Manual Muscle Testing for Post-Stroke Upper Extremity Assessment

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The Manual Muscle Testing (MMT) scoring system is an assessment tool used by rehabilitation physicians or physiatrists, physiotherapists, neurologists, and other clinicians who deal with the individuals' functional status. The most frequently used approach is the use of MMT to assess the grade of muscle weakness in different pathologies.

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1. Functional Diagnosis of Post-Stroke Patients' Upper Extremities

The assessment and functional diagnosis of patients represent the first step of their rehabilitation process. Evaluation helps medical practitioners to set the rehabilitation goals and to outline the physical therapy programs.

The use of standard methods or scientifically validated evaluation scales can be invaluable in maximizing the details of data collection and in reducing the time for diagnosis and goal setting. In addition to establishing the elements related to disability, the evaluation in medical rehabilitation and physiotherapy includes objective and subjective evaluation modalities that allow the clinical and functional diagnoses to be achieved. Functional assessment and diagnosis are related to daily activities (ADLs), instrumental daily activities (I-ADLs), or professional activities [1][2][3].

The most common impairments in the acute and chronic stages of post-stroke are cognitive states and motor deficits contralateral to the affected cerebral hemisphere. After stroke, there is profound neuromuscular reorganization. Depending on the brain injury site and dimensions, the affected limb either loses muscle strength or is characterized by spasticity, abnormal synergic motions with stereotyped movement patterns, caused mainly by abnormal co-activation of muscles and increased activity of antagonistic muscles [4][5].

Currently, patients are assessed mainly by clinical scales, with the Fugl–Meyer test being one of the most commonly used measures of motor impairment after stroke [6]. However, the accuracy of these clinical tests is limited by inter-rater and intra-rater reliability, and floor and ceiling effects. In addition, some of them require a considerable amount of time to perform. Clinical scales should therefore be combined with targeted neuro-biomechanical assessments to provide a more detailed description of the patient's clinical condition [3].

The functional diagnosis allows the medical practitioners to set the post-stroke patients' rehabilitation objectives, and can also provide a perspective on the future rehabilitation potential and prognosis, and on the necessary timeframe [7]. In stroke, spontaneous neuromotor recovery is known to occur approximately three months after the incident, so the ability to recover from severe neuromotor impairment differs from patient to patient, depending on the type of stroke, the capacity of spontaneous neurorehabilitation, early treatment, and early application of the rehabilitation protocol. There is a big difference in terms of evolution and prognosis between a patient who had a recent episode of stroke and is referred to rehabilitation in the sub-acute phase, and a patient who had a stroke two years ago, who is already in the chronic phase and has not benefited from early rehabilitation [8][9][10].

The medical history and physical examination of post-stroke patients, in addition to the continuous updating of the literature in the field of UE assessment and rehabilitation by physicians, represent added medical value. Medical rehabilitation and physical therapy aim to provide safe, efficient, and high-quality care and rehabilitation services to improve the health and

function of individuals. Therefore, the use of evidence-based treatments, performance scales, and globally defined standards in physical medicine is critical to the development of a valuable and robust healthcare system [11] that is patient centered.

When used appropriately by clinicians who have the necessary skills, validated measurement tools, even in adapted forms, are part of the improvement process of assessment and diagnosis in the context of rehabilitation development. In clinical research, the greatest advantage is that they provide clinicians and researchers with data and meaningful indicators for clinical practice and decision making [12][13].

2. Manual Muscle Testing Scoring System and Its Patient-Customized Variations

Manual testing of muscles is performed with the hands of the therapist or physician, isokinetic machines, and other portable devices. However, isokinetic machines and dynamometers used for more objective muscle tests are still too expensive or burdensome for clinical use, although these devices are valuable for research purposes [14][15]. The Manual Muscle Testing (MMT) scoring system is an assessment tool used by rehabilitation physicians or physiatrists, physiotherapists, neurologists, and other clinicians who deal with the individuals' functional status. The most frequently used approach is the use of MMT to assess the grade of muscle weakness in different pathologies [16]. To date, muscle strength has been assessed using Wright and Lovett's classical system developed in 1912, or with customized variants, such as:

(a) the Medical Research Council (MRC), scale which uses a numerical grading similar to the classical MMT scale, but differs from it because the 4th and the 5th forces are defined differently [15][17];

(b) the Kendall Scale, which uses a percentage gradation of the muscle strength and assesses individual muscles [14];

(c) Daniel and Worthingham's scale, which uses a five-point scale defined as normal, good, fair, poor, trace and zero, and assesses muscles that perform a joint motion, rather than individual muscles [15];

(d) Noureau and Vachon's scale [18], which comprises a more systematized notation variant, through which the differentiated distinction of the degrees of muscular strength may be made. The authors propose a grading system from 0 to 5, with 0.5-point splitting [18].

The classical MMT scoring system, also known as the Oxford Scale or Medical Research Council Manual Muscle Testing scale [15], is a six-point assessment system, as described in **Table 1**. Its development is attributed to Wright and Lovett [19]. It was first used to assess muscle strength impairments manifested during the polio outbreak in the early part of the 20th century, which are related to progressive muscle weakness followed by muscle atrophy, fibrosis and retraction, pain from joint degeneration, and fatigue [19].

Table 1. The classical Manual Muscle Testing scoring system.

Grade	Description	Criteria
0	No contraction	No contraction can be felt in the muscle
1	Trace muscle contraction	Muscle contraction can be felt on palpation but without motion
2	Poor muscle contraction	Muscle contraction and motion of the segment in a gravity discarded position (gravity minimized)
3	Muscle contraction	Full motion of the segment against gravity
4	Good muscle contraction	Full motion of the segment against gravity and moderate resistance

Grade	Description	Criteria
5	Normal muscle contraction	Full motion of the segment against gravity and maximal resistance

In 1940, Kendall and Kendall [14] improved the assessment technique by establishing specific testing positions and the "breaktest". The Manual Muscle Testing taught today incorporates Wright and Lovett's antigravity testing methods, with Kendall's refinement. Kendall points out that the examiner's skill is paramount in accurately assessing muscle strength. Grades of muscle contraction (grade 1) are assessed by comparison with the lack of muscle contraction (grade 0) based on examiner's visual inspection and perception skills. Grade 2 (weak muscle contraction) differs from grade 3 by position, grading two without the involvement of gravity, while for grading three the motion is performed against gravity; both scoring points require complete movement. However, this common clinical method of assessing muscle strength has limitations, such as poor sensitivity and diagnostic accuracy of only 78% [20] compared to technological measurement systems, for example, dynamometry [21].

Since 1940, different adaptations or customizations of MMT scoring have been made, especially in the last two decades, responding to the needs of patients with different muscle impairments. Adaptations of the MMT scale use +/− after every score to allow a more complex approximation of the developed muscle force.

A notable modified MMT scoring scale was proposed by Noureau and Vachon in 1999 [18] in their research focused onspinal cord injuries. Depending on the amplitude of motion performed by the subject, their approach split the scoring intervals into two, resulting in four additional scores: 1.5, 2.5, 3.5, and 4.5. The same scoring protocol was used in children with Spina Bifida, in 2009, by Mahony et al. [22]. Both attempts showed good reliability and a robust assessment correlation with dynamometry as an objective evaluation method.

MMT has become an assessment tool in all rehabilitation fields. However, it has higher importance in neurological pathologies because it actually assesses the ability of the muscle to respond adaptively to generate muscle response by recruiting motor units, to "reply" to the resistance of the therapist, and to keep the mobilized segment at the end of ROM. For grade five, the resistance provided by the therapist can be submaximal resistance ("make-test") or maximal resistance ("break-test"). Clinical practice highlighted that there were differences among the different specialists' assessments, caused either by the use of less rigorous techniques, by the time spent on the make test or the break test, or by the stabilization and positioning of the patients. Therefore, rigorous protocols must be used in clinical MMT assessment setting [16][20][23][24].

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