Effectiveness of EMG Biofeedback with Bobath Technique in Hand Function in Post Stroke Survivors - An Experimental Study

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Abstract:

- ***Introduction:***

Stroke is a major cause of long-term disability, frequently leading to diminished hand function that greatly interferes with daily life activities. Both conventional rehabilitation methods such as Bobath technique and more contemporary supplements like Electromyographic (EMG) biofeedback have shown on their own advantages in improving motor recovery. But there's not much proof about how well they work together.

- ***Methods:***

A trial involving 30 post stroke patients (45-70years) drawn from nearby hospitals was carried out. Participants met inclusion criteria of middle cerebral artery stroke (subacute to chronic stage, Brunnstrom stage 2-5, MMSE>24).Pre and post-intervention the Michigan Hand Questionnaire (MHQ) evaluated hand function. For four weeks, statistical analysis was done with paired t-test at a significance threshold of p<0.01 using EMG biofeedback training (40 minutes, 3 sessions/week) and Bobath based exercises(30 minutes/day,3sessions/week).

- ***Results:***

Post-intervention examination showed a statistically significant increase in hand function. With a mean difference of 32.5 (t = 12.574, p<0.01), the mean MHQ score rose from 77.5 to 45.0. This suggests improved neuromuscular control, motor relearning, and functional recovery when the Bobath technique was used with EMG biofeedback.

- ***Conclusion:***

The study demonstrates that Research show that post-stroke survivors' hand function greatly improves when EMG biofeedback is combined with the Bobath method. As a result of the synergistic effect, the integrated strategy promotes motor recovery and functional independence, therefore making it somewhat beneficial supplement in stroke recovery.

Keywords: *Stroke, Hand Function, EMG Biofeedback, Bobath Technique, Rehabilitation, Michigan Hand Questionnaire.*

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I. INTRODUCTION

Stroke (cerebrovascular accident) is the sudden loss of neurological function caused by an interruption of blood flow to the brain[1].The incidence range from 152/100000 persons per year and the crude prevalence of stroke ranged from 44.29 to 559/100000 persons in different parts of the country during the past decades[2].

The Circle of Willis is an anastomotic arterial network located at the base of the brain. Its primary function is to provide collateral circulation to cerebral and cerebellar tissues, ensuring consistent blood flow and minimizing the risk of ischemia**,** transient ischemic attacks (TIAs**)**, or stroke. Traditionally, the Circle of Willis is described as a symmetrical polygon, formed by the connection of branches from the internal carotid and vertebral arteries**.**

Contemporary anatomy textbooks typically depict the Circle of Willis as a roughly pentagonal circle of arteries situated on the ventral surface of the brain. The structure includes the anterior and posterior cerebral arteries**,** which supply blood to various regions of the cerebrum and cerebellum. These arteries are interconnected by the anterior communicating artery and two posterior communicating arteries, forming a vital collateral arterial network that maintains cerebral perfusion even in the event of arterial occlusion.[3]

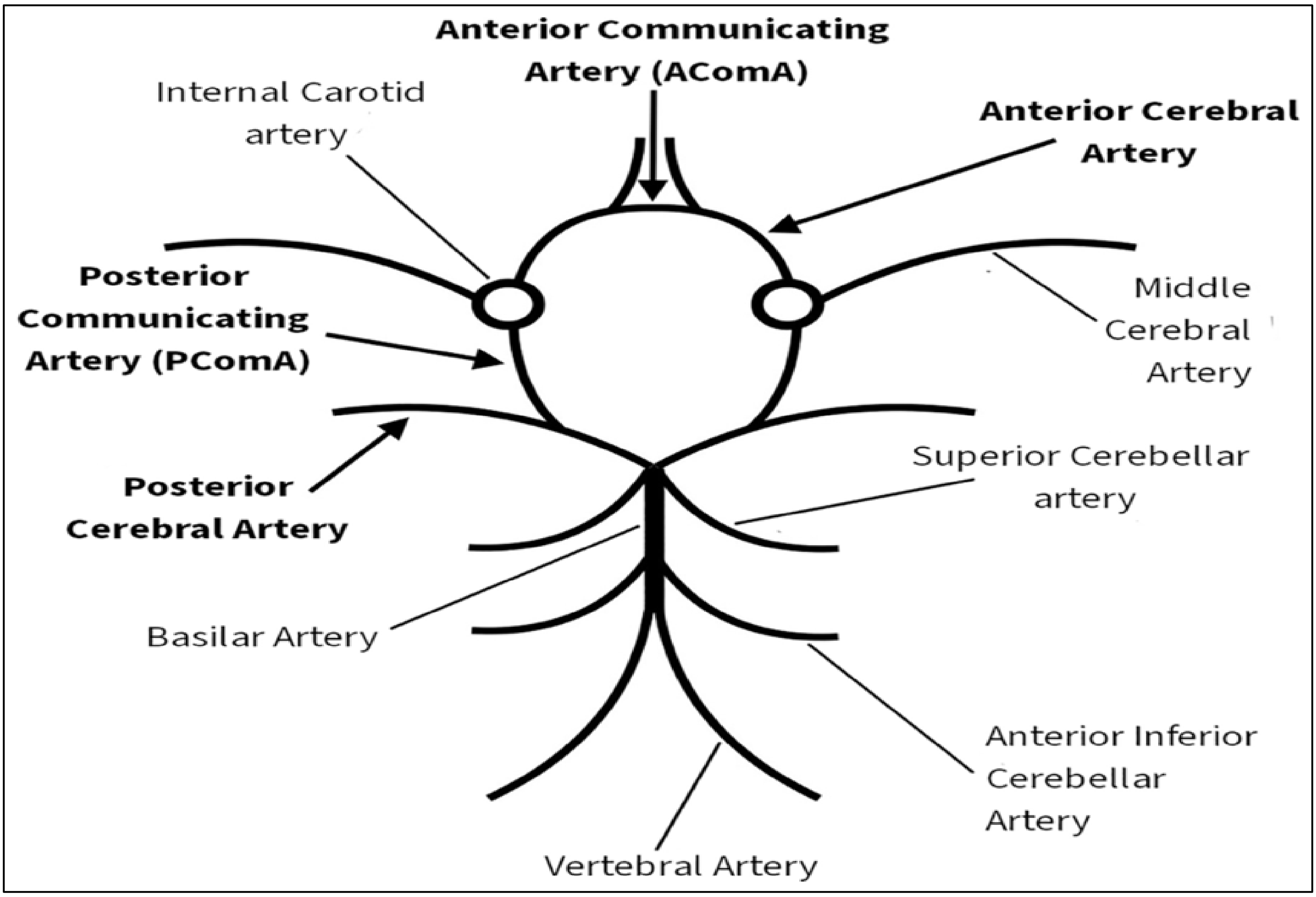

Fig 1 Circle of Willis

Ischemic stroke is the most common type, affecting about 80% of individuals with stroke, and can be the result of thrombosis, embolism, or hypo perfusion. A thrombus is a local occlusion of the blood vessel, and an embolus is material from a distant site that either blocks or impairs blood flow, depriving the brain of essential oxygen and nutrient .Lack of oxygen and nutrients results in tissue necrosis and penumbral area where the cells may be damaged but preserved. Hemorrhagic stroke occurs when blood vessels rupture, causing leakage of blood in or around the brain. Clinically, a variety of focal deficits are possible, including changes in the level of consciousness and impairments of sensory, motor ,perceptual ,and language functions .Motor deficits are characterized by paralysis (hemiplegia) or weakness (hemiparesis),typically on the side of the body opposite to the side of the lesion .The term hemiplegia is often used generically to refer to the wide variety of motor problems that result from stroke The location and extent of the brain injury, the amount of collateral blood flow, and early acute care management determine the severity of neurological deficits in an individual patients. Impairments may resolve spontaneously as brain swelling subsides (reversible ischemic neurological deficit), generally within 3 weeks. Residual neurological impairments are those that persist longer than 3 weeks and may lead to lasting disability.[1]

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Blood supply of brain: two vertebral and internal carotid arteries carry the total aterial supply to the brain Branches of internal carotid artery are as follows:

- Opthalmic artery
- Posterior communicating artery
- Anterior Choroidal artery
- Anterior cerebral artery
- Middle cerebral artery

Circulus Arteriosus or circle of Willis is a hexagonal arterial circle situated at the base of brain in the interpeduncular fossa. It is formed by the anterior cerebral branches and terminal parts of internal carotid artery that is middle cerebral artery with its posterior communicating branch and the posterior cerebral branches of basilar artery. [4]

Fig 2 Early Warning Signs and Symptoms for Stroke [1]

Recent advances in neuroscience have transformed our understanding of motor learning and recovery after brain injury, driving innovative research in motor rehabilitation.[5] Stroke survivors often experience weakness of one side of the body affecting hand and foot function due to brain damage impacting muscles contraction and control.[6] Hand function involves intricate coordination of reaching, grasping and manipulation. Tasks such as grasping of cup require integration of visuomotor, tactile and motor skills. Impairments in these abilities can led to hand dysfunction,

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emphasizing the need for rehabilitation assessment and targeted intervention.[7]

The Bobath Concept, internationally known as the Neuro Developmental Technique (NDT), has gained increasing interest in the field of rehabilitation, particularly for the treatment of stroke patients. Widely practiced across many countries, Bobath is a therapeutic approach aimed at improving motor function in individuals with neurological impairments, especially those with hemiplegia following a stroke.

Originally developed by Berta Bobath in the mid-20th century, the approach focuses on how motor dysfunction occurs and can be addressed through guided, active participation. Stroke patients engage in therapist-assisted exercises that uses key points of control and reflex-inhibiting patterns to promote more functional movement. Unlike passive therapies, the Bobath approach emphasizes the active involvement of the patient in order to facilitate motor learning and restore motor control. While earlier reviews have primarily focused on controlled clinical trials, the Bobath concept remains a foundational method in stroke rehabilitation due to its patient-centered and movement-based strategies.[8]

Electromyography (EMG) is a neurophysiological approach used to find, measure, and analyze the bioelectrical signals generated by motor units inside muscles during both deliberate motions and spontaneous activity. EMG can be divided into two major methods depending on the type of electrode employed: surface electromyography (sEMG) and needle electromyography (nEMG).

Surface EMG (sEMG) has the benefit of capturing the general myoelectric activity produced by many motor units, therefore enabling a more thorough examination of muscle performance rather than concentration on one motor unit. By using the idea of bulk electrical conductivity, this method reduces the impact of electrode distance from the signal source on the gathered data. This enables the non-invasive, more patient comfort procedure of straight skin-based electrodes.

When muscle fibers are triggered by neurological or external electrical signals, sEMG records the resulting electrical potentials. Making it a helpful instrument in both clinical and research contexts, the recorded signals provide important data on muscle contraction, tone, tiredness, patterns of activation and coordination.[9]

Electromyographic biofeedback (EMG-BF) therapy help stroke patients recover by using electrical stimulation and visual/auditory signals to rebuild nerve cells and neural networks. This therapy enables the brain to regulate muscle movement and relaxation, promoting rehabilitation.[10]

The Michigan Hand Questionnaire (MHQ) assesses hand function, daily activities, work performance, pain, appearance, and overall satisfaction and reliability of (ICC-0.8- 0.9).[11]

II. METHOD

This study was designed as a pre-post experimental investigation to assess the effectiveness of EMG biofeedback with bobath technique in hand function in post stroke survivors. The research was conducted over a period of six months at the Physiotherapy Department of RJS College of Physiotherapy, Kokamthan, in association with SJS Hospital. The sample consisted of 30 participants, including both male and female subjects, selected through a convenient sampling method. Participants were MCA stroke patients, representing a population with impaired hand function that affected quality of life. Prior to participation, all individuals were screened for eligibility based on specific inclusion and exclusion criteria. Participants presenting with subacute and chronic stage and symptoms consistent with MCA stroke were included. All participants provided written informed consent before commencing the intervention. The primary outcome measure used in this study was the Brief Michigan hand questionnaire (BHMQ). The MMSE and Brunnstrom hand recovery scale was employed as a secondary outcome measure to assess functional limitations caused by MCA Stroke. Both tools are well-established, valid, and reliable in clinical and research settings.

Participants were assessed before and after intervention at the end of 4th week. The pre- and post-intervention scores of BHMQ were statistically compared to determine the effectiveness of the treatment.

➢ *Inclusion Criteria:*

- Middle cerebral artery stroke.
- Stage – Subacute, Chronic (more than 3 months).
- No higher mental functions affected (MMSE Score 24-30).
- No Unilateral Neglect.
- Age group from 45 to 70 years.
- Both Male and Female gender.
- Brunnstrom hand recovery scale- Stage 2 to Stage 5.

III. PROCEDURE

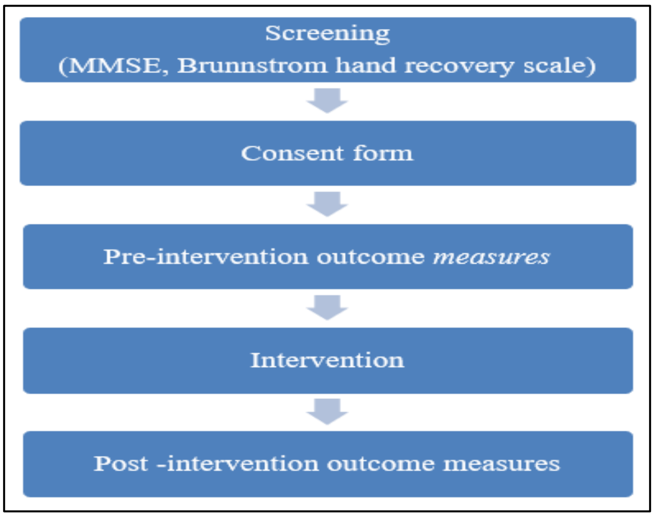

Fig 3 Flow Chart

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Ethical clearance was taken from the institution and ethical committee. In this study, all participants were drawn from the outpatient physiotherapy center of SJS Hospital .Using convenience sampling, patients who met the inclusion criteria of middle cerebral artery stroke, chronic phase of three months or more, Mini-Mental State Examination score of 24 to 30, and Brunnstrom hand stage 2 to 5 were recruited until the required sample size of 30 was attained. Informed written consent was gotten and a special study ID was distributed following a native language study explanation. Baseline assessment encompassed demographic data, stroke characteristics, and distribution of the Brief Michigan Hand Questionnaire (Brief-MHQ). Each participant had three sessions each week lasting about 70 minutes for four weeks of organized intervention. The treatment included EMG biofeedback for 40 minutes then Bobath-based workouts for 30 minutes. The EMG biofeedback system was calibrated using voluntary muscle contractions; electrodes were placed over the extensor digitorum muscle belly; the ground electrode was placed at the distal ulna of the same wrist. Participants were taught via a series of activities including graded activation, isolated wrist and finger extensions, and functional grasp-release motions with visual and auditory feedback offered. The threshold was adjusted gradually according to performance and tolerance. Following EMG biofeedback, Bobath therapy was provided using key points of control and reflex-inhibiting patterns beginning with weight-bearing activities, clasped-hand overhead motions, forward and overhead reaching with a gym ball, quadruped or modified plantigrade postures, functional transitions, and ball control exercises. Lower support, increased job complexity, and incorporating functional hand use were all used to provide advancement under close monitoring for spasticity and fatigue. Attendance records were used to track adherence; any adverse consequences including pain, tiredness, or skin irritation were noted and adequately treated. Four weeks later, a blinded assessor re-administered the Brief-MHQ under the same standard conditions to assess post-intervention results. Event record forms were used to store data, which was then entered into a secure spreadsheet with dual verification to ensure accuracy. Statistical analysis using a paired t-test was proposed to analyze pre- and post-intervention Brief-MHQ scores with a p-value of less than 0.01.

IV. OUTCOME MEASURES

The abbreviated Michigan Hand Outcomes Questionnaire, known as the Brief Michigan Hand Questionnaire (Brief MHQ), is a version of the original Michigan Hand Outcomes Questionnaire meant to swiftly gauge patient-reported outcomes pertaining to hand health and function. It comprises twelve questions covering important areas including general hand function, sensation, pain, difficulty with everyday activities, work performance, happiness with look, and finger and wrist motion. Each item is scored on a 5-point Likert scale, most responses are reversed coded such that higher scores consistently denote better functioning and happiness. The total raw score is then averaged and normalized to a 0–100 scale; 0 represents the worst function and 100 represents ideal hand function. Unlike the full MHQ, the brief version offers a general measure of hand outcomes and does not distinguish between hands. It is fast to administer, simple for patients to complete, and especially helpful in research as well as clinical settings to monitor progress, assess treatment outcomes, and gauge overall hand-related quality of life. Michigan hand questionnaire: (ICC 0.8-0.9)

V. DATA ANALYSIS

The entire data of the study statistically analyzed in STATISTIXL version 2.0.All the results are shown in tabular as well as graphical format to visualize the statistically significant difference more clearly. The data on Quantitative characteristics was presented as Mean ± Standard Deviation (SD) across study group. The paired t-test was used for pre and post intervention comparison to test change in quantitative data. The results demonstrated a significant improvement in Michigan Hand Questionnaire (MHQ) scores, with mean values rising from 45.0 ± 14.53 at baseline to 77.5 ± 16.54 post-intervention, yielding a mean improvement of 32.5 points. Statistical analysis using a paired t-test confirmed that this improvement was highly significant ($t = -12.57$, $p < 0.0001$).

A. Descriptive Characteristics:

- *Gender Wise Distribution of Subjects:*

30 patients participated in this study out of which 23 were males and 7 were females.

Table 1 Table Represents Frequency and Percentage of Total 30 Participants.

Gender	Frequency	Percentage
Males	23	76.7
Females	7	23.3
Total	30	100

The table shows there were 76.7% of male and females were 23.3% and the overall total sample number of males in our study was 23 and that of females was 7.

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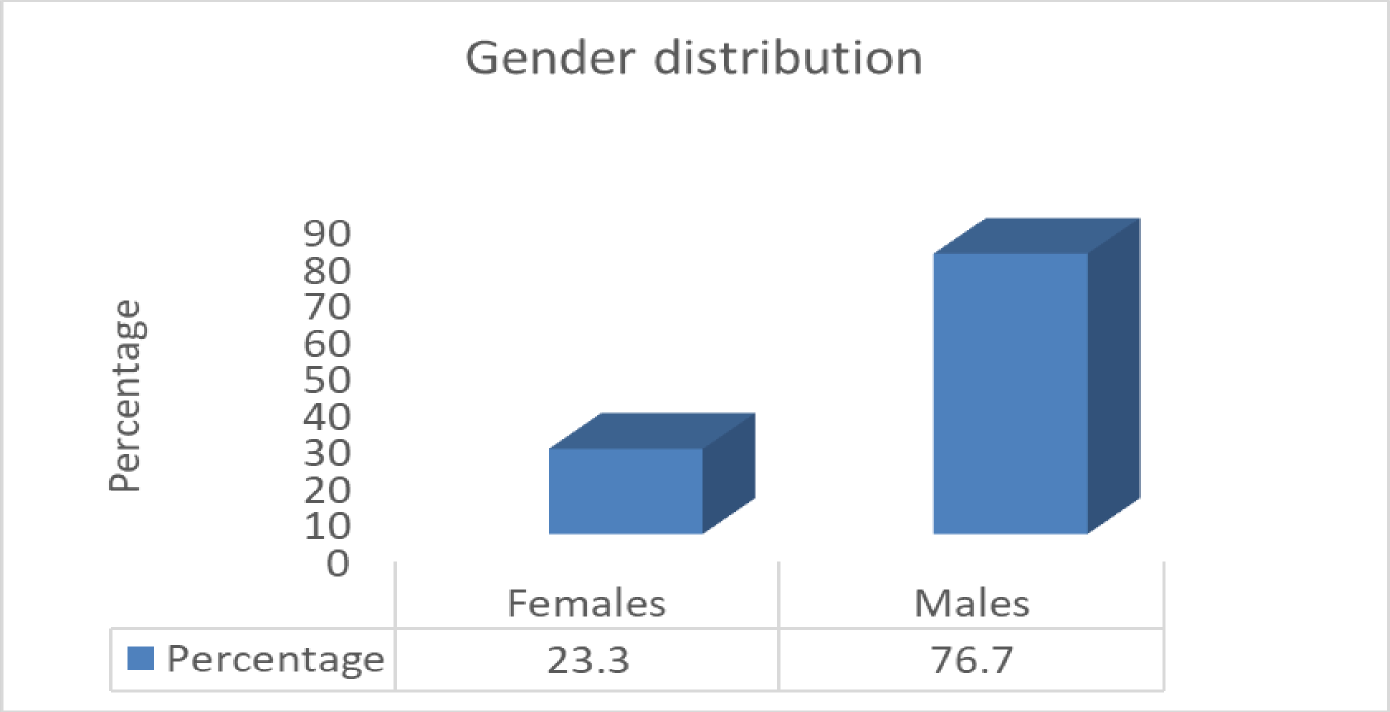


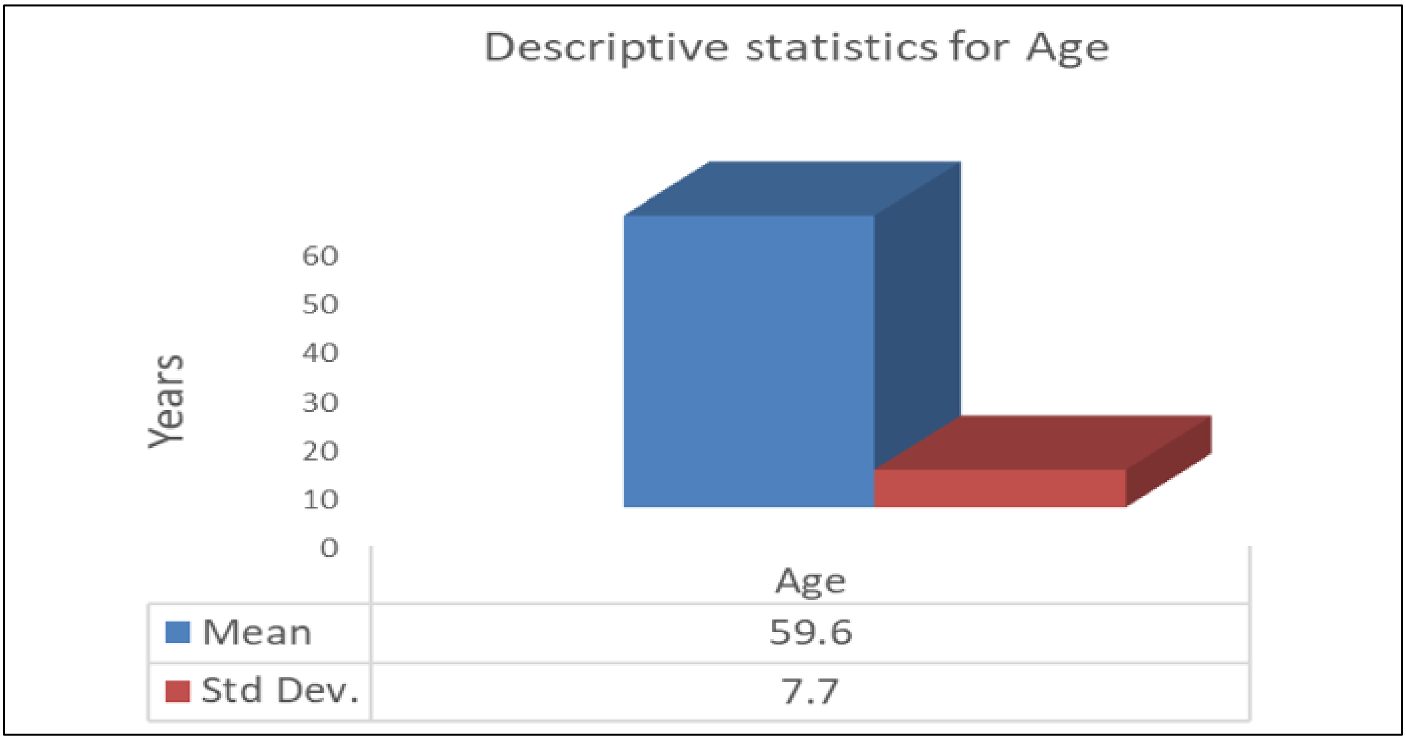
Graph 1 Graphical Representation of Gender-Wise Distribution of Subjects

➤ *Age Wise Distribution of Subjects:*

Table 2 Age Wise Distribution of Subjects

Variable	**Mean**	**Standard Deviation**
Age	59.6	7.7

The table represent the mean age of the subjects were 59.6 ± 7.7



Graph 2 Graphical Representation of Age-Wise Distribution of Subjects

The graph shows that the mean age of the subjects were 59.6 ± 7.7

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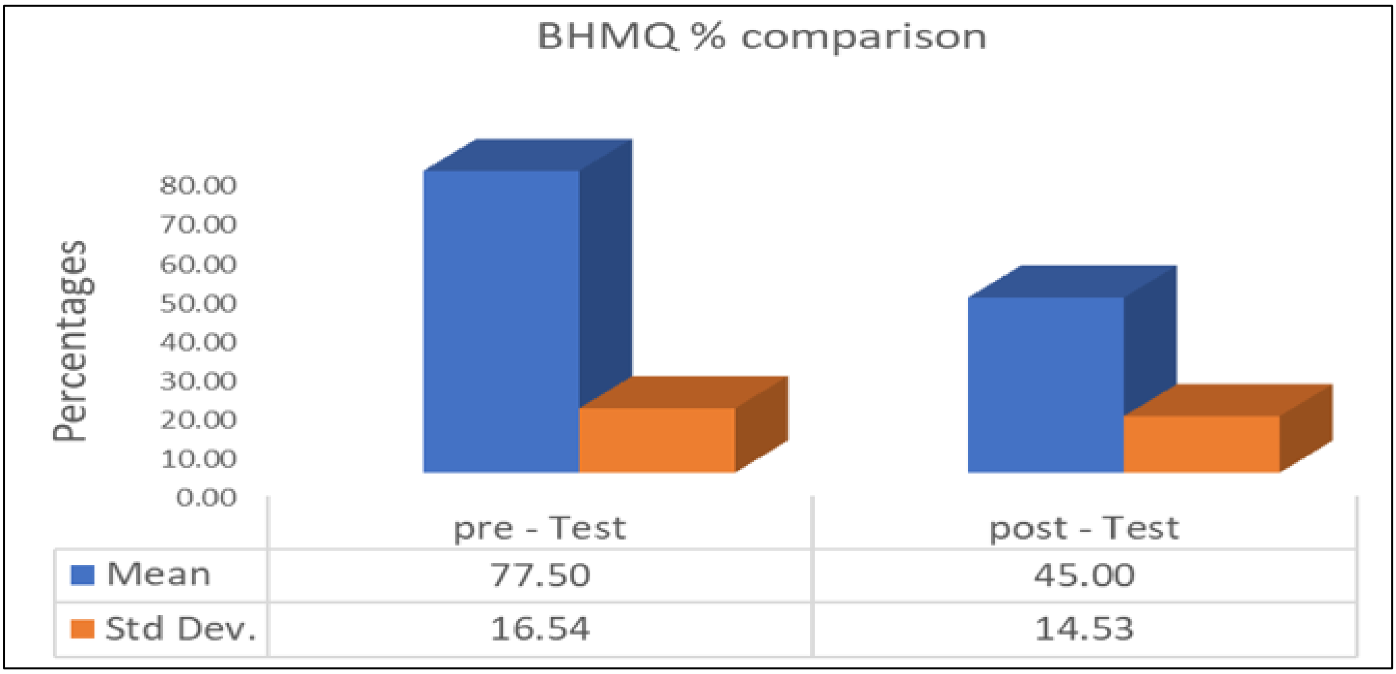
➢ *Comparison of BHMQ Score Pre and Post Intervention*

Table 3 Comparison of BHMQ Score Pre and Post Intervention

Pre – BHMQ	Post – BHMQ	Mean Difference	'P' Value	't' Value
77.50	45.0	32.50	<0.01	12.574

This table shows that mean BHMQ differs significantly between pre and posttests. From the table it can be observed that the mean BHMQ in the posttest 45.0 is less than that of the pretest 77.50 score . The 't' value 12.574 is significant ('p' <0.01). Hence the intervention used in the study group decreases the BHMQ.



Graph 3 (a) Graphical Representation of Comparison of BHMQ Score

VI. RESULTS

Reflecting the typical age distribution of stroke survivors, the study included a total of 30 post-stroke patients, where of 23 (76.7%) were males and 7 (23.3%) were women, with a mean age of 59.6 ± 7.7 years. With baseline scores averaging 45.0 ± 14.53, hand function was evaluated using the Brief Michigan Hand Questionnaire (Brief-MHQ), pointing to poor to moderate function. Statistical analysis utilizing a paired t-test confirmed this improvement to be extremely important (t =12.574, p < 0.0001). Mean post-intervention score increased considerably to 77.5 ± 16.54 after four weeks of simultaneous EMG biofeedback and Bobath treatment, representing a mean difference of 32.5 points. The integrated intervention improved neuromuscular control, voluntary muscle activation, and overall functional hand recovery noticeably, according to these results. The regular improvements seen in both male and female patients as well as across many age groups imply that the treatment was generally effective independent of demographic variety. All things considered, the research offers convincing proof that four weeks of EMG biofeedback coupled with Bobath therapy greatly improves hand function in post-stroke patients.

Statistical analysis showed that the difference between pre-treatment and post-treatment scores for BHMQ was significant, with EMG biofeedback with Bobath therapy a positive effect on hand function and functional improvement in participants with MCA Stroke.

VII. DISCUSSION

The present study investigated the effectiveness of combining Electromyographic (EMG) biofeedback with the Bobath technique in enhancing hand function among post-stroke survivors. The results demonstrated a significant improvement in Michigan Hand Questionnaire (MHQ) scores, with mean values rising from 45.0 ± 14.53 at baseline to 77.5 ± 16.54 post-intervention, yielding a mean improvement of 32.5 points. Statistical analysis using a paired t-test confirmed that this improvement was highly significant (t = -12.57, p < 0.0001). These findings provide strong evidence that an integrated therapeutic approach offers substantial benefits in post-stroke hand rehabilitation.

Earlier research showing the independent efficacy of either EMG biofeedback or the Bobath technique are consistent with our results. A thorough review and meta-analysis by Rui Wang et al. (2019) found that EMG biofeedback greatly enhanced upper and lower limb functions in stroke sufferers, especially in the near term. Sisi Feng et al. (2020) found likewise that rehabilitation training with EMG biofeedback produced superior upper limb recovery than standard treatments.

Parallel data supports the Bobath method as well. Merna Magdy Moharib et al. (2021) found that Bobath treatment enhanced balance and gait speed in stroke patients, however its direct effect on hand function called for more research. Thanchanok Pumprasart et al. (2020) saw notable gains in upper limb function in chronic stroke patients following a six-week Bobath therapy program.The present study extends this body of knowledge by demonstrating that when EMG biofeedback is combined with the Bobath technique, the improvements in hand function are greater than those reported when either intervention is applied in isolation. This synergistic effect highlights the complementary roles of both therapeutic strategies.

Underlying neurophysiological processes help to explain the success of the integrated strategy. EMG biofeedback helps patients to better regulate, selectively recruit motor units, and improve motor learning by giving them real-time visual and auditory cues of muscle activation. This supports ideas of neuroplasticity, according to which frequent voluntary activation strengthens neural pathways and improves cortical reorganization.

The Bobath technique, on the other hand, stresses the importance of helping people move normally, control their posture, and do functional tasks. Bobath treatment helps movement through important points of control by suppressing aberrant reflexes and therefore promotes smoother, coordinated motor activity. Including EMG biofeedback helps the patient not only learn to better engage their muscles but also transfer this activation into everyday functional movements needed for daily activities.Thus, the combined intervention supports both bottom-up mechanisms (via sensory feedback from EMG signals) and top-down mechanisms (through motor relearning facilitated by Bobath exercises), producing superior functional outcomes.

Impaired hand function is one of the most disabling consequences of stroke, with up to 80% of survivors experiencing incomplete recovery of the upper limb even after six months. The ability to grasp, manipulate, and perform fine motor tasks directly influences independence in activities of daily living, work participation, and quality of life.

The results of this study emphasize that combining EMG biofeedback with the Bobath approach can accelerate functional recovery within a relatively short intervention period of four weeks. This is clinically relevant, as early and intensive rehabilitation is known to produce better long-term outcomes in stroke recovery. Additionally, the combined intervention is non-invasive, safe, and feasible in clinical settings, making it a practical option for physiotherapists.

The findings of this study are consistent with those of Cristina Lirio-Romero et al. (2019), who showed that short-term EMG biofeedback significantly improved paretic upper limb function. Likewise, Goswami et al. (2022) found that EMG biofeedback combined with mirror therapy produced greater improvements in wrist extension and supination compared to mirror therapy alone. These studies reinforce the principle that combining biofeedback with a functional therapy yields superior results compared to single-modality interventions.

Conversely, some systematic reviews (e.g., Simone Dorsch et al., 2015) reported that Bobath therapy alone was less effective than task-specific training or robotics. However, our findings suggest that when Bobath is paired with adjunctive modalities such as EMG biofeedback, its effectiveness increases, particularly in hand function recovery. This indicates that rather than discarding Bobath altogether, combining it with modern techniques may optimize rehabilitation outcomes.

VIII. CONCLUSION

Post-stroke survivors' hand function is much better when EMG biofeedback is used in conjunction with Bobath approach throughout a brief rehabilitation program. Making it a viable technique for clinical use, this combined approach encourages functional recovery and neuromuscular re-education.

ABBREVIATIONS

- (EMG – Electromyographic)
- (nEMG – Needle Electromyographic)
- (sEMG – Surface Electromyographic)
- (NDT- Neurodevelopmental Technique)
- (TIA- Transient ischemic attack)
- (MHQ- Michigan hand questionnaire)
- (ICC – Intraclass correlation coefficient)

REFERENCES

[1]. O'sullivan SB, Schmitz TJ, Fulk GD. Physical rehabilitation. 7th ed. Philadelphia, Pa: F.A. Davis Company; 2019.
[2]. Kamalakannan S, Gudlavalleti AashraiSV, Gudlavalleti VenkataSM, Goenka S, Kuper H. Incidence & prevalence of stroke in India: A systematic review. Indian Journal of Medical Research. 2017; 146 (2):175.
[3]. Jones JD, Castanho P, Bazira P, Sanders K. Anatomical variations of the circle of Willis and their prevalence, with a focus on the posterior communicating artery: A literature review and meta-analysis. Clin Anat [Internet]. 2021; 34(7):978–90. Available from: http://dx.doi.org/10.1002/ca.23662
[4]. Chaurasia BD, Garg K, Pragati Sheel Mittal, Mrudula Chandrupatla, Cbs Publishers & Distributors Private Limited. BD Chaurasia's human anatomy: regional and applied, dissection and clinical. Vol. 4, Brain-neuroanatomy. New Delhi: Cbs Publishers & Distributors Pvt Ltd; 2017.
[5]. Woldag H, Hummelsheim H. Evidence-based physiotherapeutic concepts for improving arm and

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25aug1296

hand function in stroke patients: a review. Journal of neurology. 2002 May; 249:518-28.
[6]. Hasina SN, Maharani CF, Fitriasari A, Putri RA. Effect of Bobath Therapy On Extremity Muscle Strength In Post Stroke Infarced Patients. Journal for Quality in Public Health. 2023 Nov 30; 7(1):57-65.
[7]. Sabini RC, Dijkers MP, Raghavan P. Stroke survivors talk while doing: development of a therapeutic framework for continued rehabilitation of hand function post stroke. Journal of Hand Therapy. 2013 Apr 1; 26(2):124-31.
[8]. Pathak A, Gyanpuri V, Dev P, Dhiman NR. The Bobath Concept (NDT) as rehabilitation in stroke patients: A systematic review: A systematic review. J Family Med Prim Care [Internet]. 2021; 10(11):3983–90. Available from: http://dx.doi.org/10.4103/jfmpc.jfmpc_528_21
[9]. 9.Radecka A, Lubkowska A. The usefulness of surface electromyography in rehabilitation and physiotherapy: systematic review. Pomeranian Journal of Life Sciences [Internet]. 2020; 66(3):49–56. Available from: http://dx.doi.org/10.21164/pomjlifesci.724
[10]. Rodríguez-Hernández M, Polonio-López B, Corregidor-Sánchez AI, Martín-Conty JL, Mohedano-Moriano A, Criado-Álvarez JJ. Can specific virtual reality combined with conventional rehabilitation improve poststroke hand motor function? A randomized clinical trial. Journal of NeuroEngineering and Rehabilitation. 2023 Apr 4; 20(1):38.
[11]. Kim JH. The effects of training using EMG biofeedback on stroke patients upper extremity functions. Journal of physical therapy science. 2017; 29(6):1085-8.
[12]. Firoozeh F, Dehkordi SN, Dadgoo M, Islam D, Habibi SA. The effects of task-oriented training combined with Bobath program and task-oriented training alone on upper-limb function in stroke patients. Func Disabil J. 2019.
[13]. Lalwani SS, Vardhan GV, Bele A. Comparison the Impact on TENS and Conventional Physiotherapy in Stroke Patients with Upper Limb Dysfunctions: A Research Protocol. Journal of Pharmaceutical Research International. 2021 Oct 2:466-75.
[14]. Arcidiacone S, Panuccio F, Tusoni F, Galeoto G. A systematic review of the measurement properties of the Michigan Hand Outcomes Questionnaire (MHQ). Hand Surgery and Rehabilitation. 2022 Oct 1; 41(5):542-51.