

IMPACT ON ELECTRICAL STIMULATION AND GRIP STRENGTHENING TO IMPROVE HANDWRITING AMONG STROKE SUBJECTS AFFECTED WITH AGRAPHIA

A Quasi-Experimental Study

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Abstract : Stroke is a major cause of lasting disability, and agraphia, an acquired loss of writing ability, limits communication and independence. Hand weakness and poor dexterity add to the problem. **Objective:** to examine whether electrical stimulation, grip strengthening exercises and handwriting retraining improve handwriting and hand function in stroke patients with agraphia. **Methods:** in a quasi-experimental pre-test/post-test study, 50 subacute stroke patients with agraphia (aged 40–55 years) received 15 min of electrical stimulation, 20 min of grip strengthening, 15 min of handwriting retraining and 40 min of conventional rehabilitation per 90-minute session, four sessions weekly for six weeks. The Nine-Hole Peg Test (NHPT), Sollerman Hand Function Test, handwriting score and hand grip strength were compared before and after treatment with a paired t-test. **Results:** all measures improved significantly ($p < 0.001$): NHPT time fell from 44.8 ± 2.89 s to 34.5 ± 3.17 s, the Sollerman score rose from 40.1 ± 2.65 to 55.3 ± 3.70 , the handwriting score from 4.0 ± 0.78 to 7.3 ± 1.11 , and grip strength from 11.86 ± 1.64 kg to 17.6 ± 1.93 kg. **Conclusion:** the combined programme was followed by significant gains in handwriting, grip strength, dexterity and functional hand use, and may help restore writing ability and independence after stroke. **Index Terms** - Stroke, Agraphia, Handwriting Retraining, Electrical Stimulation, Grip Strengthening Exercises, Hand Function, Neurorehabilitation.

I. INTRODUCTION

Survivors of stroke frequently live with motor and language impairments. One of these is agraphia, an acquired loss of the ability to write, which interferes with everyday tasks that depend on handwriting. It typically follows lesions of the cortical and subcortical areas that govern language and movement, and it can damage both the linguistic and the motor side of writing [13, 27]. The dominant (usually left) parietal lobe is the area most often involved. Central forms are linked to perisylvian language cortex, the angular gyrus and posterior temporal regions, while peripheral forms are linked to the premotor cortex, supplementary motor area, basal ganglia and cerebellum [27, 21].

Clinically, agraphia is divided into central types (lexical, phonological, deep, surface and spatial) and peripheral types (apraxic, allographic, graphemic-buffer and visuospatial) [27, 21]. Writing by hand is a demanding motor act in which sensory input, neural control and the mechanics of the arm and hand must work together, and vision, perception and central pathways all shape the result. The hand contains 27 bones; forearm (extrinsic) muscles and the small intrinsic muscles of the thumb, little finger and palm supply the tripod grasp, precision and steadiness needed to guide a pen.

Standard rehabilitation concentrates on language retraining and writing practice, yet recovery is often partial when the affected hand itself is weak or poorly controlled. Electrical stimulation activates muscles through controlled current, can raise cortical excitability and supports neuroplasticity and voluntary muscle recruitment [12, 24]. Grip strengthening builds the power, endurance and dexterity of the hand needed for steady writing movements. This study examined whether combining these two approaches with handwriting retraining improves handwriting and hand function in stroke patients with agraphia.

II. REVIEW OF LITERATURE

According to Sinanović et al. [13], agraphia is a frequent yet under-recognized result of stroke that can appear without any obvious speech problem, since writing draws on language, spelling, perception, spatial orientation and motor planning. In a cohort of 59 stroke patients, Zukić et al. [23] observed that many still wrote poorly two years later, particularly those with severe early language deficits. A meta-analysis by Planton et al. [22] located handwriting in a network spanning the left premotor cortex, superior parietal lobule, intraparietal sulcus and temporal language areas, and Marano (2025) likewise described handwriting as an integration of sensorimotor, visuospatial and phonological processes. Ardila [21] characterized agraphia as a disorder of several systems (semantic, lexical, phonological, graphemic, orthographic and motor programming), and Tiu et al. [27] emphasized telling central from peripheral forms. Hillis [20] tied lesions of the left inferior frontal gyrus, angular gyrus and parietal cortex to agraphia, while Park [28] pointed out that apraxia can substantially impair handwriting.

Treatment. A review of 139 randomized trials (about 12,000 participants) by Pollock et al. [12] found moderate-quality evidence that neuromuscular electrical stimulation added to usual therapy improves motor function, muscle activation and voluntary control. Mehrholz et al. [19] pooled 45 trials (about 1,619 participants) and found gains in arm-hand activity and coordination with electromechanical and task-oriented training. French et al. [5] (33 trials, about 1,853 participants) reported better function after repetitive task training. Demers et al. [26] described cortical reorganization after task-specific training in 12 people with chronic stroke, and Brady et al. [18] (57 trials, about 3,002 participants) showed that speech and language therapy improves communication, including written language.

III. AIM, OBJECTIVES AND HYPOTHESES

The study aimed to find out how well electrical stimulation, grip strengthening and handwriting retraining improve handwriting and hand function after stroke with agraphia. Its objectives were to test, in this population, the effect on handwriting of (i) electrical stimulation, (ii) grip strengthening exercises, and (iii) both combined with handwriting retraining. The null hypothesis stated that none of these has a meaningful effect on handwriting; the alternative hypothesis stated that each one improves it.

IV. MATERIALS AND METHODS

4.1 Study design and setting

A quasi-experimental pre-test/post-test design was used at the Nightingale Institute of Physiotherapy Hospital and Rehabilitation, Coimbatore. Participants were enrolled by convenience sampling from the institute's physiotherapy rehabilitation department and Madukkarai Government Hospital. The whole study lasted for 8 months, and each person was treated for 6 weeks. Every participant received an explanation of the study and gave informed consent before the first assessment.

4.2 Participants

Seventy post-stroke patients were screened; 20 were excluded and 50 were enrolled (Fig. 1). To be eligible, patients had to have a subacute middle cerebral artery stroke (Dobkin and Carmichael classification), be aged 40–55 years, be of either sex, show agraphia, be at Brunnstrom stage III–V with some voluntary control, and be able to follow simple spoken commands. Patients were excluded for a repeat stroke, severe cognitive or visual impairment affecting writing, agnosia or other perceptual disorder, another neurological condition affecting the hand (such as Parkinson's disease or multiple sclerosis), poor cooperation, upper limb fracture, severe contracture or amputation, nerve injury, or a contraindication to electrical stimulation such as a pacemaker.

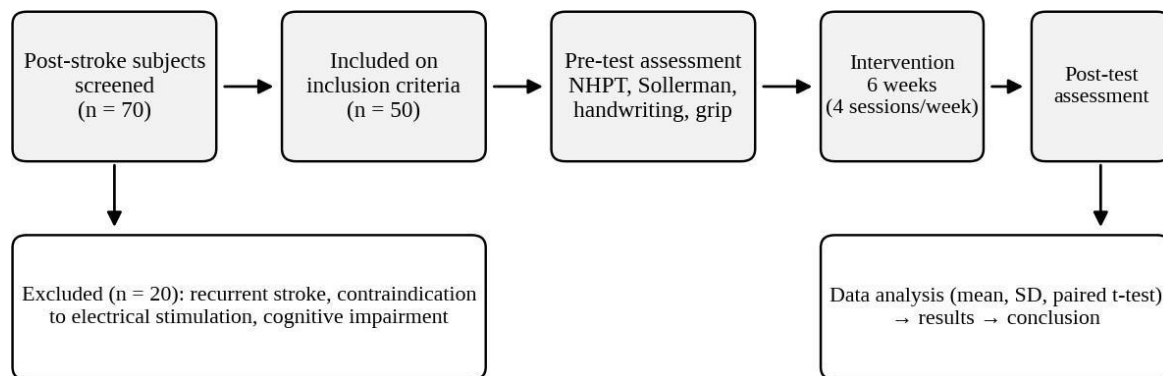


Fig. 1: flow chart of the study

4.3 Outcome measures

All measures were taken on the affected hand before and after the programme. In the **Nine-Hole Peg Test** the patient fills a 3×3 board with nine pegs and then empties it as fast as possible; the time in seconds is the score, and lower is better ^[11]. The **Sollerman Hand Function Test** rates grip patterns during 20 everyday tasks, such as picking up coins, turning a key, using a spoon, buttoning and writing; each task earns 0–4 points for a maximum of 80 ^[14]. For the **handwriting assessment** patients wrote letters, words and sentences, copied a paragraph and wrote from dictation, and the sample was scored on legibility, letter formation, spacing, alignment, speed and spelling accuracy. **Grip strength** was recorded with a hand dynamometer while the patient sat with the shoulder adducted, elbow at 90°, forearm neutral and wrist slightly extended; three maximal squeezes of 3–5 seconds were made with rests between them, and the mean in kilograms was analyzed ^[3].

4.4 Intervention

A physiotherapist supervised every 90-minute session: 15 minutes of electrical stimulation, 20 minutes of grip strengthening, 15 minutes of handwriting retraining and 40 minutes of conventional rehabilitation. Sessions take place four times a week for six weeks. **Electrical stimulation.** The patient sat with the forearm resting on a table and the wrist slightly extended. The active electrode was placed over the motor points of the wrist and finger extensors (extensor carpi radialis longus and brevis, extensor carpi ulnaris, extensor digitorum, extensor indicis, extensor pollicis longus and brevis) and the passive electrode over the proximal forearm. An interrupted (surged) faradic current of 30–50 Hz and 0.1–1ms pulse width was raised until a visible, tolerable contraction occurred, using 5–10 s on, 10–20 s off and 10–15 contractions. Patients tried to extend the wrist and fingers during each contraction, to offset flexor dominance and improve hand posture for writing.

Grip strengthening. The programme worked the long finger and thumb flexors, thenar muscles, lumbricals, interossei and wrist flexors. It included soft-ball squeezes with 3–5 s holds, therapy putty (squeezing, pinching, finger digging, rolling), rubber-band finger opening, hand-gripper training, tip-to-tip pinching, finger opposition, wrist flexor work and table-press isometrics, followed by functional tasks such as handling coins, keys, jars, a spoon, buttons, a pen and a telephone receiver. Each exercise was done for 10–15 repetitions in 2–3 sets with rests. Resistance was raised from soft to hard and the focus moved from gross grip to pinch to functional use, avoiding pain and fatigue.

Handwriting retraining. This repetitive, task-specific training was given with the patient well supported, the forearm resting on a table, the wrist slightly extended and tripod grasp encouraged. Tasks advanced from pre-writing patterns (lines, circles, loops, tracing, dot-to-dot) to letter formation (tracing, then copying, then independent writing; 3–5 repetitions per letter), words, sentences, copying, dictation, functional writing (name, address, numbers, forms, lists) and timed accuracy tasks. Verbal and visual feedback was given throughout, and difficulty rose from simple to complex and from guided to independent.

V. DATA ANALYSIS

Data from all 50 participants were summarized as means and standard deviations (SD). For each outcome the mean difference between pre-test and post-test was computed, and a paired t-test was used to judge whether the change was significant. Results with $p < 0.001$ were considered highly significant.

VI. RESULTS

The sample comprised 31 men (62%) and 19 women (38%). Nine participants (18%) were 40–45 years old, 18 (36%) were 45–50 and 23 (46%) were 50–55. The right side was affected in 37 (74%) and the left in 13 (26%), and 47 (94%) wrote with the right hand versus 3 (6%) with the left (Table 1).

Table 1: demographic characteristics of the participants (n = 50)

Variable	Category	n	Percentage
Gender	Male	31	62%
	Female	19	38%
Age (years)	40–45	9	18%
	45–50	18	36%
	50–55	23	46%
Affected side	Right	37	74%
	Left	13	26%
Writing hand	Right	47	94%
	Left	3	6%

Every outcome improved significantly over the six weeks (Table 2, Fig. 2). Peg-test time dropped by 10.3 s, from 44.8 ± 2.89 s to 34.5 ± 3.17 s ($t = 157.34$, $p < 0.001$), showing better dexterity and fine motor coordination. The Sollerman score climbed by 15.2, from 40.1 ± 2.65 to 55.3 ± 3.70 ($t = 91.24$, $p < 0.001$), showing better functional use of the hand. The handwriting score increased by 3.3, from 4.0 ± 0.78 to 7.3 ± 1.11 ($t = 50.41$, $p < 0.001$), consistent with clearer, better spaced and more accurate writing. Grip strength gained 6.0 kg, from 11.86 ± 1.64 kg to 17.6 ± 1.93 kg ($t = 93.91$, $p < 0.001$).

Table 2: pre-test and post-test outcome measures (n = 50, paired t-test)

Outcome measure	Pre-test (mean $\pm$ SD)	Post-test (mean $\pm$ SD)	Mean difference	t-value	p-value
Nine-Hole Peg Test (s)	44.8 ± 2.89	34.5 ± 3.17	10.3	157.34	<0.001
Sollerman Hand Function Test	40.1 ± 2.65	55.3 ± 3.70	15.2	91.24	<0.001
Handwriting Assessment Score	4.0 ± 0.78	7.3 ± 1.11	3.3	50.41	<0.001
Hand Grip Strength (kg)	11.86 ± 1.64	17.6 ± 1.93	6.0	93.91	<0.001

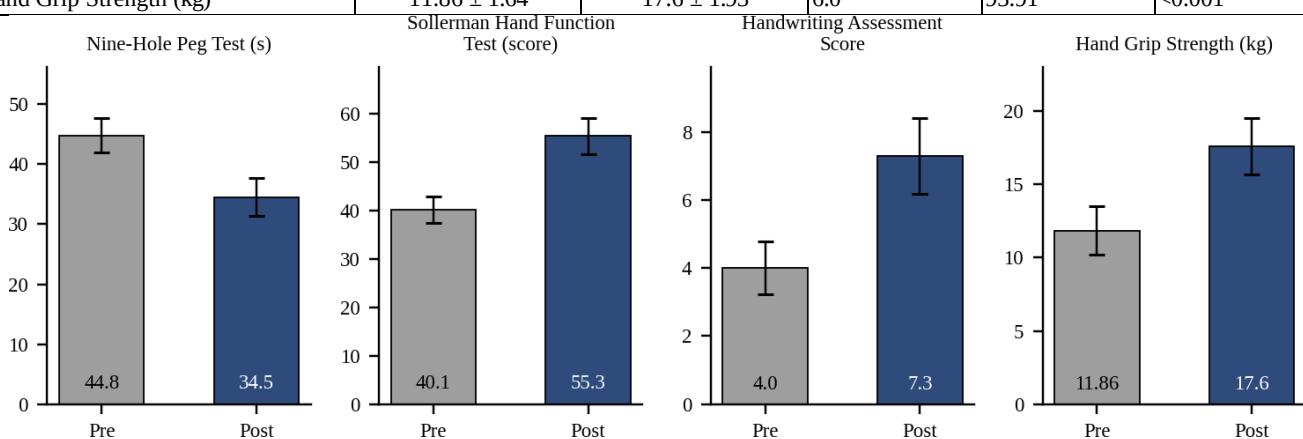


Fig. 2: pre-test and post-test values of the outcome measures (mean $\pm$ SD)

VII. DISCUSSION

The gains probably reflect the three components working together. Stimulating the wrist and finger extensors, which are often weak after stroke because the flexors dominate, should have eased hand opening, positioning and control. Strengthening the flexors and the intrinsic and extrinsic hand muscles would have improved pen holding and hand stability. Handwriting retraining, being repetitive and task-specific, likely sharpened fine coordination, visual-motor integration and accuracy, and repeated practice is known to drive neuroplastic change [30, 29].

The results fit with earlier evidence: Pollock et al. [12] found that electrical stimulation added to usual care improves upper limb motor function and muscle activation, which could help control of the wrist and fingers in writing. Reviews of task-oriented and repetitive task training [19, 5] report better arm-hand function, and Demers et al. [26] linked task-specific training to cortical reorganization. Because writing is part of language, the findings also align with Brady et al. [18] on rehabilitation of written communication. Motivation, cognitive status and stroke severity may have affected the outcomes.

VIII. LIMITATIONS AND SUGGESTIONS

There was no control group, so the programme could not be compared with other treatments or with spontaneous recovery. Six weeks of treatment without later follow-up says nothing about how long the gains last. Motivation and effort varied, home practice could not be fully checked, and coexisting problems such as cognitive loss, aphasia or sensory deficits may have influenced writing. Handwriting scoring is partly subjective, only one setting was used, and education level and age effects were not analyzed separately. Later work should use larger, multicenter samples in randomized controlled trials with long-term follow-up. Objective measures such as digital handwriting analysis, a monitored home programme, teamwork between physiotherapy, occupational therapy and speech therapy, and grouping patients by severity on standard motor and language scales would strengthen the evidence. Comparisons between ischemic and hemorrhagic stroke, first and recurrent stroke, and early and delayed treatment onset are also worth studying.

IX. CONCLUSION

Six weeks of electrical stimulation, grip strengthening and handwriting retraining together improved handwriting, hand dexterity, functional hand use and grip strength in stroke patients with agraphia ($p < 0.001$ for all measures). As the design had no control group, randomized controlled trials are needed to confirm these results.

ACKNOWLEDGMENT

The authors thank the Principal, Prof. Dr. M. N. Rajan Nethaji, the faculty and the staff of Nightingale Institute of Physiotherapy, Coimbatore, and all the participants who took part in this study.

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