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Original Article

EFFECTIVENESS OF ARM ABILITY TRAINING WITH BIOFEEDBACK TECHNIQUES TO IMPROVE NEUROPLASTICITY, DEXTERITY AND QUALITY OF LIFE AMONG SUBACUTE STROKE SURVIVORS

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ABSTRACT:

One of the main causes of physical disability is stroke, and 80% of stroke survivors suffer upper extremity dysfunction characterized by reduced muscle strength and functional limitation in muscle control and life quality. Arm ability training with biofeedback techniques is reported to enhance the functional recovery of the upper limb by improving the dexterity of the upper limb and life quality. An experimental study to find out the effects of Arm Ability Training with Biofeedback techniques on upper limb dexterity, functional ability, and quality of life in sub-acute stroke survivors. Sixty participants were chosen and randomly allocated to two groups. Group A received Arm ability training with biofeedback techniques, and Group B received conventional therapy for 60 minutes, 5 days/week for 3-4 weeks. The outcome measures were Modified standardized nine-hole peg test (mS-NHPT), Fugl-Meyer Assessment Upper Extremity, 12-item stroke-specific quality of life scale, and Wolf Motor Function Test. The mean completion time for the m-S NHPT decreased (from 113.78 ± 3.14 to 88.36 ± 2.49), and the FMA-UL increased (from 79.08 ± 2.54 to 90.52 ± 2.92). SS-QOL-12 (19.76 ± 0.99 to 40.12 ± 1.24), WMFT (Functional Ability) (from 46.76 ± 1.47 to 56.92 ± 2.03), and the time score improved (from 478.64 ± 2.9 to 435.16 ± 2.22). The variables indicates a statistical significance ($p < 0.05$). The above result statistically shows significant improvements in dexterity, functional ability, and life quality of sub-acute stroke subjects.

KEYWORDS: mS-NHPT, FMA-UE, SS-QOL-12, and WMFT

INTRODUCTION

A stroke is a sudden, focal neurological impairment brought on by central nervous system vascular damage (haemorrhage or infarction). Globally, stroke ranks as the second most common cause of death and disability. Post stroke, more than two-third of the patients have impairment in the motor function of the upper limb. As a result, there is difficulty in performing activities of daily living. Eighty five percent of strokes are ischemic, mostly due to large artery cardioembolism, small vessel arteriolosclerosis, and atherothromboembolism. Fifteen percent of younger adults develop ischemic strokes due to factors, including intracerebral haemorrhage and extracranial dissection (1). According to the GBD 2019 (the Global Burden of Disease) research, the majority of deaths worldwide (18.6 million [17.1–19.7]) in both sexes were attributed to cardiovascular illnesses (CVDs). Stroke was the second most common cause of death among CVDs, accounting for 3.33 million stroke deaths in men (3.04–3.62) and 3.22 million stroke deaths in women (2.86–3.54) (2). A major cause of death and morbidity in both developed and, increasingly, low-middle-income (LMIC) nations, stroke is a serious worldwide health concern. Seventy percent of all strokes occur in Strokes LMICs, and the resulting illness burden is higher than in high-income nations. In India, stroke is now the fourth leading cause of mortality and the fifth major cause of disability due to a rise in age-related, non-communicable diseases brought on by the country's recent increase in life expectancy to over 60 years (3).

One of the main causes of physical disabilities is stroke. Up to 80% of stroke survivors experience upper extremity disability. Paresis, its most prevalent symptom, is distinguished by decreased muscle strength (due to decreased motor unit recruitment and muscle changes as atrophy), followed by loss or limitation of function in muscle control, movement, or mobility, which can subsequently have a detrimental impact on one's ability to support oneself and one's quality of life (4).

Hemiplegia is present in over 85% of stroke survivors (Kim, 2017; Santisteban et al., 2016), and over 69% of those with hemiplegia show functional motor impairment in their upper limbs. Following a stroke, changes in muscle tone, muscular weakness, joint laxity, and reduced motor control are common signs of upper limb motor impairment. According to Hatem et al. (2016), these challenges may make it difficult to carry out daily tasks, including reaching for, picking up, grabbing, and holding onto objects. (5)

Approximately 75% of strokes are caused by damage to the middle cerebral artery, which provides a large amount of blood to the area of the brain responsible for the motor functions of the hands and upper extremities. While a slight recovery of the lower extremities allows for functional gait, recovery of the distal parts and fine motor functions (such as grasping and manipulating) is required for functional recovery of upper extremity functions (6).

Over 50 percent of stroke survivors need assistance (typically mild to moderate) with dressing or bathing because of upper extremity dysfunction, and most need full assistance with certain daily living activities like cooking or cleaning. Few of them are able to resume their pre-stroke job routines and dedicate themselves to their personal, family, and leisure activities. Therefore, from the perspective of preserving functional independence, upper limb disability is an important therapeutic target. (7)

Three months after a stroke, more than half of stroke survivors still exhibit markedly delayed distal pinch grip performance, making hand motor outcome one of the clinically most important measures. In order to maximize upper limb function, current perspectives on the efficacy of rehabilitation include relearning fundamental skills related to activities of daily living (ADL) and practicing ADL intensively. Stroke patients' quality of life (QoL) is negatively impacted by upper-limb impairment. Because it affects the majority of basic ADLs (such as crawling, balancing, walking, writing, eating, washing, and manipulating items), it makes it more difficult for them to live independently.

Robotics, electromyographic biofeedback, mental practice with motor imagery, and constraint-induced movement therapy all showed improvements in arm function recovery. Repetitive task training, biofeedback, and training on a moving platform were found to improve transfer ability or balance. These results indicate that several emerging interventions, such as constraint-induced movement therapy (CIMT), non-invasive brain stimulation (NIBS), selective serotonin receptor inhibitor (SSRI) antidepressants, mirror therapy (MT), and motor imagery/mental practice, can improve motor recovery after a stroke. (9)

Arm Ability Training (AAT) is designed to assist individuals with stroke who have mild to moderate arm paresis in regaining their manual dexterity. Our "dexterity" in daily life is influenced by a variety of sensorimotor arm and hand skills, including steadiness, finger dexterity, coordinated visually guided movements, the ability to produce accurate goal-directed arm movements, and the speed of selective motions. (10)

The AAT incorporates eight distinct tasks to explicitly and repeatedly train each of these sensorimotor skills at an individual's performance limit. Variable task difficulty levels and enhanced feedback in the form of intermittent knowledge of results are also included. The AAT is clinically helpful in promoting "dexterity" recovery in stroke subjects with reduced focal disability and mild to moderate arm paresis. (11) The Arm Ability Training rehabilitation protocol markedly enhanced the function, strength, grip strength, and dexterity of the upper extremities in stroke patients (12).

By improving sensory feedback, biofeedback is a flexible method that gives people control over physiological functions. Biofeedback is frequently used in physical therapy, neuromuscular rehabilitation, and stress management to treat diseases like motor dysfunction, anxiety, incontinence, and chronic pain. The procedure starts with the measurement of a chosen physical parameter using non-invasive equipment. The result is either shown immediately or transformed into a tactile, visual, or audio feedback signal. The patient consciously modifies the physical parameter in order to practice manipulating the feedback signal. Biofeedback provides enhanced or extrinsic feedback, which supplements the body's intrinsic sensory system. (13)

Hence the study is that there are studies conducted to know the effectiveness of AAT with biofeedback techniques for upper limb rehabilitation. The need for this study is to determine how effective Arm Ability Training with biofeedback techniques is compared to conventional physiotherapy is to improve upper limb dexterity and quality of life in sub-acute stroke.

METHODS

A single-blinded experimental study was conducted with sixty participants. Data on gender, age, stroke duration, side of involvement, Mini-Mental State Examination (MMSE), and Brunnstrom recovery stage were collected from participants aged 30 to 60 years who had been diagnosed with a stroke at the outpatient Department of Jaya College of Paramedical Sciences, College of Physiotherapy. Male and female participants with body mass index (BMIs) ranging from 24 to 29.9 who encountered both ischemic and hemorrhagic strokes during their initial episode of unilateral MCA stroke Endocrine disorders like diabetes, hypertension, subacute stroke lasting longer than three months, upper extremity Brunnstrom scores between stages II and III (14.15), and Mini-Mental State Examination scores (MMSE) ≥ 24 (21 for illiterate) (16). Participants in the study must be able to sit on their own for 30 minutes. Neurological disease (Parkinson's disease, Alzheimer's disease), musculoskeletal problems (deformities, recent fracture), any systemic disease, Pain (score 1 or at least 2 joints), Patients with severe somatosensory deficit, visual or hearing impairment, or severe shoulder pain. Any comorbid condition that might impair function in the upper extremities. Patients with psychological problems are excluded from the study. The Ethical approval obtained from institution Ethical Committee (EC/JCP/ 06/ 2024), and informed consent from the participants were obtained. Participants of Group A received AAT and Group B received Conventional Exercises for 3 weeks, 5 days/week, each session 60 min/session. Measurements were taken before and after the treatment. Based on inclusion and exclusion criteria, subjects clinically diagnosed with stroke were selected. The study was approved by the Ethical Committee (EC/JCP/8/2025). Every participant gave their informed consent after being fully aware of the study's purpose. By random sampling, 50 participants who satisfied the inclusion and exclusion criteria were divided into two study groups, each consisting of 25 persons. The following outcome measures were evaluated: Modified Standardized Nine Hole Peg Test (mS-NHPT) (17, 18), Fugl-Meyer Assessment Upper Extremity (FMA-UE) (19, 20). Stroke-specific quality of life (SS-QOL) (21, 22, 23). Wolf Motor Function Test (24, 25)

Randomization and Grouping

Fifty participants meeting inclusion and exclusion criteria were randomly assigned into two groups (n = 25 each):

- Group A: Arm Ability Training (AAT)
- Group B: Conventional Physiotherapy

Both groups underwent intervention for 3 weeks, 5 days per week, with each session lasting 60 minutes. Outcome measures were assessed before and after the intervention.

Outcome Measures

The following assessments were conducted:

- Modified Standardized Nine Hole Peg Test (mS-NHPT) (17, 18)
- Fugl-Meyer Assessment for Upper Extremity (FMA-UE) (19, 20)
- Stroke-Specific Quality of Life (SS-QOL) (21–23)
- Wolf Motor Function Test (WMFT) (24, 25)

Intervention Protocols

Group A: Arm Ability Training (AAT)

Participants in Group A performed structured AAT exercises targeting upper limb dexterity:

1. Aiming: Using a stylus, hit targets 18–23 cm away, 3–50 mm wide, and 30 cm above the table surface. Aim at specific targets displayed on a screen.
2. Tapping: Quick, repetitive, alternating movements of the thumb, index, and middle fingers on a sensor.
3. Cancellation: Mark circles of various sizes with a pen.
4. Turning Coins: Manipulate coins of 18 and 23 mm diameter.
5. Maze Tracking: Follow specified tracks along with music without losing contact on the track.
6. Bolts and Nuts: Pick up bolts of 3, 5, and 12 mm.
7. Placing Smaller Objects: Precision placement of small items.
8. Placing Larger Objects: Placement of larger objects to enhance motor control.

Group B: Conventional Physiotherapy (26)

Participants in Group B performed conventional upper extremity exercises to improve functional mobility:

- Functional tasks such as folding towels, twisting bottle lids, flipping cards, turning keys, drawing lines with a pencil, and placing coins in a piggy bank.
- Slow, continuous stretching and strengthening exercises for the paretic upper extremities.

SPSS 23.0 is used for statistical analysis. A paired-sample t-test is used to compare within the groups. A p-value < 0.05 was considered statistically significant.

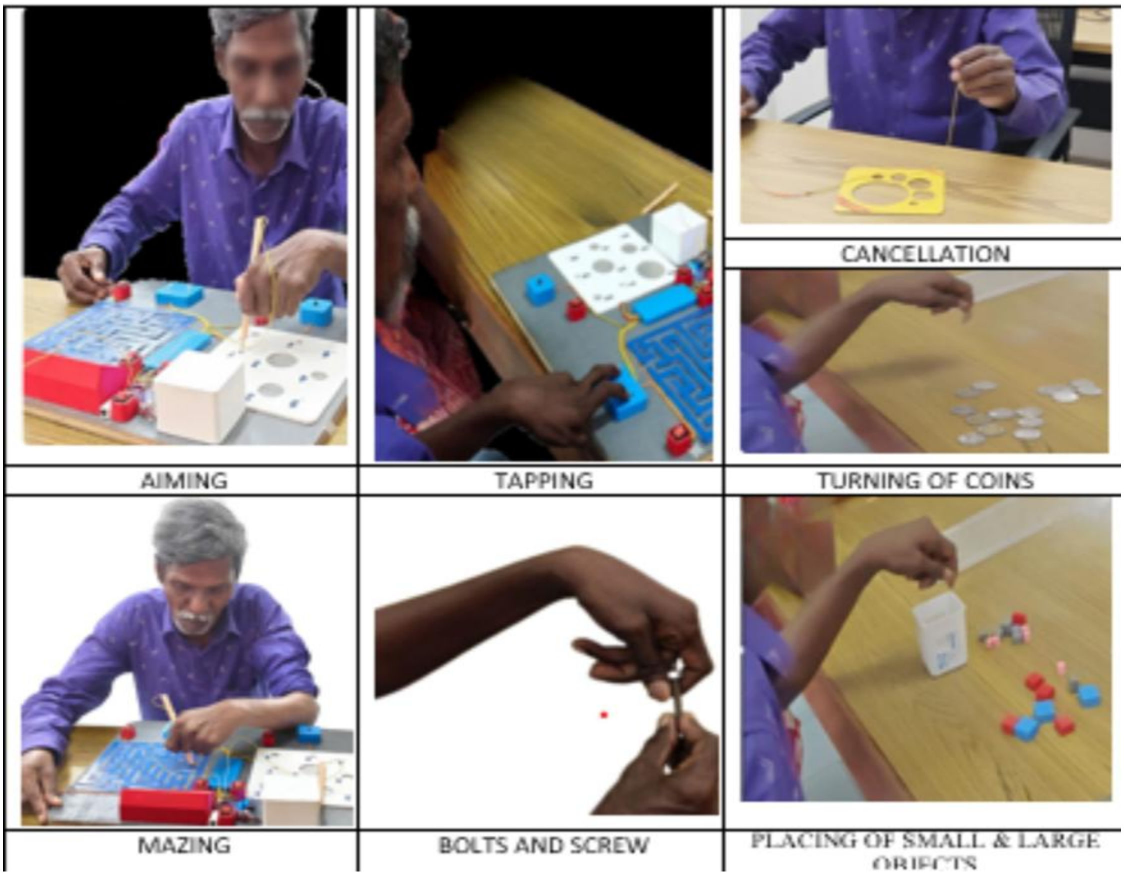

Figure 1: Arm Ability Training

RESULTS

The average age of participants in Group A was 44.00 ± 9.61 years, while in Group B it was 46.92 ± 9.86 years. The mean difference in age between the two groups was 2.92 years.

Table 1: Age of participants in Group A and Group B

		Mean (μ)	S.D.	MD	"t" value	"p" value
Age	Group – A	44.000	9.605	2.92	1.073	0.294
	Group – B	46.920	9.857			

S.D.: Standard Deviation MD: Mean Difference

In Group A, the mean completion time for the m-S NHPT decreased from 113.78 ± 3.14 at pre-intervention to 88.36 ± 2.49 post-intervention, showing a mean improvement of 125.42 ($t = -42.368$, $p < 0.05$).
The mean FMA-UL score increased from 79.08 ± 2.54 at pre-intervention to 90.52 ± 2.92 post-intervention, with a mean difference of 11.44 ($t = 11.73$, $p < 0.05$).
The mean SS-QOL-12 score improved from 19.76 ± 0.99 at pre-intervention to 40.12 ± 1.24 post-intervention, with a mean difference of 20.36 ($t = 57.29$, $p < 0.05$).
The mean WMFT (Functional Ability) score improved from 46.76 ± 1.47 at pre-intervention to 56.92 ± 2.03 post-intervention, with a mean difference of 10.16 ($t = 20.93$, $p < 0.05$). The mean WMFT (time in seconds) score improved from 478.64 ± 2.9 at pre-intervention to 435.16 ± 2.22 post-intervention, with a mean difference of 43.64 ($t = -62.15$, $p < 0.05$).

The above result statistically shows significant improvements in terms of mS-NHPT, FMA-UL, SS-QoL-12, and WMFT (functional ability and time taken in seconds) for sub-acute stroke subjects AAT with biofeedback techniques.

Table 2: Pre- and Post-scores of Arm Ability Training with Biofeedback Techniques

		Mean (μ)	S.D.	MD	"t" value	"p" value
mS-NHPT	**Pre-test**	113.78	3.14	25.42	-42.368	0.3746
	Post-test	88.36	2.49			
FMA-UL	**Pre-test**	79.08	2.54	11.44	11.7355	0.01906
	Post-test	90.52	2.913			
SS-QoL- 12	**Pre-test**	19.76	0.99	20.36	57.2972	0.03538
	Post-test	40.12	1.24			
Functional Ability WMFT	**Pre-test**	46.76	1.477	10.16	20.9318	0.1816
	Post-test	56.92	2.038			
WMFT (Time seconds)	**Pre-test**	478.64	2.924	43.64	-62.1571	0.0174
	Post-test	435.16	2.221			

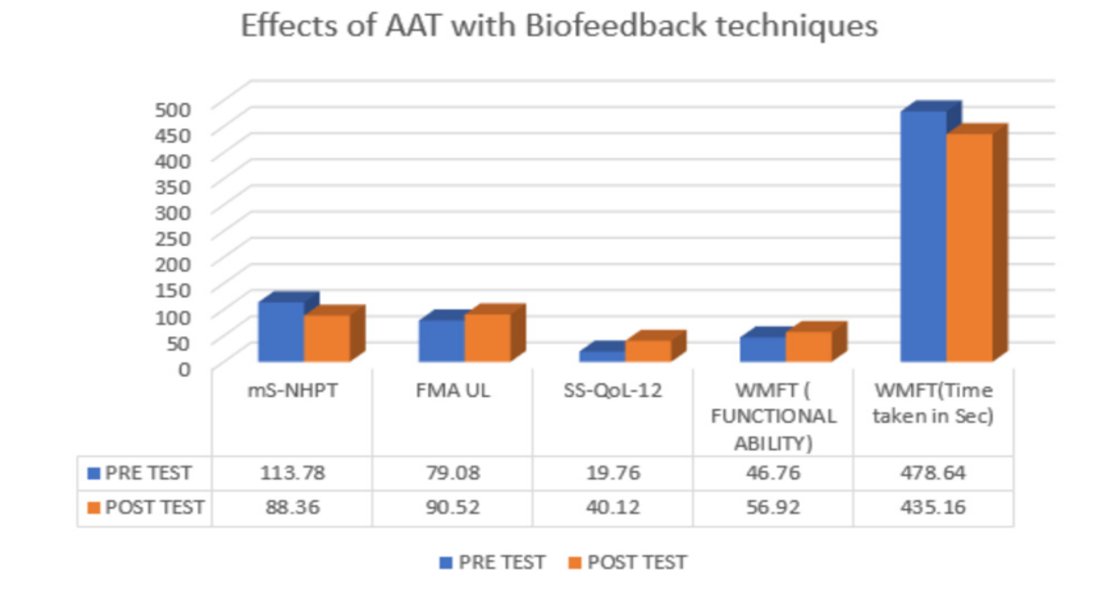

Figure 2: Pre- and Post-scores of Arm Ability Training with Biofeedback Techniques

DISCUSSION

The study objective was to find the effects of arm ability training with biofeedback techniques on improving the dexterity, functional ability of the upper limb, and quality of life in subacute stroke subjects. The outcome measures used were mS-NHPT, FMA-UL, SS-QOL-12, and WMFT. These outcomes were measured before the treatment and after the treatment in each group.

Strokes impair the brain's structural and functional integrity. The brain's intrinsic capacity to reorganize its structure and function in response to injuries and stimuli is known as plasticity. The process of plasticity begins after a stroke. Changes in neural activity and connection in terms of function and structure have been observed in the contralateral hemisphere's peri-lesional and distant areas. A number of interventions have been developed to improve the recovery of post-stroke subjects, some of which actively encourage the remaining neural circuits to promote plasticity (27).

Sensory inputs interact with the motor system as feedback for successful motor behaviours; they enable us to interact with the environment. The feedback for the somesthetic system originates from proprioceptive and cutaneous receptors and reaches to the parietal cortex. Cutaneous inputs are crucial for honing dexterous motions and enable people to do manual tasks in daily life, such as holding things or playing musical instruments. For upper extremity motor planning and adaptation, proprioceptive inputs are required (28).

The AAT with BF focuses on improving brain remodeling and restoration. The primary objective of Arm Ability Training (AAT) is to train the unique rehabilitation needs of stroke subjects by enhancing sensorimotor capabilities. AAT is a sophisticated motor training program designed specifically for survivors of stroke who have mild to moderate arm paresis. "High density" elements relevant to attaining significant recovery induced from training focusing on impairment are purposefully included in the design of AAT. Its design promotes intrinsic motivation, emphasizes motor learning, and has long-term advantages and effectively enhances a variety of sensorimotor hand and arm skills for stroke subjects.

CONCLUSIONS:

Based on the results, AAT led to statistically significant improvements in dexterity (mS-Nine Hole Peg Test), upper limb motor function (FMA-UL), WMFT, and life quality (SS-QOL) within the groups. Arm Ability Training with BF demonstrated significantly greater improvements in FMA-UL, WMFT, and SS-QOL scores, indicating a more pronounced effect on upper limb dexterity and perceived life quality. Arm Ability Training with BF may offer more focused gains in structured motor control and perceived life quality. Thus, incorporating arm ability training along with biofeedback techniques may enhance the recovery process in a sub-acute stroke rehabilitation program.

Conflict of Interest

Authors declare no conflict of interest.

Ethical consideration

The study was approved by institution Ethical Committee (EC/JCP/ 06/ 2024).

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