The Review Of
DIABETIC
STUDIES
OPEN ACCESS

Effectiveness Of Arm Ability Training With Biofeedback Techniques To Improve Neuroplasticity, Dexterity And Quality Of Life Among Subacute Stroke Survivors

Mythili D[1*], Narayanasamy K[2], Kalpana S[3], Balchandar V[4], Kotteeswaran K[5]

[1]Principal, Department of Neurology, Faculty of Physiotherapy, Madha College of Physiotherapy, The Tamil Nadu Dr MGR Medical University, Guindy, Chennai, Tamil Nadu, 600062, India. madhaphysio98@gmail.com
[2]Vice Chancellor, Faculty of Physiotherapy, The Tamil Nadu Dr MGR Medical University, Guindy, Chennai, Tamil Nadu, 600062, India. research@tnmgrmu.ac.in
[3]Research Head, Faculty of Physiotherapy, The Tamil Nadu Dr MGR Medical University, Guindy, Chennai, Tamil Nadu, 600062, India. research@tnmgrmu.ac.in
[4]Principal, Department of Neurology, Faculty of Physiotherapy, Jaya College of Physiotherapy, The Tamil Nadu Dr MGR Medical University, Guindy, Chennai, Tamil Nadu, 600062, India. jayacpt202@gmail.com
[5]Professor, Department of Neurology, Faculty of Physiotherapy, Saveetha College of Physiotherapy, Saveetha Institute of Medical & Technical Sciences, Thandalam, Tamil Nadu, 602105, India. kotteeswaran.scpt@saveetha.com
**Corresponding Author Email: drmythuphysio@gmail.com*

ABSTRACT

OBJECTIVES: 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.

METHODS: 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.

RESULTS: 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 ($p < 0.05$).

CONCLUSION: 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, focused neurological impairment brought on by central nervous system vascular damage (hemorrhage, infarction). Globally, stroke ranks as the second most common cause of death and disability. Post stroke, more than 2/3 of the patients have impairment in the motor function of the upper limb. As a result, there will be difficulty in performing activities of daily living. 85%of strokes are mostly ischemic, mostly due to large artery cardioembolism, small vessel arteriolosclerosis, and

atherothromboembolism. 15% of younger adults develop ischemic strokes due to factors, including intracerebral hemorrhage 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. Strokes account for 70% of all strokes in LMICs, and the resulting illness burden is higher than in high-income nations. In India, stroke is now the fourth greatest 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 like 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 a 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)

All strokes about 75% 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 minute functions (such as grasping and manipulating) are required for the 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 are important as the therapeutic approach (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. 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. Because biofeedback offers enhanced or extrinsic feedback, which is a type of feedback that goes beyond 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. So the need for this study is to find how effective arm ability training with biofeedback techniques vs. conventional physiotherapy is to improve upper limb dexterity and life quality in sub-acute stroke.

METHODS:

A single-blinded experimental study with sixty participants. The Participants gender, age, stroke duration, side of involvement, MMSE, and Brunnstrom recovery stage were the primary data collected from 60 samples of people aged 30 to 60 who had been diagnosed with a stroke from the outpatient Department of Jaya College of Paramedical Sciences, College of Physiotherapy. Male and female subjects with 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 (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.

PROCEDURE:

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)

Group A - Arm Ability Training and Group B – Conventional Exercises

Arm Ability Training: 3 weeks, 5 days/week, each session 60 min/session

1. Aiming: Using a stylus, hit targets that are 18–23 cm away, 3–50 mm wide, and 30 cm above the table surface. Aiming at a specific target as displayed on the screen
2. Tapping: Quick, repetitive alternating selective movements of the thumb, index, and middle fingers on the specified sensor
3. Cancellation: Circles of various sizes are indicated with a pen.
4. Turning of Coins: 18 and 23 mm
5. Maze tracking over the specified tracks along with music (instruct patient not to miss the contact on the track)
6. Bolts and nuts: picking of bolts 3, 5, and 12 mm
7. Placing smaller objects
8. Placing Larger Objects.

Figure 1: Arm Ability Training

Group B: Conventional Physiotherapy (26)

To improve functional mobility, subjects were given instructions to perform tasks such as folding towels, twisting off bottle lids, flipping cards, turning keys, drawing a line by holding a pencil, and placing coins in the piggy bank. For the paretic upper extremities, slow, continuous stretching and strengthening exercises were also administered.

RESULTS:
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.

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

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 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			

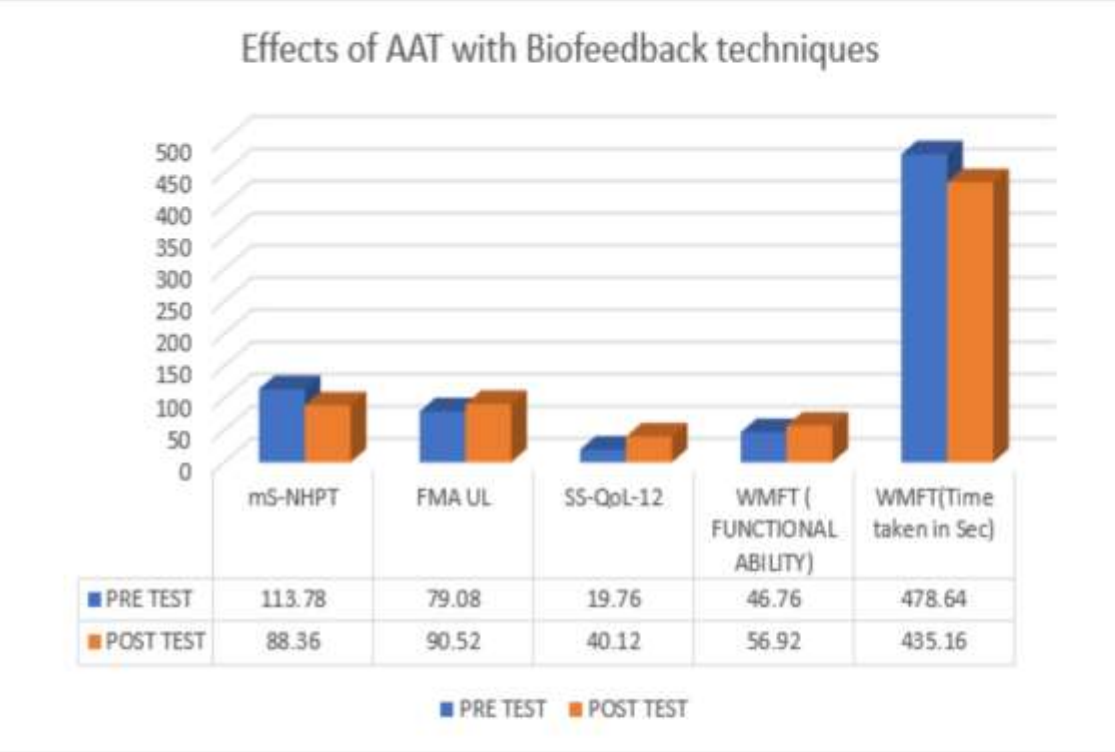

Figure 2: Pre- and Post-scores of Arm Ability Training with Biofeedback Techniques

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.

DISCUSSION:
The study objective was to find the effects of arm ability training with biofeedback techniques on improving dexterity, functional ability of the upper limb, and life quality in subacute stroke subjects. The outcome measures used were mS-NHPT, FMA-UL, SS-QOL-12, and WMFT. These outcomes were measured prior to the treatment and post the treatment for the 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 recovery of post-stroke subjects, some of which actively encourage the remaining neural circuit to promote plasticity (27).

Sensory inputs interact with the motor system feedback for successful motor behaviors; 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.

ACKNOWLEDGEMENT: In the development Arm ability Training kit, Twin Bot Technologies provided excellent insight and support, for which I am grateful. We would especially like to thank faculties of Jaya College of Physiotherapy in data collection and recruitment. I express my sincere gratitude to each one of the study for their valuable time, experiences and wisdom.

CONFLICTS OF INTEREST: No conflicts of interest declared by authors.

FUNDING: This Research works is funded under Theme Based Research- Physiotherapy, **Lr. No: DoR /43637/2023, TBR/Pharmacy/OT/PT** by “The Tamil Nadu Dr MGR Medical University”, Chennai, Tamil Nadu, and India.

ABBREVATIONS: Arm Ability Training (AAT) Modified standardized nine-hole peg test **(**mS-NHPT), Fugl-Meyer Assessment Upper Extremity (FMA-UE), 12-item stroke-specific quality of life scale (SSQoL-12), and Wolf Motor Function Test (WMFT).

REFERENCES:

1. Murphy SJ, Werring DJ. Stroke: causes and clinical features. Medicine (Abingdon). 2020 Sep;48(9):561-566. doi: 10.1016/j.mpmed.2020.06.002. Epub 2020 Aug 6. PMID: 32837228; PMCID: PMC7409792.
2. Joseph, Jaison[1]; Varkey, Biji P.[2]; et al , Age, gender, and regional variations in stroke epidemiology in India: A systematic review and meta-analysis. Indian Journal of Community and Family Medicine 10(1):p 7-17, Jan–Jun 2024. | DOI: 10.4103/ijcfm.ijcfm_22_23
3. Jones SP, Baqai K, Clegg A, Georgiou R, Harris C, Holland EJ, Kalkonde Y, Lightbody CE, Maulik PK, Srivastava PM, Pandian JD, Kulsum P, Sylaja PN, Watkins CL, Hackett ML. Stroke in India: A systematic review of the incidence, prevalence, and case fatality. Int J Stroke. 2022 Feb;17(2):132-140. doi: 10.1177/17474930211027834. Epub 2021 Jul 2. PMID: 34114912; PMCID: PMC8821978.

4. Řasová K. 1,3*, Martinková P. 2, Vařejková M et al Improvements in upper extremity isometric muscle strength, dexterity, and self-care independence during the sub-acute phase of stroke recovery: an observational study on the effects of intensive comprehensive rehabilitation Front Neurol 2024 Oct 23:15:1442120. doi: 10.3389/fneur.2024.1442120. https://doi.org/10.3389/fneur.2024.1442120
5. Zahra Goodarzi, Ali Asghar Jamebozorgi, Ashkan Irani, Alireza Akbarzadeh Baghban, Aliyeh Daryabor, Effect of visual biofeedback on fine motor function and activity daily of life in stroke patients: A pilot study, Journal of Bodywork and Movement Therapies, Volume 41,2025,Pages 109-114, ISSN 1360-8592, https://doi.org/10.1016/j.jbmt.2024.11.011.
6. Han SH, Choi YW, Kam KY: Effects of EMG biofeedback training on the hand functions of stroke patients. J Korean Soc Occup Ther, 2009, 17: 13–24.
7. Motor recovery after stroke: a systematic review Langhorne, Peter et al. The Lancet Neurology, Volume 8, Issue 8, 741 – 754 August 2009
8. Ciceron C, Sappey-Marinier D, Riffo P, Bellaiche S, Kocevar G, Hannoun S, Stamile C, Redoute J, Cotton F, Revol P, Andre-Obadia N, Luaute J, Rode G. Case Report: True Motor Recovery of Upper Limb Beyond 5 Years Post-stroke. Front Neurol. 2022 Feb 17;13:804528. doi: 10.3389/fneur.2022.804528. PMID: 35250813; PMCID: PMC8891374.
9. Claflin ES, Krishnan C, Khot SP. Emerging treatments for motor rehabilitation after stroke. Neurohospitalist. 2015 Apr;5(2):77-88. doi: 10.1177/1941874414561023. PMID: 25829989; PMCID: PMC4357600.
10. Platz T, Lotze M. Arm Ability Training (AAT) Promotes Dexterity Recovery After a Stroke-a Review of Its Design, Clinical Effectiveness, and the Neurobiology of the Actions. Front Neurol. 2018 Dec 11;9:1082. doi: 10.3389/fneur.2018.01082. PMID: 30619042; PMCID: PMC6298423.
11. Arm ability training for stroke and traumatic brain injury patients with mild arm paresis: A single-blind, randomized, controlled trial Platz, Thomas et al. Archives of Physical Medicine and Rehabilitation, Volume 82, Issue 7, 961 - 968
12. Ansana Elizabath 1 Kalidasan Varathan Effect of Arm Ability Training on Functional Mobility and Dexterity in Hemiparetic J Health Allied Sci NU 2024;14:472–476.
13. Malik K, Dua A. Advancing Patient Care With Biofeedback. [Updated 2025 Jan 18]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK553075/
14. Chien-Yu Huang, PhD,[a] Gong-Hong Lin, 2016 Improving the utility of the Brunnstrom recovery stages in patients with stroke
15. Robert Teasell MD, Norhayati Hussein MD, Magdalena Mirkowski MSc, MScOT, Danielle Vanderlaan RRT, Marcus Saikaley HBSc, Mitchell Longval BSc, Jerome Iruthayarajah MSc Hemiplegic Upper Extremity Rehabilitation Stroke Rehabilitation Clinician Handbook 2020
16. Quoc Cuong Truong, Matti Cervin, Carol C. Choo, Katya Numbers, Adam C. Bentvelzen, Nicole A. Kochan, Henry Brodaty, Perminder S. Sachdev, Oleg N. Medvedev Examining the validity of the Mini-Mental State Examination (MMSE) and its domains using network analysis Psychogeriatrics, The official journal of Japanese Psychogeriatrics
17. Gudrun M Johansson and Charlotte K Häger 2019. A modified standardized nine-hole pegtest for valid and reliable kinematic assessment of dexterity post-stroke, Journal of Neuro Engineering and Rehabilitation
18. E. Prochaska and E. Ammenwerth, "Validity and Reliability of a New Developed Digital Version of Nine Hole Peg Test," in IEEE Access, vol. 11, pp. 97169-97176, 2023, doi: 10.1109/ACCESS.2023.3311270
19. Huynh BP, DiCarlo JA, Vora I, Ranford J, Gochyyev P, Lin DJ, Kimberley TJ. Sensitivity to Change and Responsiveness of the Upper Extremity Fugl-Meyer Assessment in Individuals With Moderate to Severe Acute Stroke. Neurorehabil Neural Repair. 2023 Aug;37(8):545-553. doi: 10.1177/15459683231186985. Epub 2023 Jul 24. PMID: 37483132.
20. Hiragami S, Inoue Y, Harada K. Minimal clinically important difference for the Fugl-Meyer assessment of the upper extremity in convalescent stroke patients with moderate to severe hemiparesis. J Phys Ther Sci. 2019 Nov;31(11):917-921. doi: 10.1589/jpts.31.917. Epub 2019 Nov 26. PMID: 31871377; PMCID: PMC6879402.

21. Sakr F, Dabbous M, Akel M, Salameh P, Hosseini H. Construction and Validation of the 17-Item Stroke-Specific Quality of Life Scale (SS-QOL-17): A Comprehensive Short Scale to Assess the Functional, Psychosocial, and Therapeutic Factors of QOL among Stroke Survivors. Int J Environ Res Public Health. 2022 Nov 25;19(23):15668. doi: 10.3390/ijerph192315668. PMID: 36497746; PMCID: PMC9741031.
22. Post, M. W., Boosman, H., van Zandvoort, M. M., Passier, P. E., Rinkel, G. J., & Visser-Meily, J. M. (2011). Development and validation of a short version of the Stroke Specific Quality of Life Scale. Journal of Neurology, Neurosurgery & Psychiatry, 82(3), 283–286. link
23. Psychometric properties of the 12-item Stroke-Specific Quality of Life Scale among stroke survivors in Hong Kong. Sci Rep **13**, 1510 (2023)
24. An Evaluation of the Wolf Motor Function Test in Motor Trials Early After Stroke Edwards, Dorothy F. et al. Archives of Physical Medicine and Rehabilitation, Volume 93, Issue 4, 660 - 668
25. Hodics TM, Nakatsuka K, Upreti B, Alex A, Smith PS, Pezzullo JC. Wolf Motor Function Test for characterizing moderate to severe hemiparesis in stroke patients. Arch Phys Med Rehabil. 2012 Nov;93(11):1963-7. doi: 10.1016/j.apmr.2012.05.002. Epub 2012 May 10. PMID: 22579647; PMCID: PMC3483403.
26. Kisner C, Colby LA, Borstad J. Therapeutic Exercise: Foundations and Techniques. 7th ed. Philadelphia: FA Davis; 2018:534–584 30 Edwards DF, Lang CE, Wagner JM, Birkenmeier R, Dromerick AW
27. Fan Su Wendong Xu Enhancing Brain Plasticity to promote Stroke Recovery Front. Neurol., 30 October 2020 Sec. Stroke Volume 11 - 2020 | https://doi.org/10.3389/fneur.2020.554089
28. Proulx CE, Louis Jean MT, Higgins J, Gagnon DH, Dancause N. Somesthetic, Visual, and Auditory Feedback and Their Interactions Applied to Upper Limb Neurorehabilitation Technology: A Narrative Review to Facilitate Contextualization of Knowledge. Front Rehabil Sci. 2022 Mar 1;3:789479. doi: 10.3389/fresc.2022.789479. PMID: 36188924; PMCID: PMC9397809.