REVIEW ARTICLE

Application of the Fugl-Meyer Assessment (FMA) and the Wolf Motor Function Test (WMFT) in the recovery of upper limb function in patients after chronic stroke: a literature review

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ABSTRACT
It is estimated that 45-75% of chronic adult stroke patients have difficulty in using the hemiparetic upper limb (MS) in their daily life activities (DLAs). Functional scales are used in the practice of rehabilitation, in the search for diagnoses and prognoses, and in evaluating response to treatment. The Wolf Motor Function Test (WMFT) and Fugl-Meyer Assessment (FMA) scales are the instruments most commonly mentioned in the literature. **Objective:** The aim of this study was to review the use of the WMFT and FMA scales in the recovery of upper limb function in patients after chronic stroke. **Method:** We searched the MedLine database (PubMed) for articles published from 2000 to 2013. The PICO method was adopted as the search strategy. The descriptors used for the search were: (stroke OR cerebrovascular disorders OR intracranial arteriosclerosis OR thrombosis intracranial embolism) AND (Fugl-Meyer assessment OR wolf motor function test). Therapy/narrow was used as a search filter. **Results:** We found 181 studies, 89 of which were excluded because they did not meet the inclusion criteria or did not have a topic relevant to the review search. After selection by title and by abstract, 92 articles were fully read. Of these articles, 47 were excluded because they did not fulfil the search objective. All in all, 45 articles were reviewed. FMA is the tool most used and it was found that 80% of the studies applied this scale to evaluate responses to the different therapies. In these studies, the intervention most used was the Constrained Induced Therapy (CIT) (25%), followed by Robotics Therapy (22.2%). Although the WMFT was initially developed to assess the effects of CIT, nowadays this scale is used, after the application of other techniques, to assess the functional recovery of patients with stroke sequelae. In our survey, 44.4% of the studies used WMFT; of these, 35% assessed the effects of CIT, 15% assessed robotic therapy for the upper limbs, and 65% for different therapies. **Conclusion:** For randomized controlled trials, the FMA scale was more used to assess functional recovery in the upper limbs of chronic stroke patients, even after application of robotics therapy. However, we found that it is not the most appropriate scale to assess the same outcomes after CIT use. WMFT is the scale most widely used for functional assessment after application of CIT; it is more sensitive than FMA for bilateral therapy, and is highly applicable in virtual reality therapy.

Keywords: Stroke, Upper Extremity, Rehabilitation, Questionnaires, Review Literature as Topic

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INTRODUCTION

Strokes are a major public health problem and one of the main causes of death and long term disability.[1,2,3]

Studies estimate that its worldwide prevalence is of 5 to 10 cases per 1,000 inhabitants.[4] The incidence of stroke doubles with every decade of life from the age of 55, however, this has been changing as the presence of predisposing factors is growing and, more and more, this neurological condition affects a larger number of young people.[5,6]

Stroke is considered the most common neurological illness in clinical practice, leading to neurological deficits such as total or partial paralysis of the hemibody (hemiplegia and hemiparesis), in addition to compromising the visual, sensory, and cognitive fields, as well as communication/speech.[2,5,7]

Up to 85% of patients have shown hemiparesis immediately after a stroke, and between 55% and 75% of the survivors continued experiencing associated motor deficits, many times resulting in losses that could limit their autonomy in daily life activities (DLAs) and their quality of life.[5,8,9]

Normally, the capacity for the central control of movement shows severe impairment due to the damages caused by the stroke to the neural mechanisms that control voluntary movement. These damages lead to weakness and alterations in muscular tone and stereotyped movement synergies, which collectively limit functioning. Stroke survivors many times perform tasks through compensating movement strategies. These compensations are considered prejudicial to the recovery of the capacity for voluntary movement.[3,10]

Approximately 45% to 75% of adults who have suffered a stroke have difficulty using their hemiparetic upper limb (UL) in the DLAs during their chronic phase.[11,12] Many studies in the area of neurological rehabilitation demonstrate the incentive of techniques and protocols for intensive training aiming to improve the function of the compromised upper limb.

Functional scales are used in the rehabilitation practice for diagnostics, prognostics, and responses to treatments. The *Wolf Motor Function Test* (WMFT) and *Fugl-Meyer Assessment* (FMA) are instruments widely mentioned in the literature.[1,11,13]

The WMFT was initially developed to evaluate the effects of Constraint-Induced Movement Therapy (CIMT) in individuals with hemiparesis. The original version was composed of 21 sequenced tasks specific to the articulations involved (from the shoulder to the fingers) and level of difficulty (from gross to fine motor activity), evaluating the function of the upper limb through one or multiple articular movements and functional tasks. This test was later modified to a version with 17 sequential tasks to simplify its application. The WMFT evaluates the speed of execution of the task, quantifies the quality of movement via a scale of functional ability, and measures the shoulder prehension and flexion strength in two specific tasks.[11,12,14]

Developed by Fugl-Meyer et al,[15] the FMA was the first quantitative instrument for sensory-motor measurement in the recovery after a stroke, and it is probably the best-known and used scale in research and clinical practice. The FMA is characterized as a cumulative numerical score system that evaluates six aspects of the patient: amplitude of movement, pain, sensitivity, motor function of upper and lower limbs, and balance, in addition to coordination and speed. The motor evaluation includes measuring the movement, coordination, and the reflex activity of the shoulder, elbow, wrist, hand, hip, knee, and ankle. This scale has a total of 100 points for the normal motor function, in which the maximum score for the upper limb is 66 and for the lower limb is 34.[1,5]

In this context, the importance of correctly choosing the functional evaluation instrument for post-stroke patients is confirmed, optimizing the rehabilitation process.

OBJECTIVE

The objective of the present study was to verify the use of the *Wolf Motor Function Test* and the *Fugl-Meyer Assessment* in controlled and randomized clinical studies in the functional recovery of the upper limb in chronic post-stroke patients.

METHODS

A literature review was made searching the MedLine (PubMed) database for articles published from 2000 to 2013. The PICO method was adopted as a research strategy, it is the acronym formed by the initials of the words Patient, Intervention, Control, and Outcome. The descriptors used for the research were: (stroke OR cerebrovascular disorders OR intracranial arteriosclerosis OR intracranial embolism and thrombosis) AND (Fugl-Meyer assessment OR wolf motor function test). The search filter used was "therapy/narrow".

The selection of articles followed the following inclusion criteria:

1. articles were published in English or Portuguese;
2. they used the WMFT and/or FMA scales in the methodological procedures;
3. sampled individuals were over 18 years of age;
4. chronic stroke (≥ 3 months) was the profile for time of lesion;
5. clinical tests were the type of study; and
6. the studies evaluated the effect of a rehabilitation technique having the functioning of upper limbs as the outcome.

Articles were excluded in the following situations:

1. isolated effects of medication therapy and/or surgical procedures;
2. ongoing studies;
3. acute or subacute stroke for the time of lesion;
4. studies that had no relationship to the function of the upper limbs; and
5. studies of low quality (JADAD < 3).[16]

After the selection, the articles included were read completely and evaluated through the JADAD scale, which has a score from 1 to 5. The studies were classified as having good quality, for JADAD ≥ 3 and low quality for JADAD < 3.

The descriptive statistic was presented in the form of frequency (%), average (A), and standard deviation (SD). The data obtained was tabulated in spreadsheets in the Microsoft Office Excel® 2007 program.

RESULTS

After searching the Medline database, 89 of the 181 studies found were eliminated for not meeting the inclusion criteria or for not having a theme relevant to the study. After selecting by title and abstract, 92 articles were read completely. Of those, 47 were excluded for not addressing the objective of the present study (Table 1); overall, 45 articles were reviewed. The organizational chart below details the selection process of the studies (Figure 1). The summary of the studies is described in Table 2.

Table 2 below details the reasons for exclusion from the studies that did not enter in this review.

Table 1. Exclusion criteria of articles

Reasons	Included (45)	Excluded	Excluded (%)
JADAD (< 3)	-	20	13.16
Sub-acute/acute stroke	-	45	29.61
In progress	-	3	1.97
Not available online	-	5	3.29
Lower limb evaluation	-	16	10.53
Divergent outcome	-	34	22.37
Different language	-	15	9.87
Other types of study	-	4	2.63
Published before 2000	-	6	3.95
Did not use scales	-	4	2.63
Total	-	152	100.00

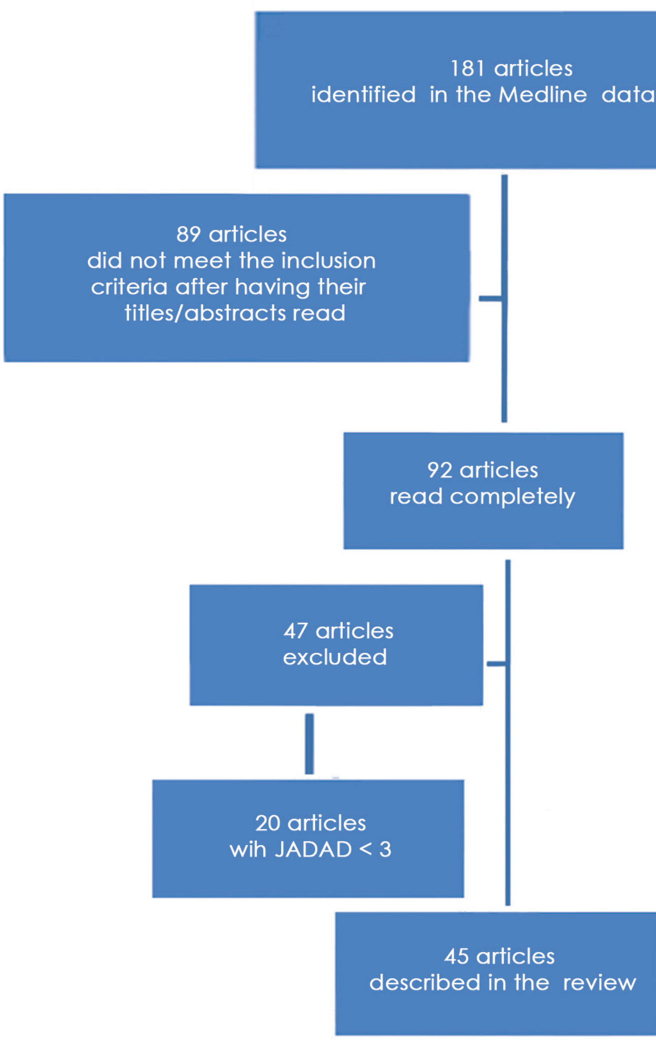

Figure 1. Organizational chart of the study

The quality classification of the studies in the JADAD scale that scored ≥ 3 and the countries where the studies were developed are described in Tables 3 and 4, respectively.

According to the inclusion criteria, all the reviewed articles used the WMFT and/or the FMA. Many studies also used other scales. The scales used are described in Table 5.

In all, 23 types of therapy were applied in the articles, combined with conventional therapy or not (Table 6).

The average time of treatment was 35.47 ± 26.77 days, with an average of 5.12 ± 2.21 days per week. The average age of the population in the studies was 60.75 ± 3.68 years.

DISCUSSION

In order to better understand the impact of strokes, it is important to incorporate evaluative measurements of the disabilities provoked by this condition. In recent years, functional evaluation scales have been developed and used in rehabilitation and in research for diagnostics, prognostics, and responses to treatments. Physiotherapeutic evaluation uses functional scales to monitor the clinical evolution and recovery of the patient with stroke sequelae. Normally, it measures sensory-motor function impairments, especially the independence in the DLAs.[1,2,62]

In our research, we found predominance in the use of the FMA tool. We found that 80% of the studies used this scale to evaluate the responses to different types of therapies. In those studies, the most used intervention was CIMT (25%), followed by robotics therapy (22.2%).

The FMA is the preferred measuring scale for studies, for its validity has already been established. The scale was accepted internationally due to its easy application and appropriate measuring of motor recovery in rehabilitation. The instructions are relatively direct and simple and the evaluation does not demand any special equipment, contrary to other evaluation scales.[1,63] In addition, studies on the validation of the FMA have clearly shown a high intra-observer and inter-observer reliability, among chronic patients as well as in acute post-stroke patients.[64]

When compared to other scales such as the Functional Independence Measure (FIM) and Functional Test for the Hemiplegic Upper Extremity (FTHUE), the FMA was the most effective in evaluating functional recovery after the application of FES on the impaired limb

Table 2. Summary of the articles

Author and Year	Country	Evaluation Instrument	Therapy
Wu CY et al. 2013[17]	Taiwan	FMA	Conventional, CIMT
Linder SM et al. 2012[18]	USA	FMA, WMFT, ARAT, SIS	Conventional, Robotics
Hsieh et al. 2012[19]	Taiwan	FMA, MAL, SIS, MRC	Robotics
Zhuang LX et al. 2012[20]	China	FMA, Barthel	Conventional, Acupuncture
Han C et al. 2013[21]	China	FMA, ARAT, Barthel	Conventional
Jeon HS et al. 2012[22]	Korea	FMA, BBT, ARAT	Conventional, SaeboFlex orthosis
Nilsen DM et al. 2012[23]	USA	FMA, JTHFT, COPM	Conventional, Mental practice
Wu CY et al. 2012[24]	Taiwan	FMA, MAL, SIS, MAS	Conventional, Robotics
Page SJ et al. 2012[25]	USA	FMA, AMAT, ARAT, BBT	RTP, ESN
Huseyinsinoglu BE et al. 2012[26]	Turkey	WMFT, MAL, FIM, MESASP	Bobath, CIMT
Wolf SL et al. 2011[27]	USA	WMFT, MAS, SIS	Conventional, Botulin Toxin
Kiper P et al. 2011[28]	Italy	FMA, MAS, FIM	Conventional, RFVE
Conroy SS et al. 2011[29]	USA	FMA	Robotics
Liao WW et al. 2012[30]	Taiwan	FMA, FIM, MAL, ABILHAND Scale	Conventional, Robotics
Bolognini N et al. 2011[31]	USA	FMA, MAL, JTHFT, Barthel	Transcranial stimulation, CIMT
Hsieh YW et al. 2011[32]	Taiwan	FMA, MRC, MAL, ABILHAND Scale	Conventional, Robotics
Page PJ et al. 2011[33]	USA	FMA, ARAT	Mental practice, Specific task
Wu CY et al. 2010[34]	Taiwan	FMA, ARAT, MAL	CIMT, Bilateral therapy
Lindenberg R et al. 2010[35]	USA	FMA, WMFT	Conventional, Brain Electromagnetic Stimulation
Michielsen ME et al. 2011[36]	Holland	FMA, ARAT, ABILHAND Scale, EQ-5D	Mirror therapy
Wu CY et al. 2011[37]	Taiwan	WMFT, MAL	CIMT, Bilateral therapy
Globas C et al. 2011[38]	Switzerland	FMA, WMFT	Conventional, Bilateral therapy, Auditory rhythmic stimulation
Whitall J et al. 2010[39]	USA	FMA, WMFT	Conventional, Bilateral therapy, Auditory rhythmic stimulation
Saposnik G et al. 2010[40,41]	Canada	WMFT, SIS, BBT	Virtual reality, Recreational therapy
Lo AC et al. 2010[42]	USA	FMA, WMFT, SIS	Conventional, Robotics
Lin KC et al. 2010[43]	Taiwan	FMA, FIM, MAL	Conventional, Bilateral therapy
Lo AC et al. 2009[44]	USA	FMA, WMFT, SIS, BBT	Conventional, Robotics
Chae J et al. 2009[45]	USA	FMA, AMAT	FES
Lin KC et al. 2009[46]	Taiwan	FMA, MAL, SIS, FIM	CIMT, Bilateral therapy
Chan MC et al. 2009[47]	Hong Kong	FMA, MAS, FTHUE, FIM	Conventional, FES, Bilateral therapy
Lin KC et al. 2009[48]	Taiwan	FMA, FIM, MAL, SIS	Conventional, CIMT
Park SW et al. 2008[49]	Korea	FMA, WMFT, MAL, MAS	CIMT, Repeated tasks
de Kroon JR et al. 2008[50]	Holland	FMA, ARAT	Electrical Stimulation
Page SJ et al. 2008[51]	USA	FMA, ARAT, MAL	Conventional, CIMT
Wolf SL et al. 2008[52]	USA	WMFT, MAL, SIS	CIMT
Malcolm MP et al. 2007[53]	USA	WMFT, MAL, BBT	Conventional, CIMT
Page SJ et al. 2007[54]	USA	FMA, ARAT	Mental Practice
Fischer Hc et al. 2007[55]	USA	FMA, WMFT, BBT, RLA	Conventional, Pneumatic Orthosis
Richard L et al. 2006[56]	USA	WMFT, MAL	Conventional, CIMT
Wolf SL et al. 2006[57]	USA	WMFT, MAL	CIMT
Pang MY et al. 2006[58]	Canada	FMA, WMFT, MAL	Conventional, Therapeutic Groups
Kondziolka D et al. 2005[59]	USA	FMA, SIS, ARAT	Conventional, Neuronal Transplant
Nadeau SE et al. 2004[60]	USA	FMA, WMFT, MAL, BBT	Donepezil, CIMT
Page et al. 2004[61]	USA	FMA, ARAT, MAL	Conventional, modified CIMT

AMAT: Arm Motor Ability Test; RTP: Repetitive task specific practice; ESN: Electrical Stimulation Neuroprothesis; CIMT: Constraint-Induced Movement Therapy; RFVE: Reinforced feedback in virtual environment; FES: Functional Electrical Stimulation; FMA: Fugl-MeyerAssessment; WOLF: Wolf Motor Function Test; ARAT: Action Research Arm Test; MAL: Motor Activity Log; SIS: Stroke Impact Scale; BBT: Box and Block Test; FIM: Functional Independence Measure; MT: Mirror Therapy; BRS-H: Brunnstrom Hand Manipulation; MRP: Motor Relearning Program; JTHFT: Jebsen-Taylor Hand Function Test; RLA: Rancho Los Amigos; COPM: Canadian Occupational Performance Measure; SBT: Sirigu Break Test; MAS: Modified Ashworth Scale; MESASP: Motor Evaluation Scale for Arm in Stroke Patients; AMPS: Assessment of Motor and Process Skills; MSS: Motor Status Scale; MRC: Medical Research Council; EQ-5D: EuroQol Group Index; FTHUE: Functional Test of the Hemiparetic Upper Extremity.

Table 3. Classification of the studies according to JADAD

JADAD	N	%
3	20	44.44
4	16	35.56
5	9	20.00
TOTAL	45	100.00

N: Total number of articles evaluated (≥ 3 good quality)

Table 4. Countries related to the development of the studies included

Countries	N	%
Taiwan	10	22.22
USA	22	48.89
Canada	3	6.67
China	2	4.44
Holland	2	4.44
Korea	2	4.44
Hong Kong	1	2.22
Turkey	1	2.22
Italy	1	2.22
Switzerland	1	2.22
Total	45	100.00

N: Total number of articles evaluated

Table 5. Scales used in the articles

SCALES	N	%
FMA	36	26.47
WMFT	20	14.71
ARAT	10	7.35
MAL	17	12.50
SIS	10	7.35
BBT	8	5.88
FIM	3	2.21
Others	32	23.53
Total	136	100.00

FMA: Fugl-Meyer Assessment; WOLF: Wolf Motor Function Test; ARAT: Action Research Arm Test; MAL: Motor Activity Log; SIS: Stroke Impact Scale; BBT: Box and Block Test; FIM: Functional Independence Measure

of chronic stroke patients.[44] In contrast, Lin et al.[46] explained that the use of the FMA was less effective in evaluating functional recovery after the application of CIMT, when compared to other scales such as the FIM, Motor Activity Log (MAL) andthe Stroke Impact Scale (SIS).[46]

The WMFT is another instrument also widely used to evaluate the function of the upper paretic limb in post-stroke adults. It is a scale that evaluates motor deficit through quantitative variables, performance in time, and concurrent fine coordination and fluidity, among other clinically relevant characteristics.[11,65]

The test consists of 17 tasks that must be done with the limb impaired by paresis. Each one of the tasks is timed so as to evaluate the dexterity of the patient in the execution of each activity, comparing the median of the times registered for each one of the tasks. These tasks must be filmed with a camera placed at a standard position and distance, and the score is given based on an analysis of the videos. Video observation has shown to be a reliable means to evaluate time and quality of movement.[11,66,67]

Despite the WMFT having been initially developed to evaluate the effects of CIMT, nowadays it is used to evaluate the functional recovery of patients with stroke sequelae after the interventions. In our research, 44.4% of the studies used the WMFT, and of those, 35% evaluated the effects of CIMT, 15% the upper limb robotics therapy, and 65% used different therapies. In the Saposnisk et al.[40] study involving the Virtual Reality technique, the WMFT showed more sensitivity when compared to the other scales used, such as BBT and SIS. This growth and expansion in the use of the WMFT may be justified for it including a gamut of movements useful as much in clinical evaluation as in research.

Whitallet al.[39] compared the functional benefits promoted by the Bilateral Therapy and CIMT techniques by using the WMFT and FMA scales. Both scales showed improvement of the paretic upper limb function of patients with chronic stroke. However, the WMFT showed more quantitative significance when compared to the FMA. According to Pereira et al.[11] the FMA evaluates only movement components, while the WMFT is the only test that combines time and quality measurements in the execution of the movement, in isolated movements of specific articulations as well as in complex functional tasks, being an evaluation applicable to patients with various levels of impairment. Other advantages of the WMFT are that it also includes a bimanual task and uses common daily materials, in contrast to the ARAT, which uses wooden cylinders and blocks, materials with little environmental validity for they are not real objects in the daily life.

In a comparative study on sensitivity and validity of the FMA, WMFT, and ARAT scales, Hsieh et al.[68] verified that the FMA and the WMFT showed more sensitivity to detect functional gains of the upper limb in patients who underwent rehabilitation after a stroke. In that study, the subjects were randomized to receive three types of rehabilitation: CIMT, bilateral manual therapy, and conventional therapy; however, there was no correlation between the sensitivity of the scales and the type of therapy.

Although the FMA and WMFT scales evaluate domains concerning the upper limb function, currently studies have been using an association of broader scales, such as the FIM, which includes, for example, the evaluation of the patient's cognitive aspects, expanding the observation of potential therapeutic outcomes. The FIM has been widely used to evaluate independence in the DLAs of patients with stroke sequelae.[68,69]

The FIM was developed in 1986 by Granger et al.[68] and validated in Brazil in 2000 by Riberto et al.[70] representing good cultural equivalence and reproducibility. It is widely used and internationally accepted as a functional evaluation measurement.[2,10] This instru-

Table 6. Therapies applied in the studies

THERAPY	N	N (%)	FMA	WMFT
Conventional	26	30.95	24	9
Constraint-Induced Movement Therapy	15	17.86	9	7
Robotics	8	9.52	8	3
Bilateral therapy	7	8.33	6	3
Mental practice	3	3.57	3	0
Orthosis	2	2.38	2	1
Transcranial stimulation	2	2.38	1	1
Auditory Rhythmic Stimulation	2	2.38	2	2
Virtual reality	2	2.38	0	2
Recreational therapy	2	2.38	0	2
FES	2	2.38	2	0
ESN	1	1.19	1	0
Bobath	1	1.19	0	1
RFVE	1	1.19	0	1
Botulin toxin	1	1.19	0	1
RTP	1	1.19	1	0
Specific therapy	1	1.19	1	0
Acupuncture	1	1.19	1	0
Electromagnetic brain stimulation	1	1.19	1	1
Mirror therapy	1	1.19	1	0
Repeated tasks	1	1.19	1	1
Electrical stimulation	1	1.19	1	0
Exercises, therapeutic groups Upper and Lower Limbs	1	1.19	1	1
Donepezil	1	1.19	1	1
TOTAL	84	100.00	67	37

FES: Functional Electrical Stimulation; ESN: Electrical stimulation neuroprothesis; RFVE: Reinforced feedback in virtual environment; RTP: Repetitive task specific practice

ment was developed to measure functional capacity through a seven-level scale that represents the degrees of functioning, ranging from independence to dependence. The classification of an activity in terms of dependence or independence is based on whether an individual needs to be assisted by another person, whether that help is necessary, and how much so. The FIM is an instrument that evaluates functional independence, regardless of the physical, communicative, functional, or emotional sequelae, among others shown by patients.[2,10,67]

Nevertheless, the literature still needs instruments that evaluate the individual more generally, in all his or her complexity, including the environment in which the patient is inserted and the other aspects related to their functional state. Currently, the International Classification of Functioning, Disability and Health (ICF) is regarded as an instrument capable of including functional aspects associated to contextual factors (environmental and social),[71,72] and to allow the standardization and unification of the professional language in the functional classification of individuals, healthy or not. The ICF defines the domains of health and the domains related to health. They are described from the perspective of the body, of the individual, and of the society in two essential parts: (1) Functions and Structures of the Body, and (2) Activities and Participation. The ICF also relates the environmental factors that interact with all these concepts. In that sense, the instrument allows the registration of useful profiles of the functioning, disability, and health of the individuals in various domains.[73]

The ICF has concepts coherent with some specific scales for post-stroke patients.[74] Using the ICF in 2004, Geyh et al.[75] developed a specific Core Set for patients with stroke sequelae, the result of a consensus among 36 specialists from 12 different countries. In the study by Paanalahti et al.[76] the ICF (stroke core set) was applied to 22 chronic post-stroke patients to evaluate their prognoses, comparing them with the improvement prospects reported by the patients themselves. According to the score of the codes, it was seen that the ICF correlated with the reports in all the patients' aspects, including functioning.

The ICF is a very recent classification and is still evolving. Although promising, its use in clinical practice is not completely consolidated. Studies are being developed to assure its employment and efficacy in the functional evaluation and classification of patients, including those with stroke sequelae.

As to the scales and/or instruments for evaluating functional recovery, another important characteristic is that the majority of these instruments does not consider the life history of the patient or his or her abilities and affinities.

The therapy chosen can either generate a positive impact, if there is a motivational link to the proposed intervention, or a negative impact, if the activity is neither pleasurable nor interesting to the patient. For a higher effectiveness of the rehabilitation process and functional recovery evaluation, therapists must be aware of the patient's functioning in their daily context involving cognitive and social aspects. The patient must acquire the capacity to plan and organize his or her daily life activities and to recover a place in society.

CONCLUSION

The Fugl-Meyer Assessment was the most widely-used scale to evaluate the functional recovery of the upper limb in chronic stroke patients, even after the application of robotics therapy. However, we confirmed that it was not the most suitable scale to evaluate the same outcomes after the use of CIMT. In contrast, the WMFT was the most widely used instrument for functional evaluation after CIMT. The test was more sensitive than the FMA in bilateral therapy, in addition to it being highly applicable to virtual reality therapy.

More comprehensive scales such as FIM, which evaluates the functional capacity and independence for daily life activities, and the ICF, which includes functional aspects associated with social and environmental factors, are being more and more studied and used and are gaining more prominence in the evaluation of functional recovery of chronic stroke patients.

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