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Original Article

Algorithm for selecting clinical instruments for the assessment of walking function in post-stroke patients

DMYTRUK MYKHAILO BOGDANOVYCH[1], ROKOSHEVSKA VIRA VIKTORIVNA[2]
[1,2]Department of Physical Therapy and Ergotherapy, Lviv State University of Physical Culture, UKRAINE

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Abstract:
Aim: The study aims at improving the method of physical rehabilitation by developing an algorithm for selecting clinical tools for walking function assessment in post-stroke patients. Based on the analysis and generalization of the conventional rehabilitation techniques used for correcting the clinical tools of walking function diagnostics, the aim is to determine the model of the correct walking stereotype and walking function status. **Materials and methods**: Domestic and foreign specialized publications as well as methodological and educational literature on causes of ischemic stroke, classification of the disease courses, functional disorders, walking disorders and methods of physical rehabilitation for restoration of walking function were analysed. **Results**: An algorithm for selecting clinical tools for assessing walking function was created, including a step-by-step survey of this function. **Conclusions**: The developed algorithm for selecting clinical tools for assessing walking function makes it possible to determine major motor dysfunctions that affect the correct walking patterns and to select a group of tests effectively diagnosing walking disturbances.
Key words: algorithm, walking, stroke, rancho observational gait analysis, four-step quadrant, upper motor control test (vertical motor control test).

Introduction.

The main effects of stroke include motor disturbances and coordination disorders. According to the register of stroke, the NCN of the Russian Academy of Medical Sciences, at the end of the acute stroke period, hemiparetic syndrome incidence reaches 81%, including hemiplegia (11%), common hemiparesis (11%), moderate and non-acute hemiparesis (59%). Motor disorders are manifested in the form of paralysis, paresis of extremities, or only parts of the limb, facial muscles expression and tongue. Any motor disturbances give an impetus to a change in walking patterns. Therefore, the use of effective clinical tools for assessment of walking function is of topical importance [11, 12, 13, 14].

The research is carried out in accordance with the consolidated research plan 2016-2020 within the framework of theme 4.2, Theoretical and Methodological Foundations of Physical Rehabilitation of the Disabled with Impaired Locomotor System and Respiratory Systems. The issues of walking function post-stroke patients were studied and discussed in many scientific sources. Y.V. Flomin consideres the main features of the syndromes of walking disorders associated with paresis of muscles, spasticity or ataxia [10]. The author presents the following subtypes of pathological walking: hemiparetic walking, vestibular walking, sensational atactic walking, cerebellar atactic walking, apraxical walking and psychogenic walking. Professor Dmitry Donskoy [13] distinguishes four phases of walking: leg transfer, depreciation, rollback and repulsion. Scientists at the Rancho Los Amigos Medical Center laboratory distinguish eight biomechanical walking phases: initial contact; stage of loading the foot; middle of the reference phase; final phase of the reference phase; preparatory stage of the wave phase; the initial stage of the wave phase; middle stage of the wave phase; the final phase of the wave phase. The Rancho Los Amigos and Dr. Jacqueline Perry [6] developed the concept of critical moments of pathological walking in its eight phases. A critical moment is considered a mutual movement or a certain position that causes a significant disruption of walking in one of the eight phases.

Main materials and methods. Based on the conducted analysis, the main clinical tools for studying walking function, which are to be used in a certain sequence, have been selected.

Adequate treatment of patients using such a system allowed us to normalize the necessary vital functions in patients and led us to consider the creation of an algorithm for the selection of clinical diagnostic tools, which includes the step-by-step survey of the walking pattern.

Four Step Square (test four squares)

This test is needed to assess the patient's balance to determine patient's stability and risk of falls. The four-square test allows you to determine the coordination of the research object, which will further affect the performance of the following diagnostic tests for walking [8].

Corresponding Author: DMYTRUK MYKHAILO BOGDANOVYCH, E-mail: muxailodmutryk@gmail.com

Test method. Form a square of four sticks. Before starting the test, the patient is in the upper left square. Then the patient consistently carries out the following movements: the first square - the second square - the fourth square - the third square - the first square. The next stage of this test is the movement against the clockwise arrows: the third square - the fourth square - the second square - the first square (Fig. 1).
Test results: over 15 seconds or unsuccessful attempt mean an increased risk of falling [8].

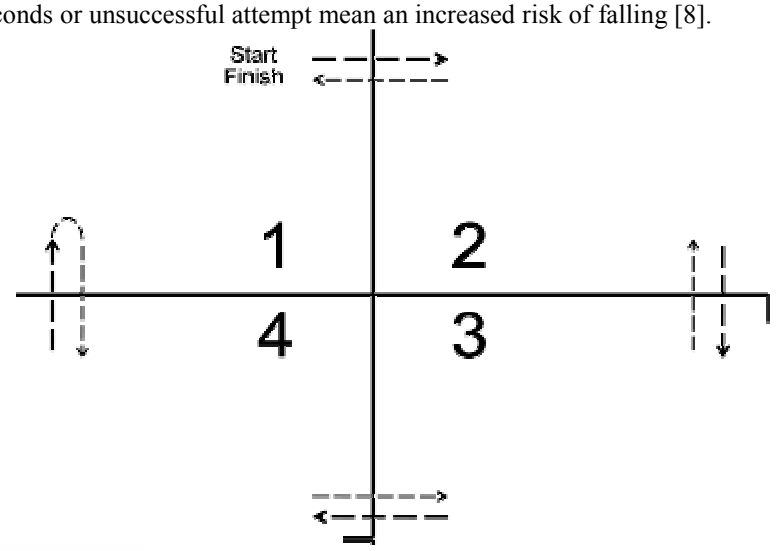

Figure 1. Four Step Square

Rancho observational gait analysis

The correct walking pattern is determined using the Rancho observational gait analysis, which involves the eight phases of the survey of this function given in Table 1 [6]. The data in the table are used to determine the algorithm of examination of patients with a violation of the correct walking stereotype. Goniometry is used to identify the involvement in the pathology of the capsular ligamentous apparatus. The Aschard scale helped us determine whether spasticity had been the initiator of movement disorders.

Rancho observational gait analysis ***Table. 1***

Big deviation Small deviation No deviation		**Weight Acceptance**		**Single Limb Support**		**Swing limb Advancement**			
		Initial Contact	**Loading Response**	**Midstance**	**Terminal Stance**	**Pre swing**	**Initial Swing**	**Mid Swing**	**Terminal Swing**
Trunk	Tilting : backward / forward								
	Tilting to the left / right								
	Rotation: backward / forward								
Hip	Raising								
	Tilt: backward / forward								
	Limited forward rotation								
	Limited rotation backward								
	Excessive rotation forward								
	Excessive rotation backward								
	Ipsilateral drop								
	Contraallateral drop								
Femur	Limited flexion								
	Excessive flexion								

	Retraction								
	Rotation: internal / external								
	Adduction / Abduction								
Knee	Limited flexion								
	Excessive flexion								
	Vibrating								
	Reshuffling								
	Quick Reshuffling								
	Valgus / varus								
	Excessive contralateral flexion								
Foot	Contact Fingers on surface								
	Contact the entire foot on the surface								
	Dropping the foo								
	Excessive planar flexion								
	Excessive dorsal flexion								
	Inversion / eversion								
	Raising the heel								
	Lack of heel lift								
	Drawing of the drop foot								
	Contralateral lifting on the fingers								
Great toe	Extension / lifting up								
	Hyper extension								
	Deformation								

To evaluate the muscle strength in the presence of selective motion and detecting the key moment of the disorder of motion, Lovett's manual muscle testing was used. In the presence of synergistic motion estimation of muscle strength, motor control of verticalization was used. The measurement of the amplitude of motion in the joints was carried out using a special device - a goniometer consisting of two armholes (shoulders) - movable and immobile, connected with a measuring scale graded from 0 ° to 360 °, or from 0 ° to 180 °. Measurements were made from the specified zero (initial) position [6].

The axis of the goniometer was superimposed on the axis of the joint; the stationary shoulder was placed in parallel with the longitudinal axis of the fixed proximal segment of the joint, while the mobile one was placed in parallel to the distal segment of the joint [6].

Determination of the recovery type. Two types of recovery were identified: selective and synergistic. The selective type is characterized by controllable, conscious, voluntary movements and lack of synergies. The synergistic type includes the spatial-temporal sequence of muscle activity, when muscles are forced to work in conjunction with each other.

The degree of muscle spasticity was estimated on the modified Ashford 6-point scale. Before testing spasticity, the method of palpation was used to determine the tone of the muscles and establish their elasticity

and compression. After that, a test of spasticity was conducted - a method of passive extension of muscles at a fast pace. [2, 3].

The final monitoring showed the expressed normalizing effect of the developed program according to the following scheme:

0 (0) - there is no increase in tone;
1 (1) - a small increase in tone, which is felt in flexion and extension of the limbs;
2 (2) - a more pronounced increase in tone, and the limb is easily curved;
3 (3) - a significant increase in muscle tone, passive movement is difficult;
4 (4) - the affected limbs are rigid during flexion and extension of the limbs.

Modified Ashworth Scale.

0 (0) - there is no increase in muscle tone;
1 (1) - a small increase in muscle tone, which is manifested by an increase or minimal resistance at the end of the range of motion, with flexion and extension of the limb;
1+ (2) is a small increase in muscle tone, which is manifested by an increase or minimal resistance for the rest (less than half) of the range of motion;
2 (3) - a more pronounced increase in muscle tone over the entire range of motion;
3 (4) - a significant increase in muscle tone, passive movement is difficult;
4 (5) – the effected limbs are rigid during flexion and extension [2, 3].

Manual muscle testing (MMT) was carried out by Lowett's method and provided for the exercise of the force of the muscle based on three principles:

• motion at full amplitude against gravity with average (score 4) or maximum (score 5) resistance at the end of the motion amplitude;
• motion at full amplitude against gravity without resistance (score 3) or without gravity and resistance (score 2);
• palpated contraction of the muscle without movement (score 1) or without visible and palpated contraction (score 0) [1, 5].

Table 2

Lowett Test

Characteristics of muscle strength	The ratio of the strength of the affected and healthy muscle	Degree of paresis
Motion at full amplitude under the action of force with maximum external resistance	100%	absent
Motion at full amplitude under the action of force with a slight external resistance	75%	slightly
Motion at full amplitude under the action of gravity	50%	moderate
Motion at full amplitude without gravity	25%	pronounced
A muscle tension feeling during free movement	10%	rough
The absence of signs of tension during free movement	0%	paralysis

Upper Motor Control (motor vertical control)

For prediction of functional walking abilities in persons with selective controlled motion, a simple, fast and efficient clinical instrument - motor control of verticalization, which is a practical tool for assessing the strength of the hemiparetic lower limb in post-stroke patients with existing synergies, was used [4].

Criteria for evaluation of motor control verticalization were test tasks and organizational and methodical instructions.

Hip flexion. The patient is in standing position. Flexing three times the affected knee to the chest as high as possible.

Score: no movement and the patient actively flexing the thigh of less than 30 ° or performs three repetitions in more than 10 seconds - weak flexion of the thigh; the patient actively flexing the thigh in the range from 30 ° to 60 ° three times for 10 s - the average hip flexion; the patient actively flexing the hip more than 60 ° three times for 10 seconds - strong hip flexion.

Bending knee. The patient is in standing position. Flexing three times the affected knee to the chest as high as possible.

Score: no movement and the patient flexes the knee less than 30 ° or performs flexing of the knee for more than 10 s - weak flexion of the knee; the patient actively flexes his knee in the range from 30 ° to 60 ° three times for 10 s - the average flexion of the knee; the patient actively flexes his knee more than 60 ° three times in 10 seconds - strong bending of the knee.

Dorsiflexion of the foot. The patient is equal. Flexing the affected knee three times as fast as possible and above.

Score: no movement or active dorsiflexion of the foot is less than 0 ° (not to be confused with the extension of the fingers with dorsiflexion of the foot), or does the extension of the foot for more than 10 s - weak

dorsiflexion of the foot; active dorsiflexion of the foot more than 0 ° or faster than 10 s - strong dorsiflexion of the foot.

Extension of the thigh. The patient is on the affected leg, as straightforward as possible. It is necessary to raise a healthy leg and continue to stand on the affected leg.

Two physical therapists are involved; one stands on the side of a healthy limb and gives his/her hand to stabilize the patient; with the other hand fixes the patient's pelvis; the second is on the side of the affected limb and stabilizes the thigh and leg.

Score: uncontrolled extension of the trunk forward - weak hip dislocation; the patient does not have enough control of the trunk, falls backward, keeps moving forward - back, but keeps this position - the middle hip extension; the patient keeps the straight position of the trunk directly - strong hip extension.

Extension of the knee. The patient is in kneeling position (30 °). It is necessary to raise a healthy leg, keeping the flexion position of the knee on the affected limb.

Score: the patient is incapable of maintaining this position, the knee continues to move forward, which is accompanied by a detachment of the heel from the floor - weak knee extension [8]; the patient holds the weight of the body without further flexion of the knee forward, however, with the separation of the heel from the floor - the average knee extension;

The patient holds the weight of his own body on a flexed knee and, upon the request of the physical therapist, can straighten his leg to the existing amplitude of motion (knee reopening is allowed) - severe knee extension; excessive knee recurrence - it is impossible to perform a test due to spasticity of the quadriceps of the thigh;

It is impossible to test: spasticity of quadriceps muscle of the thigh; lack of ability to keep standing position.

Plantar flexion of the foot. The patient stands on his feet straight. It is necessary to raise and hold a healthy leg. Keep this position with planar flexion of the foot. If excessive planar flexion or weakness of the dorsal flexors is necessary, put a foot on the platform to compensate for this process.

Score: the patient is not able to hold his knee in a neutral position. The knee flexes and the leg moves in the direction of the dorsal flexion. The knee and the leg noticeably swaying forward - backward doing that flexion, then extension - weak planar flexion of the foot; the patient can control the knee in a neutral position of 0 ° and a foot in a neutral position of 90 ° without displacement of the tibia - the average plantar flexion of the foot; the knee of the patient is in a neutral position, the heel detached from the ground - strong plantar flexion of the foot;

Unable to test: excessive equidistant. Varus or Valgus of the foot; Extensor contracture of the knee joint [4].

Results. An algorithm for selecting clinical walking instruments has been developed, which includes a step-by-step walk pattern survey (Figure 2).

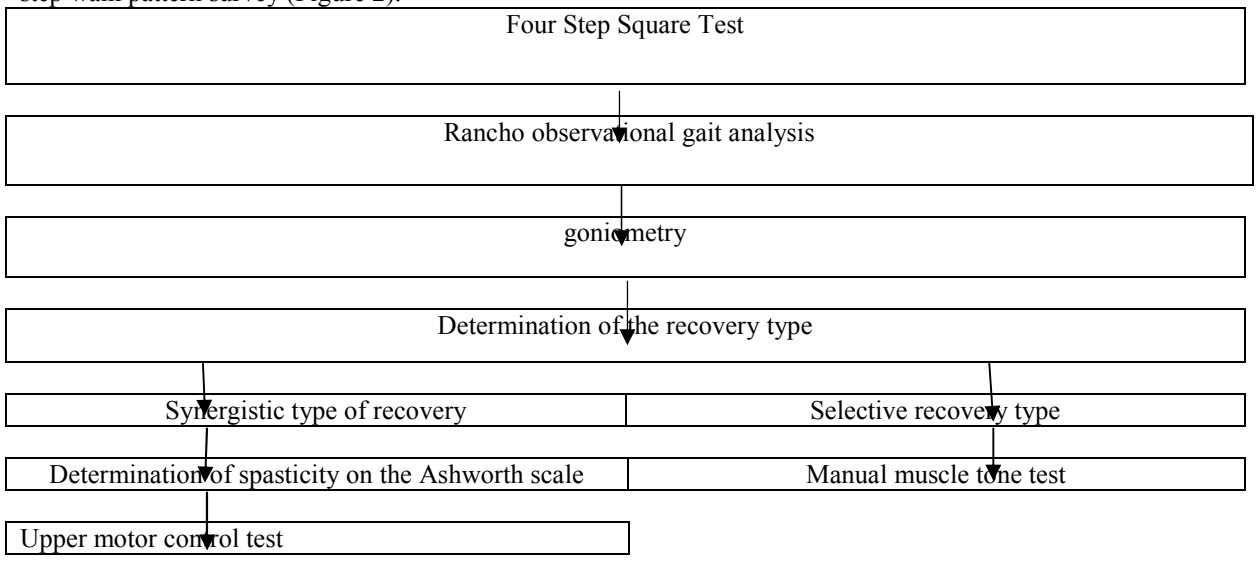

Figure 2 *Algorithm for the selection of clinical tools for the diagnostics of walking function*

Step 1 - Four Step Square Test. This test allows you to determine whether there is a disturbance in patient's balance and coordination. It tests dynamic coordination, which clinically assesses the person's ability to move forward, back, right, and left.

Step 2 - Rancho observational gait analysis. The test of walking analysis allows you to identify the main deviations and disturbances of walking;

Step 3 - Goniometry - Definition of the range of motion in the joint;

Step 4 - Define the type of recovery.

In the presence of a synergistic movement, the following tests should be performed: determine the level of spasticity on Ashworth scale and the strength of the muscles by using the upper motor control test.

The analysis showed that when using these techniques, specific muscle groups are important during standing. It is plantar flexors that stabilize the thigh and trunk during the weighting phase. Therefore, the quadriceps muscle controls the knee during its loading.

Discussion. The obtained results make it possible to make a conclusion about the effectiveness of this method in patients after a cerebral stroke and may be recommended for use in complex rehabilitation in the recovery period.

Conclusions. The chosen algorithm for selecting clinical instruments for studying walking function provides an opportunity to determine motor disturbances that impede the correct walking pattern. The test of four squares and upper motor control test gives an assessment of the balance and coordination of the patient. Upper motor control test measured muscle strength in the presence of synergistic motion, and rancho observational gait analysis determined the correct stereotype and the most likely disturbance of the walking pattern. Identification of the main motor disturbances in post-stroke patients due to the use of the algorithm we have developed will allow one to form an effective method of physical therapy. The quantitative and qualitative indices of the patients in this study are under development, and, therefore, will be described in subsequent publications. They will give an opportunity to conduct a more profound study of the results of the experiment using instrumental techniques.

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