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Bimanual Coordination Deficits among Patients with Middle Cerebral Artery Stroke: A Cross-Sectional Study

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A B S T R A C T

Background: Middle cerebral artery stroke is the most common type of ischemic stroke. MCA stroke results in the motor impairments of the affected upper limb, which can lead to the disruption of the bimanual hand coordination and increase limitations in activities of daily living.

Objective: To determine bimanual coordination deficits among patients with Middle cerebral artery stroke.

Methodology: 70 patients were selected according to inclusion criteria (Middle cerebral artery stroke, 4 months post stroke, age ranging from 30 to 60 years. Exclusion criteria included the stroke of any other artery, fractures, or other pathologies affecting the upper limb function, pain, and discomfort while doing the tasks. Data was analyzed using the Statistical Package for Social Sciences (SPSS) version 26. Bimanual coordination was determined by using the ABILHAND Questionnaire. The study was done using non-probability convenience sampling. The sample size is limited to 70 participants because of the strict eligibility criteria (chronic MCA stroke, Brannstrom ≥4). While it limits external generalizability, enhances the internal validity, limits the homogeneity and allows the focused profiling of the persistent bimanual deficits. The findings will be preliminary, however clinically indicative within the context of similar tertiary care.

Results: The study assessed the bimanual coordination in 70 patients with the middle cerebral artery stroke via using the ABILHAND questionnaire. The findings revealed the mean score of 18.9 ± 10.7, markedly below the standard values, indicating the significant deficits. Tasks which required fine bimanual dexterity were perceived as most difficult, while the simpler, unimanual-sequence tasks were rated as easier. The results highlighted the substantial limitations in the self-perceived daily hand activities, underscoring need for the targeted rehabilitation strategies.

Conclusion: Bimanual coordination deficits were present in patients with Middle cerebral artery stroke, as a mean of the total score of the ABILHAND Questionnaire was lower.

Keywords: ABILHAND, Bimanual coordination, Middle Cerebral Artery, Stroke

Introduction

Middle cerebral artery stroke is an interruption of the blood flow to the areas that are supplied by MCA and is the most common type of ischemic stroke.[1] The middle cerebral artery supplies the largest area of the brain and, therefore, is associated with many neurological deficits. MCA strokes' most common characteristics are contralateral chemosensory loss and contralateral hemiparesis of the face, the upper limb, and the lower limb, with the face and upper limb involved more than the lower limb. The corticospinal tract, responsible for the hand's fine motor activity, is also present in the middle cerebral artery territory; therefore, motor weakness is the most disabling outcome of middle cerebral artery stroke.[1]

Every year in the US, about 795,000 persons experience a stroke, out of which 610,000 are the first attack and 185,000 are recurrent ones.[2] The prevalence of MCA stenosis in patients with ischemic stroke is 2.5%.[3] Stroke survivors experience motor disability in both affected and unaffected extremities. When two disabled extremities are needed to execute a coordinated bimanual movement, this problem is even more challenging. Bimanual hand coordination is when two hands move cooperatively to perform a common task goal. It is vital for upper limb function

and essential in daily activities.[4] It also helps the person hold and exchange objects with both hands. MCA stroke results in motor impairments of the affected upper limb that can lead to the disruption of the bimanual hand coordination and increase limitations in activities of daily living. Injury to the brain region that controls bimanual coordination causes further impairments in bimanual hand activities.[5]

Conceptualization of task goals is a critical factor that affects bimanual coordination in a motor task. In some bimanual tasks, each hand moves to execute an independent goal; in others, both hands move cooperatively to perform a common task goal.[6] In everyday tasks, the success depends on coordination between two hands. The critical factor in bimanual performance is the symmetry of inter-limb movement. Individuals with stroke have more significant deficits in motor performance and inter-limb coordination during asymmetrical movements than symmetrical movements while executing independent goals.[7] The assessment of the abilities to perform the daily hand tasks is either done in a standardized setup by different task observation or by the questionnaires that are patient-reported. The benefit of utilizing the questionnaires is that they provide the better comprehension of the individual`s self-reported difficulties in ADLs and a more individually targeted design for rehabilitation.[8]

It's critical to understand the factors that affect the perceived ability of performing the daily hand activities to improve the bimanual function of the upper extremities after the stroke. ABILHAND is the recommended questionnaire and tool to assess the self-perceived abilities to perform the bimanual tasks in the stroke patients with upper extremity disability.[9] In the previous studies, handgrip strength, motor functions, pain, somatosensations, spasticity, and dexterity were included as the contributing factors in the bimanual coordination. However, the self-reported ability to perform the bimanual hand functions was neglected.[10] ABILHAND questionnaire measures the self-reported abilities to perform the bimanual hand activities in the 23 daily situations and movements.[11] It shows the cutoff score of about 1.78 with an excellent test-retest reliability of ICC=0.85-0.91 and an excellent internal consistency of 0.91.[12]

The study is intended to be helpful in the goal setting for the stroke patients, as the ability to perform the daily hand activities is the essential goal of the rehabilitation after stroke. The study highlights need to better understand the post-stroke bimanual coordination, addressing the gap in existing literature via linking the motor deficits with the functional outcomes. The contribution lies in guiding the rehabilitation strategies for improving the quality and recovery for the stroke survivors.

The study contributes the region-specific evidence about the self-perceived bimanual coordination deficits in the patients with the chronic MCA stroke, the area underreported in the rehabilitation literature of South Asia. Unlike the prior studies emphasizing objective dexterity and force metrics, but the current research prioritizes the functional and self-reported manual ability using the Rasch-validated tool (ABILHAND), aligning the outcomes with the patient-centered goals of rehabilitation. Theoretical underpinning is also grounded in the interhemispheric motor control and the corticospinal tract involvement within MCA territory that disrupts the predictive coordination control and bilateral motor integration. Damage to the sensorimotor cortical networks impairs the asymmetrical and symmetrical interlimb coordination, so affecting the functional bimanual task execution.

Methodology

A descriptive cross-sectional study was conducted at the "Mayo Hospital Lahore" from July to December 2021, the ethical approval was taken from Ethical Review Board of the university under Ref no (DPT/ERB/18). 70 participants/patients were recruited via using the non-probability convenient sampling technique as the sample size was calculated according to the WHO sample size calculator.[13] The prevalence was followed as about 1.2%, with a 95% confidence interval, and 0.025 margin of error.[14]

The age of the patients was between 30 and 60 years, with the inclusion criteria following the diagnosed MCA stroke via CT Scan, 6 months after the stroke, Brannstrom stage 4 or above, upper limb impairments mild to moderate, and stable cardiovascular status. The exclusion criteria included the stroke with other arteries and other upper limb disabilities. The data was collected via the ABILHAND Questionnaire via the phone calls. The questionnaire assessed the 23 bimanual activities with the interpretation of (0), difficult (1), or easy (2) for each section. The items of the questionnaire with activities and movements not used in the last three months were marked as not applicable. Ethical approval was obtained, the confidentiality of the patients was maintained, and the informed consent (written) was also followed by all participants. The statistical analysis was

performed via SPSS version 26. The categorical data were presented as percentages and frequency tables, and the continuous variables were represented using bar charts and histograms.

The sample was calculated via using "WHO sample size calculator" based upon the estimated prevalence of the stroke prevalence, 2.5% error margin and confidence interval. The formal post-hoc power calculation indicated the moderate statistical power to detect the medium effect sizes.

Non-probability convenience sampling was used because of clinical accessibility and time constraints. While it limits the population-level generalization, inclusion criteria (strict) reduce the heterogeneity and improve the internal consistency.

The participants were recruited from the tertiary hospital serving the diverse socioeconomic groups, improving the contextual representativeness; but the rural and the private-sector populations can be underrepresented. Severity of stroke (Brannstrom stage ≥4) and the confirmed MCA lesion via the CT scan were considered. But, the side of the lesion, dominance of hand, and the detailed rehabilitation history are not stratified, representing the limitation which can influence the coordination outcomes. Age range was selected for minimizing the confounding from the advanced age-related musculoskeletal and neurodegenerative decline. But it restricts the applicability to the elderly stroke people, where the coordination deficits can be more pronounced. Inclusion criterion was about the ≥6 months post-stroke (chronic phase). The mention of 4 months in the abstract reflects the earlier error of draft and has been corrected to ensure consistency throughout manuscript.

Results

The mean age of the participants was about 49.58 ± 8.69 years. 57.1% (n=40) were males and 42.9% (n=30) were females.

Table 1: Patient Demographics

Variable	Frequency (n)	Percentage (%)	
Gender			
Male	40	57.1%	
Female	30	42.9%	
Age Groups (Years)			
N	Min	Max	Mean ± SD
70	32	65	49.58± 8.69

The mean total score of the ABILHAND Questionnaire was about 18.91 ± 10.79. The assessment showed varying degrees of the difficulty in bimanual coordination. (Table 2).

Table 2: ABILHAND Questionnaire Scores

N	Mean	Std. Deviation
70	18.91	10.79

There was a negative correlation between age and bimanual function. As age increases, bimanual functions decrease (Table 3).

Table 3: Correlation of Age with the Bimanual Function

Age in years	Pearson Correlation	-0.570**
	Sig. (2-tailed)	<0.001
	N	70
Total	Pearson Correlation	1
	Sig. (2-tailed)	
	N	70

7 out of the 23 tasks in the Questionnaire were reported as the difficult or impossible to perform by most of the participants. Tasks or movements requiring fine bimanual dexterity (Level C) were the most challenging, and simple tasks were rated more effortlessly (Table 4).

Table 4: Distribution of ABILHAND Questionnaire

Items	Impossible Frequency (n) Percentages (%)	Difficult	Easy	N/A
Hammering a nail	0 (0)	1 (1)	1 (1)	69 (990
Threading a needle	0 (0)	0 (0)	0 (0)	70 (100)
Peeling potatoes	11 (16)	3 (4)	6 (9)	50 (71)
Cutting one`s nails	17 (24)	26 (37)	22 (31)	5 (7)
Wrapping up gifts	0 (0)	1 (1)	1 (1)	68 (98)
Filing one`s nails	17 (24)	26 (37)	22 (31)	5 (70
Cutting meat	7 (10)	1 (1)	3 (4)	59 (84)
Peeling onions	7 (10)	3 (4)	7 (10)	53 (76)
Shelling hazel nuts	12 (17)	26 (37)	30 (43)	2 (3)
Opening a screw-topped jar	11 (16)	36 (51)	23 (32)	0 (0)
Fastening the zipper of a jacket	12 (17)	21 (30)	32 (46)	5 (7)

Tearing open a pack of chips	10 (14)	23 (32)	33 (47)	4 (6)
Buttoning up a shirt	12 (17)	21 (30)	32 (46)	5 (7)
Sharpening a pencil	0 (0)	0 (0)	0 (0)	70 (100)
Taking the cap off a bottle	12 (17)	37 (53)	19 (27)	2 (3)
Spreading butter on a slice of bread	8 (11)	6 (9)	10 (14)	46 (66)
Fastening a snap (jacket, bag)	13 (19)	22 (31)	29 (41)	6 (9)
Buttoning up trousers	12 (17)	22 (31)	33 (47)	3 (4)
Opening a email	3 (4)	27 (39)	28 (40)	2 (3)
Pulling up the zipper of trousers	12 (17)	22 (31)	33 (47)	3 (4)
Squeezing toothpaste on a toothbrush	16 (23)	42 (60)	12 (17)	0
Unwrapping a bar of chocolate	3 (4)	29 (41)	38 (54)	0
Washing one`s hands	2 (3)	22 (31)	46 (66)	0

Discussion

The primary findings of the study indicated that the mean total score for the ABILHAND Questionnaire was significantly lower than the standard mean, which highlighted the presence of the bimanual coordination deficit in the stroke patients with MCA. The tasks that necessitate high bimanual coordination were perceived to be most challenging for the execution. According to a study by Hussain et al., the bimanual tasks demanded manual dexterity on the affected limb and were difficult to perform. The key factors related to the self-perceived ability of the bimanual tasks included the perceived participation and dexterity.[15]

A randomized pilot study by Geller et al. explored the effects of the UMT (unimanual mirror therapy) and BMT (bimanual mirror therapy) along with the occupational therapy to improve the function of the upper limb in the stroke patients (with moderate to severe) impairments. The outcomes were measured with the ABILHAND questionnaire, with significant improvements in the outcome measures of the patient for the UMT. The daily hand task performance assessment can be conducted via patient-reported questionnaires and standardized observational tasks.[16]

A study by Patel and Lodha (2020) evaluated the role of the bimanual force coordination in the stroke patients performing functions with the unified goals. Using the pegboard assembly and the dynamic force tracking task, the study assessed the poor coordination and reduced dexterity. The findings elaborated that beyond the patient-reported assessments, including the ABILHAND, standardized bimanual coordination tasks may provide objective insights into the severity of the motor impairments. Incorporating these assessments into the rehabilitation planning can enhance the identification of the coordination-specific deficits and guide the targeted interventions to restore the collaborative hand function in the daily tasks.[17]

Another study by Johnson et al. (2022) evaluated how the task goals and the lesion laterality influence the bimanual coordination in the stroke patients during the reach-to-grasp functions. The study examined that the patients have severe deficits in the coordination of grasp, strongly associated with the paretic arm motor impairment. The findings highlighted that for the bimanual control, there is the need for individualized rehabilitation strategies that have to consider both the motor and the cognitive deficits.[4] Another study by Verhage et al. (2022) evaluated the bimanual performance in the children with the PAIS (perinatal arterial ischemic stroke) and PVHI (periventricular hemorrhagic infarction). Children with the PAIS demonstrated the superior bimanual function associated with preserved cognitive abilities.

In comparison, children with the PVHI had poorer dexterity because of the prematurity related to the neurodevelopmental challenges. The study emphasizes that the cognitive capacity and the functions of the dominant hand significantly influence the bimanual performance, highlighting the need for the cognitively integrated strategies of rehabilitation.[18] A study by Lai et al. (2022) examined the force coordination of the bimanual grip in the stroke patients using the dual-dynamometer system. The survivors of the Stroke showed the significant reduction in the grip strength, increased variability in the coordination, and a shorter time of alternation when there is transitioning grip force from the paretic to the non-paretic hand, indicating compensatory motor patterns. The findings underscored the value of the targeted bilateral coordination training and the quantitative assessment tools in the stroke rehabilitation for improving the upper-limb recovery and the performance of the daily functions.[19]

In that study, the ABILHAND Questionnaire was used to evaluate the bimanual coordination, and it revealed that poor bimanual coordination persists after 6 months of stroke. In the current study, the item rating of the ABILHAND questionnaire revealed 7 out of 23 items as impossible or difficult to perform. Three tasks required a high level of fine bimanual dexterity at level C, and 2 required only stabilization

by the affected limb at level B. Four items were regarded as the easiest by most of the patients. They were primarily breakable into the unimanual sequences at level A and required stabilization at level B. Three items, 'hammering a nail,' 'threading a needle,' and 'sharpening the pencil,' were not completed by the majority within the last three months and were therefore classified as not applicable. The findings of the ABILHAND Questionnaire can be significantly used in the goal-setting for the rehabilitation of stroke, and daily performance of the hand is crucial after stroke.[20] Categorization into different levels could assist clinicians in determining the extent of bimanual involvement and the dexterity demands required for specific tasks. The study was limited, and the factors, including fatigue, cognitive functions, self-efficacy, aids, family, and health care support, were not included in the present study. The sample size is small and was collected from Mayo Hospital.

The discussion critically interpreted observed reduction in the ABILHAND scores in context of the established neurophysiological models of the corticospinal disruption following the MCA stroke, primarily the bilateral integration deficits and the impaired interhemispheric motor coordination. Consistent with the prior research, reporting the compromised bimanual performance (post-MCA infarction), the current findings reinforce association between the unilateral (cortical) damage and the bilateral (functional) impairment.

Recommendation and Limitation: But, unlike the studies focusing on unilateral dexterity, the current study primarily quantifies the bimanual coordination limitations within the defined chronic phase, so extending the current understanding of the functional deficits beyond the impairments of the isolated limb. Methodological limitations are also acknowledged for contextualizing the interpretation. Conclusion is grounded in statistical findings, emphasizing the clinically relevant implications for the structured bilateral rehabilitation in spite of the reiterating general stroke outcomes.

Conclusion

Bimanual coordination deficits were present in the patients with Middle cerebral artery stroke, as the mean of the total score of the ABILHAND Questionnaire was lower. The study highlighted the significant deficits in the bimanual coordination among the post-stroke patients, with the lesion side and the chronicity of stroke influencing the motor performance. The findings emphasize the need for early, the targeted rehabilitation strategies for improving the functional outcomes. Incorporating the structured bimanual training can enhance recovery and support greater independence in the daily activities.

Conflict of Interest: None

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Data Availability Statement: *The datasets generated and/or analysed during the current study are not publicly available due to ethical, legal, and participant confidentiality considerations but may be available from the corresponding author upon reasonable request, subject to institutional approval where applicable.*

Disclaimer: *We authors want to declare that we used AI-assistant tools in this article for improving language. We authors are fully responsible for the accuracy, originality, integrity, and scientific validity of this article.*

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