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Original Article

Physical Medicine and Rehabilitation Section

Exploring Motor Recovery Differences in Paretic Upper and Lower Extremity after Stroke: A Cross-sectional Analytical Study

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ABSTRACT

Introduction: Stroke globally cause permanent disability, often impairing upper and lower limb function. Poststroke rehabilitation focuses on enhancing functional outcomes, but limb recovery differs and has various contributing factors. Understanding these differences and their clinical and demographic relationships helps develop comprehensive or individualised rehabilitation plans for better outcomes.

Aim: To compare the motor recovery of paretic upper and lower extremities in poststroke patients and analyse their relationship with demographic and clinical factors.

Materials and Methods: This cross-sectional study was conducted at the Department of Physiotherapy, Government Medical College and Hospital, Annamalai Nagar, Chidambaram, Tamil Nadu, India. A total of 41 stroke participants were recruited through purposive sampling. The Fugl-Meyer Assessment (FMA) scale was used to evaluate both Upper Limb (FMA-UL) and Lower Limb (FMA-LL) motor recovery. Statistical tools such as t-tests and Chi-square tests were used for data analysis.

Results: The mean age of the participants was 52.15±13.51 years, with a mean stroke duration of 21.17±16.96 months. Most participants were males (63.41%) with right-sided involvement (75.6%), and the most common subtype was ischaemic stroke (78%). The mean FMA-LL score was 23.88±5.13 (70.2%), which was significantly higher than the FMA-UL mean score of 28.07±11.13 (42.5%), indicating better motor recovery in the lower extremity. Most patients had moderate to severe strokes, with 14.6% experiencing very severe impairment. Gender differences were statistically significant for lower-limb recovery (p-value=0.024), with males showing a mean score of 24.73±5.59, indicating greater recovery. Differences in stroke type were also statistically significant for lower-limb recovery (p-value <0.001), with ischaemic stroke patients having a mean score of 25.50±3.90, demonstrating greater improvements. No significant relationship was observed between age and duration of stroke with recovery patterns.

Conclusion: Lower extremity demonstrated better motor recovery than upper extremity in poststroke patients. Ischaemic and male stroke subjects showed better lower extremity recovery than haemorrhagic and female stroke survivors respectively. The results indicate the implications for customised therapeutic plans in poststroke rehabilitation.

Keywords: Cerebral haemorrhage, Gender factors, Hemiplegia, Ischaemic stroke, Treatment outcome

INTRODUCTION

Motor dysfunction is one of the most prevalent and disabling consequences of stroke and continues to be a significant cause of permanent disability globally [1,2]. Due to severe impairments in both the upper and lower extremities following a stroke, patients often face difficulties that severely impact their ability to perform regular activities and maintain independence [3]. As the global burden of stroke grows, having a thorough understanding of the intricacies and challenges associated with motor recovery is crucial for formulating effective rehabilitation strategies [4]. Interestingly, clinical data consistently indicate differences in recovery between the upper and lower extremities following a stroke [5,6]. Typically, the recovery of the upper limb is more challenging due to its involvement in fine motor skills and complex movements, in contrast to the lower limb, which is predominantly involved in gross motor tasks like standing and walking and often recovers more easily [7,8]. Although the reasons behind these differences in recovery are not completely understood, they significantly influence a patient's quality of life and recovery outcomes [9]. Motor recovery can be influenced by many factors following a stroke [10]. Patient characteristics such as gender, age, type of stroke (ischaemic or haemorrhagic), and stroke duration are all potential variables that may affect recovery [11]. Additionally, the outcome is significantly determined by the initial severity of motor impairment, acute care and the size and location of the brain lesion [12]. Understanding how these factors influence the recovery of the upper and lower extremities can provide critical information for tailoring rehabilitation strategies [13].

The FMA scale is widely recognised as the gold standard for assessing motor recovery in stroke patients [14]. Due to its comprehensive nature, the FMA is an excellent instrument for comparing recovery patterns between the upper and lower extremities [15]. The FMA allows researchers to assess and analyse variations in motor recovery across limbs, which can help in predicting outcomes and making therapeutic decisions [16]. This study intends to investigate the variations between the paretic upper and lower extremities in motor recovery among poststroke patients, considering various influencing factors. Additionally, it seeks to analyse the relationships among various clinical and demographic variables and recovery patterns, which will enhance our understanding of stroke rehabilitation [17]. The ultimate goal was to identify opportunities for focused and effective rehabilitation methods that can profoundly improve the functional outcomes and overall wellbeing of stroke survivors [18]. Therefore, the present study aimed to explore the differences in motor recovery of the paretic upper and lower extremities after stroke and to analyse their relationship with clinical and demographic factors.

MATERIALS AND METHODS

This was a cross-sectional study conducted at the Department of Physiotherapy Outpatient Department (OPD), Division of Physical Medicine and Rehabilitation (PMR), Government Medical College and Hospital, Annamalai Nagar, Chidambaram, Tamil Nadu, India, from November 2022 to April 2023. The Institutional Human Ethics Committee of Government Medical College and Hospital approved the study (Approval number: IHEC/916/2022, dated: 26.04.2023) and informed consent was obtained from all participants.

Inclusion criteria: All stroke subjects diagnosed as having a cerebrovascular accident either by Computed Tomography (CT) or Magnetic Resonance Imaging (MRI) scan in a medical report compatible with unilateral or hemispherical involvement with a duration of more than six months were included in the study.

Exclusion criteria: Participants with medical emergencies such as acute coronary syndrome, heart failure, hypertension urgency, malignancy, major musculoskeletal problems requiring intervention, other neurological conditions, significant visual and auditory problems, severe cognitive impairment or inability to understand and follow verbal commands, global sensory aphasia, perceptual dysfunction, or a history of multiple episodes of stroke were excluded from the study.

Sample size calculation: Using G*Power software (version 3.1.9.2), the sample size was calculated based on effect size, alpha level and power. The calculation follows a well-established statistical formula for determining sample size in studies comparing two independent groups (e.g., male vs. female stroke patients)

- Effect size (d=0.5): This represents the magnitude of the difference we expect between the groups.
- Alpha (α=0.05): The Type I error was limited to 5%.
- Power (1-β=0.80): We aimed to ensure an 80% probability of detecting a true effect.

G*Power applies the formula using these values:

$n=\{Z(\alpha/2)+Z(\beta)/\delta\}^2$

Where:

- $Z(\alpha/2)$ is the Z-score corresponding to the alpha level (1.96 for α=0.05),
- $Z(\beta)$ is the Z-score corresponding to the power (0.84 for power of 80%),
- δ is the effect size (0.5).

Substituting these values:

$n=((1.96+0.84)/0.5)^2=(2.8/0.5)^2=(5.6)^2=31.36$

Since this formula gives the sample size for one group, it was multiplied by 2 (for two groups: male and female stroke patients):

N (total)=2×31.36=62.72.

However, considering possible rounding and adjustments made by the G*Power software, the final total sample size required was 41 participants.

Final sample size: G*Power determined that a minimum of 41 participants was required to ensure the study has enough statistical power (80%) to detect a moderate effect (0.5) while maintaining a 5% risk of Type I error. This ensures that the study was sufficiently powered to observe meaningful differences between groups, such as male vs. female stroke patients in terms of motor recovery, without compromising the validity of the results.

Out of 63 enrolled and screened stroke participants, 41 eligible individuals were included in the study as they met the selection criteria. Twenty-two patients were not included due to recurrent stroke (n=5), inability to understand and follow verbal commands (n=8), severe aphasia (n=4) and other neurological conditions (n=5).

Study Procedure

Stroke patients attending the PMR-OPD and those previously discharged from the medicine ward were included in the study. To trace the discharged patients, their details were collected from the Medical Record Department office. Initially, 63 stroke patients were enrolled and screened for selection criteria. Out of these, 41 stroke patients who fulfilled the selection criteria were included in the study. After a thorough explanation of the study, informed consent was obtained. Demographic details such as gender, age and clinical information regarding side involvement, stroke type and duration were collected from the patients' medical records. Motor function was evaluated using FMA scale for both the paretic upper limb (FMA-UL) and lower limb (FMA-LL). The FMA is a widely used and standardised tool for assessing motor recovery in stroke subjects (Fugl-Meyer et al., 1975) [19].

The materials used for assessment included a pencil, a reflex testing hammer, a single cylindrical jar or can, a tennis ball, a goniometer, a stopwatch, a scrap of paper, an eye cover, a bedside table and a chair. The FMA scale consists of subscales for the upper and lower extremities, with 33 items for the upper extremity and 17 items for the lower extremity. The items measure reflex activity, movement inside and outside synergy patterns and coordination/speed. Scores are given on a "3-point ordinal scale" (0 indicates cannot perform, 1 indicates performs partially and 2 indicates performs fully) [19,20]. A hemiplegic's maximum FMA motor score is 0, while a normal motor performance score is 100. The optimal recovery is indicated by the motor score, which is divided into 66 points for the upper extremities and 34 points for the lower extremities. The stroke severity of motor impairment is categorised based on the total FMA motor score of 100 points as follows: (0-35 is very severe, 36-55 is severe, 56-79 is moderate and >79 is mild [21].

STATISTICAL ANALYSIS

The Statistical Package for Social Sciences (SPSS) software version 21.0 statistical software for the social sciences (IBM Corp., Armonk, NY, USA) was used to perform the full statistical analysis. Descriptive statistics were employed to analyse the clinical and demographic factors. The Shapiro-Wilk test was utilised to confirm the normality of data distribution. For comparing FMA scores between the upper and lower extremities, paired t-tests or Wilcoxon signed-rank tests were used as appropriate. The comparison of motor recovery between male and female patients, as well as between ischaemic and haemorrhagic stroke patients, was analysed using an Independent t-test or the Mann-Whitney U test. This analysis was conducted for both FMA-UL and FMA-LL motor recovery. The relationship between age and duration of the condition with motor recovery was analysed using Pearson's correlation coefficients. The level of significance was set at 5%. It is presumed that a patient's score at the time of a stroke is likely to be very poor or even zero. The percentage of recovery was calculated using the formula: Obtained or mean value÷actual value×100.

RESULTS

[Table/Fig-1] presents a consolidated view of stroke-related variables. Out of 41 stroke patients, right-sided hemiplegia accounted for 75.6%, while left-sided hemiplegia represented 24.4%. Based on the distribution of stroke type, ischaemic stroke was more common, accounting for 78% of the sample, while haemorrhagic stroke represented 22%. Likewise, the distribution of gender was skewed toward males (63.41%), while females accounted for 36.59% of the sample. The FMA-LL mean score of 23.88±5.13 indicated greater

Variables	Values
Age (years) (Mean±Standard deviation)	52.15±13.51
Duration of stroke (months) (Mean±Standard deviation)	21.17±16.96
Affected side (right/left) (%)	31 (75.6)/10 (24.4)
Stroke type (ischaemic/haemorrhagic) (%)	32 (78)/9 (22)
Gender (male/female) (%)	26 (63.41)/15 (36.59)
Severity (very severe/severe/moderate/mild) (%)	6 (14.6)/20 (40.8)/15 (36.6)/0
FMA scores (Mean±Standard deviation)	
Upper limb	28.07±11.13
Lower limb	23.88±5.13

[Table/Fig-1]: Distribution of age and duration of stroke, stroke variables and values.

recovery in the FMA-LL (70.2%) compared to the FMA-UL mean score of 28.07±11.13 (42.5).

[Table/Fig-2] shows a comparison of upper and lower limb recovery between genders. For lower limb recovery, males demonstrated an FMA-LL mean score of 24.73±5.59, which was significantly higher compared to females' FMA-LL score of 22.26±2.98 (p-values=0.024). No significant differences were observed for upper limb recovery, indicating that gender does not have an impact on upper limb recovery.

Gender	N	Upper limb Mean±SD	z-value	p-value	Lower limb Mean±SD	z-value	p-value
Male	26	28.08±12.06	0.18	0.86	24.73±5.59	2.25	0.024*
Female	15	28.07±9.73			22.26±2.98		

[Table/Fig-2]: Demonstrates FMA-UL and FMA-LL score comparison by gender (N=41).
M: Mean; SD Standard deviation; z: Mann-Whitney U

[Table/Fig-3] presents the comparison of upper and lower limb motor recovery between stroke types. For lower limb motor recovery, the FMA-LL mean score for ischaemic stroke was 25.50±3.90, demonstrating substantial improvement compared to those with haemorrhagic strokes. Although there were no significant differences in upper limb recovery between the types of stroke, appreciable differences were found in the FMA-UL mean scores.

Stroke type	N	Upper limb Mean±SD	p-value	Lower limb Mean±SD	p-value
Ischaemic	32	29.06±11.88	0.368	25.50±3.90	0.001
Haemorrhagic	9	24.56±7.45		18.11±4.99	
Mann-Whitney U test		0.9	0.368	3.36	0.001

[Table/Fig-3]: Shows comparison of FMA-UL and FMA-LL scores by type of Stroke (N=41).
M: Mean; SD: Standard deviation

[Table/Fig-4] shows that stroke duration did not had a significant correlation with FMA motor recovery scores for either the upper or lower limbs.

[Table/Fig-5] shows that the age of the patients did not have a significant correlation with FMA-UL and FMA-LL motor recovery scores.

Duration	Pearson's correlation (r)	p-value
Upper limb	0.041	0.8
Lower limb	-0.204	0.201

[Table/Fig-4]: Demonstrates relationship of stroke duration with upper and lower limb FMA motor recovery score (N=41).

Age	Pearson's correlation (r)	p-value
Upper limb	0.056	0.727
Lower limb	-0.086	0.595

[Table/Fig-5]: Illustrates relationship of age with upper and lower limb FMA motor recovery score (N=41).

DISCUSSION

The study was conducted over a duration of six months to evaluate the differences in motor recovery between the upper and lower extremities in poststroke patients. Among the 61 poststroke subjects recruited, 41 were selected for the study, consisting of 26 males and 15 females. Out of these, 31 patients had right-sided hemiplegia and 10 had left-sided hemiplegia. Stroke type data showed that 32 patients experienced ischaemic strokes and 9 suffered from haemorrhagic strokes, with an average age of 52.15±13.51 years and a duration of 21.17±16.96 months. Based on the FMA impairment severity score, 14.6% were categorised as very severe, 40.8% as severe and 36.6% as moderate. The study focuses on the chronic phase of stroke, which is defined as lasting more than six months, where recovery processes have mostly stabilised. This period is crucial because the brain's neuroplasticity and spontaneous recovery have plateaued, typically occurring between three to six months during the subacute phase [22]. Therefore, exploring patients beyond six months allows for a more precise and comparable evaluation of differences between upper and lower limb motor recovery.

The present research findings reveal significant differences in motor recovery between the paretic upper and lower limbs. The FMA-LL mean score of 23.88±5.13 indicates greater recovery in the lower limb (70.2%) compared to the FMA-UL mean score of 28.07±11.13 (42.5%). This pattern of recovery differences was consistent with earlier studies [3,6,23,24]. For instance, Jørgensen HS et al., observed that the recovery of arm function plateaued earlier than that of leg function, with an FMA-LL mean score of 24.1 compared to an FMA-UL score of 20.3. Furthermore, patients' ability to walk, which relies heavily on lower limb recovery, showed greater improvement than upper limb function [6]. The results highlight the persistent challenge of upper limb rehabilitation in stroke survivors, as noted by Nakayama H et al., whose longitudinal study involving 421 individuals with acute stroke showed similar results [5]. Verheyden G et al., also observed better recovery for lower limbs, with an FMA-LL mean score of 25±6 compared to an FMA-UL score of 20±10 [7]. Despite the functional differences between the upper and lower extremities, the upper extremity demonstrated comparatively less improvement, which may be due to the gross motor nature of lower extremity tasks such as standing and walking, which involve larger muscle groups. These movements are important for basic daily activities, making patients more motivated to perform them. On the other hand, upper extremity tasks, which involve fine motor skills requiring dexterity, precision and co-ordination, are harder to compensate for and slow down recovery. Other factors contributing to poor upper extremity functional recovery include shoulder subluxation, reflex sympathetic dystrophy and cortical thumb [9].

Interestingly, when stroke types were considered, individuals with ischaemic stroke showed significantly better lower extremity recovery. The FMA-LL mean score for ischaemic patients was 25.50±3.90, compared to 18.11±4.99 for haemorrhagic patients (p-value <0.001) [25-28]. This supports the findings of Schepers VP et al., who reported better functional outcomes for ischaemic stroke patients, with a mean FMA-LL score of 27.5 compared to 20.2 in haemorrhagic stroke patients [25]. Similarly, Kelly PJ et al., observed the same trend, with FMA-LL scores averaging 26 for ischaemic stroke, while haemorrhagic patients had an average score of 19 [27]. However, research by Paolucci S et al., found that patients with haemorrhagic stroke showed better outcomes than those with ischaemic stroke [29]. This difference of opinion suggests the need for more extensive research, with the variation possibly explained by study demographics, timing of assessments, or methods of approach.

In terms of gender, the study found that men showed overall better recovery, particularly in lower limb function, with FMA-LL mean scores of 24.73±5.59 in males and 22.26±2.98 in females (p-value=0.024). These findings were consistent with a large-scale study by Caso V et al., which found that men demonstrated superior functional outcomes, having a mean FMA-LL score of 26 compared to 21 in women. This study also reported that women had worse functional outcomes within three months poststroke [30]. However, the underlying causes of these gender differences are not clear and need to be investigated. Possible factors that could contribute to these differences include hormonal differences, muscle mass, menopause and varying responses to rehabilitation strategies.

Surprisingly, this study found no significant correlations between age or stroke duration and recovery patterns. This was unexpected, as previous studies have found age to be a predictor of stroke outcomes [31-34]. For example, Nakayama H et al., observed a negative correlation, noting that younger age was associated with better functional recovery, with patients under 65 achieving an average FMA-UL score of 30 compared to 20 in older patients [31]. Similarly, Kwakkel G et al., found that earlier rehabilitation was associated with greater outcomes, with FMA-UL scores improving by an average of 10 points compared to those with longer stroke durations [35]. The focus on the chronic phase of stroke, where recovery has mostly plateaued, may explain the lack of correlation between these variables.

The FMA scale was employed in this study, which allows for a detailed comparison of upper and lower extremity motor recovery due to its thorough and sensitive evaluation of motor function. Gladstone DJ et al., emphasised the importance of using standardised, validated tools and the FMA scale is well-suited to current research trends in stroke rehabilitation [15]. The FMA is particularly beneficial when tracking recovery patterns and analysing the success rate of treatment strategies, as it can identify minor changes in motor function. Moreover, distinguishing between neurological recovery and compensatory recovery is important for both stroke research and clinical practice. In this study, the FMA motor impairment scale was specifically used to assess true motor function recovery, apart from compensatory recovery measured by activities of daily living. Therefore, evaluating physiological recovery using the FMA is more suitable, demonstrating the value of the work being conducted at present.

For developing an appropriate rehabilitation plan for stroke patients, identifying the extent of physiological recovery is vital. Anticipating the course of recovery may help therapists design suitable therapeutic interventions. For instance, while choosing an intervention, the therapist can make more informed decisions about whether to focus on improving motor function or teaching patients compensatory techniques for their neurological deficits. Future studies on the acute and subacute phases of stroke patients are required for a better understanding of motor recovery over time. Further studies should evaluate specific therapies and standardise rehabilitation protocols, particularly for upper extremity recovery, which may help address the persistent gap in functional outcomes between upper and lower limbs in poststroke patients.

Limitation(s)

This study focused only on the chronic phase of stroke recovery (>6 months), which may not reflect the recovery seen in earlier phases. The study involved a single time-point assessment, lacking long-term follow-up assessments to determine whether the observed motor improvements were sustained over time. Additionally, recovery outcomes may be influenced by the variability in rehabilitation approaches received by the patients, which were not considered in this study.

CONCLUSION(S)

The upper extremity demonstrated significantly poorer recovery than the lower extremity in poststroke patients. Age and stroke duration were not correlated with recovery patterns. Ischaemic stroke patients demonstrated better recovery compared to haemorrhagic stroke patients, particularly in the lower extremity. Men exhibited better lower extremity recovery compared to women, though no gender differences were found in upper extremity recovery. The marked difference in recovery between upper and lower extremities demonstrated the need for tailored rehabilitation strategies that address the specific challenges of upper limb rehabilitation. Furthermore, the observed differences based on stroke type and gender suggest that personalised rehabilitation approaches may lead to improved outcomes for stroke survivors.

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