of spontaneous recovery, restitution (restoring damaged tissue and impaired functions), substitution (reorganization of spared neural paths) and compensation [4].

The number of physical therapists is insufficient, and even if there would be more, the society would not be able to support them from a financial point of view. Therefore, as an alternative, the use of ultra-specialized medical robots, at least for the repetitive, stereotyped part of the rehabilitation, might be a feasible approach. Technical difficulties limit the refinement of a rehabilitation robot. At this point, these devices don't reach the complexity level of the human motion. Developing such a device has its own limits in order to remain feasible and practical. But this kind of device should be an innovative model from a biomechanical point of view.

In order to be able to comparatively assess the effectiveness of classical physical therapy and robot assisted rehabilitation, there's a need for objective, reproducible methods. Functional assessment tools fulfill the criteria for classical physical therapy and are widely used to monitor recovery, providing more or less objective measures for the implemented rehabilitation programs. Over the years, several assessment techniques and scales were developed to evaluate the status of the patient before, during, and after the rehabilitation process. The most relevant are the Fugl-Meyer Test, the Action Research Arm Test and the Motor Activity Log assessment scale, all trying to evaluate, in a holistic manner, the functional status of the post-stroke disabled patient.

The Fugl-Meyer assessment-scale is a stroke-specific, performance-based impairment index, widely accepted measure of body function impairment after stroke, being developed to be used at all ages. It consists of 5 domains, covering motor and sensory function, balance, and also range of motion and joint pain. The test might be applied routinely in hospitals or as an assessment method in research activities. It helps to determine disease severity, to describe recovery, and to plan and assess treatment [9].

The motor domain evaluates the upper and lower extremity, presenting reliability and validity indicating the motor impairment severity across different stages of recovery. Still it uses a mainly qualitative or at the best semi-quantitative, subjective, in our opinion evaluator-dependent approach. It might be a good solution for classical physiotherapy, the evaluation test being administered by the physical therapist, always by the same person, in the same manner.

The test is seemingly a reliable clinical measure to determine the severity of light touch and proprioception impairment, as parts of the sensory function. Still, there is no generally valid agreement on a consistent method to measure sensory impairment after stroke [8].

Balance, range of motion and joint pain are also evaluated, but without the use of objective, function-dedicated tool-based method. For the use of the Fugl-Meyer assessment scale, trained physical therapists are needed.

The Action Research Arm Test is another measure to assess specific changes in limb function among individuals with stroke. It focuses on the ability of the patient to handle differently sized, weight and shaped objects; therefore, it can be considered to be an arm-

specific measure of activity limitation [3]. It uses observational methods, consisting of 19 points of assessment, divided into 4 sub-tests. It assesses activities of daily living, coordination, dexterity, upper extremity function. Age limits are 13-65+ years, and there is no need to train the personnel administering the test [10]. The method carries a degree of subjectivism, dependent on the evaluator's opinion.

The Motor Activity Log is a structured interview for the hemi-paretic stroke patients, in order to assess the use of their paretic arm and hand during activities of daily living. Patients have to rate their quality and amount of movement during several daily functional tasks - use of fork, comb, pen, etc., and during gross motor activities - transferring wheelchair to car, pulling a chair into a table without sitting. For both measurement scales, items are scored from 0-5, and the outcomes are patient reported [12]. Being an interview, the results might also be subjective, and evaluator-dependent.

Goniometry and dynamometry are standard, tool-based objective measures focusing on the mechanical and dynamic abilities of the debilitated limb. These are used to precisely measure the range of motion of joints and the forces during the assessed movements. The tools are simple and the method for the measurement is standardized, this combination providing an evaluator-independent approach.

The paper is structured as follows: Section 2 presents the main objectives; Section 3 describes the used materials and methods; Section 4 presents shortly the results obtained to this time-point and discusses the benefits and disadvantages of the standardized assessment methods along with gonio- and dynamometry, and Section 5 summarizes relevant conclusions.

2. Objectives

The goal of the paper is to comparatively describe and present the advantages and disadvantages of the different methods for the evaluation of a stroke patient's status before and after the robot-assisted physical therapy. We are trying to present the main methods and to draw a parallel with our proposal.

3. Materials and Methods

Goniometric and dynamometric measurements. Goniometric measurements were obtained from more than 60 patients, the data was assessed statistically and presented in our groups previous paper [6]. The dynamometric measurements are in process and the data are subject of another paper.

Fugl-Meyer Assessment Scale, Action Research Arm Test, Motor Activity Log Test are used in this paper with a descriptive role, to compare the benefits and the disadvantages of these 5 evaluation methods. The use of the last three is questionable because of the permission, which is needed in order to use them.

4. Results - Discussion

The chosen, ongoing assessments in our project are done using goniometry for the range of motion of the limbs, and dynamometry to evaluate the degree of deficit of strength. When the robot becomes available, the precise data from measurements will be compared for assessment accuracy with the aforementioned predefined tests.

To that future moment, we have started an evaluation of subjects in order to build reliable databases of normal ranges for both gonio- and dynamometry. To this point, the range of motion of 69 patients (both males and female), aged between 40-86 years, from the Neurology and Cardiology Departments of the Municipal Clinical Hospital Cluj-Napoca was measured. The main risk factors were cardio- and cerebro-vascular. Other, mainly degenerative muscular and skeletal pathologies, with possible influences on the range of motion of joints were not taken into account, being characteristic also for the target population in the selected age group.

A standard goniometer was used to assess the angle of shoulder flexion, extension, abduction, adduction, elbow and wrist flexion and extension, forearm pronation-supination and flexion of the metacarpal-phalanx joint of the index. A stepwise, detailed presentation of the measurement method one can find presented in detail by our group [6].

Dynamometric measurements are an ongoing activity of the project, providing a continuously increasing pool of data, still under evaluation. For this purpose a hydraulic push-pull dynamometer is used.

To get a point of view regarding the standardized evaluation methods, the functional assessment tools, we are summarizing here the available instructions.

At first it should be stated that these tests are only summarized, were not used in the clinical setting, and are not allowed to be reproduced without permission.

As presented before, the Fugl-Meyer test assesses the motor and sensory impairment of both the upper and the lower limb. It should be performed in a quiet area, on an alert patient, having a mean duration of approximately 45 minutes. The needed equipment are a chair, a bedside table, reflex hammer, cotton ball, pencil, small piece of paper, small can, tennis ball, stop watch and blindfold.

The evaluation of movement requires assessment of flexion, extension and the ability of combining these movements. The non-affected side performs first, the affected side should be tested three times. If scoring is maximum already for the first and second testing then the third isn't necessary. Only verbal encouragement of the patient is permitted. Wrist and hand function is tested independently from arm.

Second, reflex activity is tested for the biceps, triceps, Achilles and knee flexor reflexes. Flexor and extensor ability of the hip, knee and ankle is also tested with the patient in supine position. The motion is rated as it follows: cannot perform (0), partial movement (1), full motion (2). Next the score is calculated from these values. The affected side is tested three times. The testing continues in both sitting and standing position, but it is not discussed here, being unpractical with a robotic device. Durig the test the patient performs scapular elevation, shoulder retraction, abduction, adduction/internal and external rotation, elbow flexion, extension and forearm supination and pronation. For the combined movements the patient performs individual movements, as follows: hand to lumbarspine, shoulder flexion to 90^0, elbow at 0^0, pronation/supination of forearm, elbow at 90°, shoulder at 0°. Out of synergy movements are tested by asking the patient to perform shoulder abduction to 90°, elbow at 0°, and forearm pronated, shoulder flexion from 90°-180°, elbow at 0°, and forearm in mid-position, pronation/supination of forearm, elbow at 0°, and shoulder at 30°-90° of flexion [11].

The Action Research Arm Test (ARAT) consists of four subtests assessing the grasp, grip, pinch and gross movement. It addresses mainly deficits caused by stroke. By passing the first item, which is the most difficult, there is no need to further assess. If the

patient fails the first two, then no other tests are needed to be performed. Otherwise, he needs to complete all tasks within the subtest. Performance on each item is scored on a 4 point scale from 0 (no movement possible) to 3 (normal performance) [13].

The required equipment consists of objects of different sizes, cricket ball, stone, jug or glass, tube, washer and bolt, ball bearing, a marble etc. The reproduction of the test is free of charge and no training of the examiner is required. Daily activity, coordination, dexterity and upper limb function is tested, and the assessment type is only observational [14].

The last chosen test is the Motor Activity Log. This test rates quality and amount of movement in stroke patients. Activities of daily living are assessed through object manipulation and the use of the arm during gross motor activities. Items are scored on a 6-point ordinal scale 0 (never) - 5(normal use) [15].

Testing the performance of rehabilitation requires, as seen previously a comprehensive approach. From the point of view of classical rehabilitation, the approach should be holistic. Still, if the goal of rehabilitation is motor function only, as in robotic rehabilitation, then the other tests are not suitable for this purpose.

Along this idea, when considering the Fugl-Meyer Assessment Scale, only the motor domain is relevant, and it uses an exhaustive mechanical evaluation, with objective measured, comparable with the accuracy of plain goniometry. On the other hand, dynamic approach is mainly semi-quantitative and qualitative, offering a less precise approach as dynamometry for each joint. The latter gives valuable information about joint pain and stiffness also. On the other hand, goniometry and dynamometry is not suitable for assessing sensory function and balance, but for our specific task it is not even required, performing the tests in a target-oriented fashion being more time- and cost-effective.

Considering all the presented data, in our opinion, these two measurement techniques are more adequate for the given task, mainly because of the more objective data - rather than the evaluator-dependent data in Motor Activity Log test and Action Research Arm Test.

Furthermore Fugl-Meyer Assessment Scale, Action Research Arm Test and Motor Activity Log Test needs a validation for the Romanian population in order to be used in research. The advantage to use gonio- and dynamometry is that there is no need for approval and validation and the obtained data are objective and reproducible, comparable with data from literature - see the preliminary report, which gives us a further proof of sustainability.

5. Conclusion

Gonio- and dynamometric approach seems to have the most valuable, cost-effective, standardized and objective approach needed to correctly assess the motor function improvement after robot-assisted rehabilitation. The above statement is purely observational. In order to have a statistical proof for this, a comparative measurement should be performed on a group of patients, an ongoing part of our research.

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