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Relationship between Motor and Somatosensory Function of the Upper Extremity in Hemiparetic Stroke Patients

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Abstract : Background. An intact somatosensory system is important for the recovery of motor function after stroke. **Purpose.** This study evaluated the relationship between motor and somatosensory function outcome measures of the affected upper extremity in hemiparetic stroke patients, in the sub-acute phase. **Method.** Fifteen hemiparetic stroke patients in the subacute phase participated in this study. The Fugl-Meyer Assessment of the Upper Extremity (FMA-UE) and the Nottingham Sensory Assessment (NSA) scales were used to evaluate both motor and somatosensory function of the affected upper extremity in stroke patients. **Results.** There was strong positive correlation between the sensory domain of the FMA-UE and the NSA overall score **(ρ=-0.884, p= 0.0001)** in hemiparetic stroke patients in sub-acute phase. Also, no significant correlation was found between the FMA-UE and NSA total scores **(ρ=-0.182, p= 0.517)**. **Conclusion.** Both the sensory domain of the FMA-UE and the NAS can be used to evaluate somatosensory function of the affected upper extremity in stroke patients.
Keywords: stroke, sub-acute phase, upper extremity, somatosensory deficits, Fugl-Meyer Assessment of the Upper Extremity (FMA-UE), Nottingham Sensory Assessment (NSA).

Introduction

Stroke is a major cause of impairment and functional disability in millions of people worldwide [1, 2, 3, 4, 5] . A stroke, or cerebrovascular accident (CVA), is a rapid loss of brain function due to disturbance of the blood supply going to the brain[6].

Common upper extremity (UE) impairments after stroke include paresis, loss of fractionated movement, abnormal muscle tone, and/or changes in somatosensory function. These impairments are caused by direct damage to the primary motor cortex, the primary somatosensory cortex, secondary sensorimotor cortical areas, subcortical structures, and/or the corticospinal tract[7, 8 ,9 ,10].

Motor impairment after stroke is common. Upper extremity weakness post stroke occurs in 70-80% of patients, and is persistent in 40% of patients[11,12]. Nearly 20% of these patients regain part of their motor functions in the subsequent months and 50-60% remain with chronic motor disorder [3,13]. This includes balance, timing and co-ordination, and loss of strength and/or spasticity in the affected limbs[3].

Deficits in sensory abilities, are reported in 11-85% of cases, [14,15] 65% of cases, [16,17] or 85% [17, 18] of cases. This variability is due to differences in evaluation procedures and the definition of sensory impairment [17, 19].

Presence of an intact somatosensory system is important for motor recovery after stroke [20, 21]. Stroke patients with only motor disturbance have a better prognosis than patients with both sensory and motor disturbances [20, 22, 23]. Somatosensory deficits in the upper extremity results in problems with object recognition and manipulation, loss of motor control and difficulty in controlling hand function during reaching [20, 24, 25].

Gaining motor control of the affected upper extremity is important to enable patients return to normal activities of daily living [20, 26]. **Tyson et al.** [27] postulated that the severity of deficits after a stroke correlates with sensory disturbances, but not necessarily with muscle weakness. A recommendation for further studies to examine the correlation between sensory and motor deficits after stroke was put in consideration.

Choosing a functional outcome method is important in the design and execution of different clinical trials, with different purposes [28, 29]. Outcome measurements should be valid, reliable, sensitive to change and feasible to use in the given setting. It should be standardized, with explicit instructions for administration and scoring [30, 31].

For optimal stroke rehabilitation outcomes and in randomized, clinical trials (RCT), selection of outcomes measures with psychometric properties based on a conceptual framework of health and disability, such as the International Classification of Functioning, Disability, and Health is mandatory [29, 32].

One of the most recognized and clinically relevant measures of body function and impairment after stroke is the Fugl-Meyer Assessment (FMA)[29, 33]. The Fugl Meyer Assessment has been reported to have excellent reliability and validity[34, 35, 36, 37, 38, 39, 40, 41].

In this study, the Fugl-Meyer Assessment for the Upper Extremity (FMA-UE) was used. The motor domain of the FMA-UE has been established for being reliable and valid, as an indicator of motor impairment severity across different stroke recovery time points[29, 42, 43].

In the Fugl-Meyer Assessment for the Upper Extremity, greater motor severity is indicated by lower FMA-UE motor scores and this correlates with lower functional ability, such as spontaneous upper extremity use in activities of daily living [29, 44].

A study using motor-evoked potentials and diffusion tensor imaging demonstrated that the FMA-UE motor score was a reliable clinical measure associated with corticospinal tract integrity and prognosis for motor impairment recovery after stroke [29, 45] . It is possible to demonstrate that the FMA motor score can be used as a clinical measure that indicates white matter damage in corticospinal tract fibers[29, 43].

The sensory domain of the FMA is rarely used in clinical practice or in clinical trials even though sensory loss is a predictor of poor functional recovery after stroke[29, 46] . It evaluates [30, 33] light touch and position sense of the thumb, wrist, elbow and glenohumeral joint in the upper extremity. Thus it measures limited modalities of sensation. Scores of each item are added together to get a total score. One study of psychometric properties of this scale found it to have low to moderate reliability, validity and responsiveness, thus suggesting its clinical use in stroke patients was not supported [30, 47]. The lack of published procedures might be the cause for the low intratester and intertester reliability reported for the sensory FMA score[29, 48, 49].

Several randomized clinical trials using rehabilitation interventions have used the FMA-UE motor score either as the primary end,[29, 48, 49] or as a stroke severity stratification variable[29, 44, 50]. However, there are no published standardized procedures on using the total motor or sensory assessment scores of the UE [29, 39, 51].

The Nottingham Sensory Assessment (NAS) was developed by Lincoln, and included tests of light touch, pressure, pinprick, and temperature. It also examines tactile localization, bilateral simultaneous touch, proprioception, two-point discrimination and stereognosis[30, 52].

The Nottingham Sensory Assessment was found to have good intra-rater reliability but poor inter-rater reliability [30, 52] and was considered a lengthy scale. This led to revisions of the NSA**,** shortening the scale and producing a hierarchy of items, so that testing can be stopped if no impairment was detected in the distal part of

the extremity. The inter-rater reliability of the revised NSA was then investigated and found to be acceptable though not good[30, 53]. The stereognosis assessment within the NSA has also been investigated and found to reliable between raters [30,54]. The Nottingham Sensory Assessment is therefore a standardized outcome measure, that can be used clinically, and has acceptable reliability.

This aim of this study was to verify the relationship between outcome measures of motor and sensory function, in hemiparetic stroke patients.

Subjects and Methods

This study was cross-sectionally designed. Fifteen male and female stroke patients participated in this study. Patients were recruited from both Ain Shams Teaching Hospital, Out-Patient Stroke Clinic and Kasr Al-Ainy, Cairo University Hospital, Out-Patient Stroke Clinic. Patients were diagnosed based on a clinical neurological examination and confirmed by radiological investigations {structural magnetic resonance imaging (MRI) on the brain}. The magnetic resonance images included the following sequences T1, T2, Flair and DWI. The patients were selected according to the following inclusion criteria: age ranged from 40-65 years, a clinical confirmed diagnosis of first ever ischemic stroke causing hemiplegia or hemiparesis, side and site of lesion were confirmed using magnetic resonance imaging (MRI) sequences, post stroke duration ranged from one - six months, score on the Folestein Mini-mental state examination (MMSE) ranged from 21-30 [55], medically stable, presence of adequate comprehension of instructions during the evaluation period, absence of any cardiovascular, pulmonary, or musculoskeletal related problem that interfered with patient management.

Patients were excluded if they had a previous stroke, stroke caused by hemorrhage or traumatic brain injury, presence of degenerative neuromuscular disease, any neurological conditions or skin disorders that involved the affected upper extremity, upper extremity sensory deficits attributable to non-stroke pathology such as diabetes, or peripheral neuropathy, pre-stroke orthopaedic or neurological injury that caused somatosensory or motor impairment of the affected upper extremity, pain in the affected upper extremity that interfered with the evaluation procedures, presence of receptive (sensory) or expressive (motor) aphasia, impaired vision, presence of visuospatial or unilateral spatial neglects, uncontrolled seizure disorder, psychiatric illness including severe alcohol or drug abuse and depression.

Patient evaluation was performed at Physiocare Clinic for Physical Therapy and Rehabilitation, Nasr City, Cairo, Egypt. The study was approved by the ethical committee of the Faculty of Physical Therapy- Cairo University.

Outcome Measures

1- Fugl-Meyer Assessment for the Upper Extremity (FMA-UE) - is a comprehensive performance assessment of sensation and motor function (reflexes, volitional movement assessment, flexor synergy, extensor synergy, movement combining synergies, movement out of synergy, normal reflex assessment, wrist movement, hand movement, and coordination and speed. [33] The motor and sensory domains of the FMA-UE are scored on a 3-point ordinal scale (0 - 2, were 2 points for complete performance of the item, 1 point for partial performance of the item, and 0 for no performance of the item). The FMA- UE motor domain is used to measure voluntary limb movement. It includes (33 items, score range, 0 - 66). The FMA-UE sensory domain is used to measure limb sensation. Sensation is assessed as absent, impaired, or normal for exteroception/ light touch (2 items, score range, 0 - 4) and proprioception/ joint position (4 items, score range, 0-8) for a total sensory FM score of 12 [29].

The lowest and highest scores correspond to worse and better function, respectively. Patients with scores greater than 50 have mild affection of the upper extremity and those with scores less than 50 have moderate to severe affection [20, 56]. Scores of 33 denote moderate impairment of the affected upper extremity.

2- Nottingham Sensory Assessment (NSA). This is an outcome measure that evaluates sensation in the upper extremity in the following sensory domains: tactile sensation (pressure, light touch, temperature, pinprick, tactile location and bilateral simultaneous touch), conscious proprioception, stereognosis and two-point discrimination. The objects used in the stereognosis test are: coins of USD 0.01, USD 0.10 and USD 1.00 (real currency), a ballpoint pen, a pencil, a cup, a glass/ beaker, a comb, a scissors, a sponge, a piece of

flannel fabric. Each item of the NSA is scored from 0 (absent), 1 (impaired), 2 (normal), except for conscious proprioception, which is scored from 0 (no appreciation of movement taking place), 1 (patient indicates on each movement that a movement takes place but movement direction is incorrect, 2 (patient is able to appreciate and mirror the direction of the test movement taking place each time, but is inaccurate in its new position), to 3 (accurately mirrors the test movement to within 10°of the new test position) [30, 52].

Procedures

Prior to data collection, the purposes and procedures of this study were fully explained to each patient. After which, each patient signed a consent form. The evaluation procedure was following a standard protocol. Outcome measures were administered in a single day in the afternoon, and patients were offered rest periods between tasks to avoid fatigue. Data collection was done using a neurological sheet specifically designed for this study. The FMA-UE motor and sensory domains were administered first followed by NSA scales.

Statistical Analysis

All statistical measures were performed using the Statistical Package for Social Science (SPSS) version 20 for windows. As a prerequisite for parametric assumption, data was screened for normality. Normality assumption was assessed using the tests of normality in addition to assessing for the presence of extreme scores, and skewness and kurtosis.

Descriptive analysis using histograms with the normal distribution curve showed that the data were not normally distributed and violates the parametric assumption for the total score of FMA-UE, total score for the sensory domain of FMA-UE and total score of NAS. All these findings allowed the researchers to conduct a non-parametric analysis. So, the association between total score of FMA-UE, total score of NAS, sensory domain of the FMA-UE, and NAS was done using Spearman product-moment correlation coefficient (r) in order to determine if there is any significant relation. The level of significance was ($P<0.05$).

Results

Fifteen patients with hemiplegia/hemiparesis due to ischemic stroke participated in this study (demographic data in **table 1**).

Patients demographic data		
Demographic data		**N=15**
Mean age (range)		**54.93 (40-65)**
Mean time after stroke onset in months (range)		**2.167 (1-5)**
Gender		**8 male/ 7 female**
Stroke Characteristics	Type of stroke	**Ischemic**
	Side of hemiparesis	**7 right/ 8 left**
Folestein Mini-mental state examination (MMSE) score (range)		**28.067 (21-30)**
Fugl Meyer score	Upper extremity sub score	**85.2 (46-124)**
	Total sensory score	**9.867 (6-12)**
Nottingham Sensory Assessment (NAS)		**51.333 (20-82)**

Positive or negative p / r / strong or weak

As illustrated in figures (1 and 2), correlation between total scores of FMA-UE, total score of NAS, sensory domain of the FMA-UE, and NAS in patients with ischemic stroke were studied through the spearman product moment correlation coefficient. It revealed no significant correlation **(ρ=-0.182, p= 0.517)** between FMA-UE and NAS total scores.

On the other hand, there was positive strong correlation **(ρ=-0.884, p= 0.0001*)** between sensory domain of the FMA-UE, and total score of NAS, which means that when sensory score of the FMA-UE increase, the total score of NAS increased.

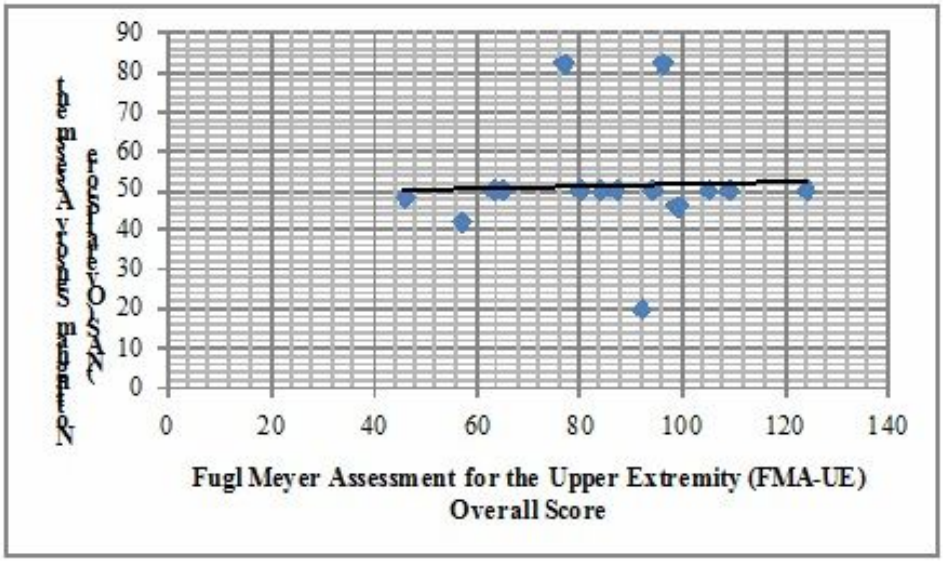

Figure 1. Scatter plot for the bivariate correlation between FMA-UE and NAS total scores in stroke patients

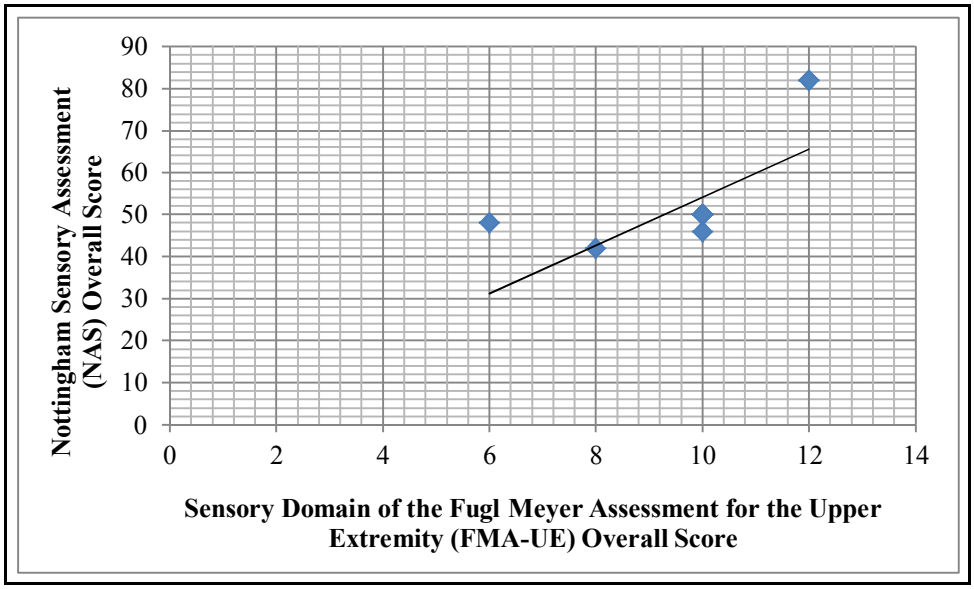

Figure 2. Scatter plot for the bivariate correlation between sensory domain of the FMA-UE, and total score of NAS in stroke patients.

Discussion

Hemiparetic stroke patients in the sub-acute phase showed both somatosensory and motor dysfunctions in the affected upper extremity. Scores on the sensory domain of the FMA-UE and NAS correlated with each other, but no correlation was found between the total score of FMA-UE and NSA overall scores.

Welmer et al. [57] evaluated 66 patients at one week post-stroke and reassessed them after 3 months and 18 months. The authors found moderate to strong correlations between hand function and fine sensory testing (light touch and positioning of the thumb) in acute and subacute stroke, but found a weak correlation in patients

with chronic hemiparesis. One possible explanation for that is that neural plasticity occurring after stroke is greatest in stroke during the acute and sub-acute stages but decrease in the chronic stage, unless proper rehabilitation is applied to promote functional reorganization and neural plasticity of the brain[58, 59].

Tyson et al. [27] used the Rivermead Assessment of Somatosensory Perception (RASP), which includes two sensory modalities, light touch and proprioception, and two functional assessments, detection and discrimination of objects. A higher deficit in tactile sensation than proprioception in hemiparetic patients during the acute phase was found. A correlation between these methods, was also found, suggesting that measuring these abilities may serve as a tool to quantify sensory recovery.

The results of this study, showed no correlation between motor function of the affected upper extremity evaluated by FMA-UE and sensory function evaluated by NAS in hemiparetic stroke patients. One explanation could be the degree of sensory affection in the affected upper extremity wasn't severe to cause limitation in motor performance of affected upper extremity. Further investigation is required to determine the degree of relationship between sensory and motor affection of the affected upper extremity using functional outcome measures.

Correlation between the sensory domain of the FMA-UE and NAS showed that both scales can be used as an outcome measure to evaluate somatosensory loss in stroke patients.

However, there is a need for further investigations, particularly to compare various instruments used for measuring and analyzing sensory-motor recovery of hemiparetic patients and to determine their use in the planning and implementation of effective rehabilitation programs. The limitations of this study were the small sample size used.

Conclusion

A standardized method to gather clinical data on sensorimotor impairment after stroke has value both for clinical practice and research investigations of recovery after stroke. This study shows that FMA-UE sensorimotor assessment can be used as a functional outcome measurement to evaluate the severity of sensory and motor impairment after stroke. The FMA-UE can be used in clinical practice or in future investigations in stroke patients. Nottingham Sensory Assessment (NAS) can also be considered a reliable measurement of sensation for the affected upper extremity in hemiparetic stroke patients in sub-acute phase.

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Conflict of Interest

The Author(s) declare(s) that there is no conflict of interest.

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