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A Review on Combined Effect of Functional Electrical Stimulation and Robotic Hand Glove for Hand Rehabilitation in Post-Stroke Patients

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ABSTRACT

Background: In stroke patients, upper extremity hemiplegia and loss of hand functions are primary impairments. Combined use of Functional Electrical Stimulation and Robotic Hand Glove was done to overcome the limitations in separate applications.
Aims/Objective: To assess the combined effect of Robotic Hand Glove and Functional Electrical Stimulation to improve the hand functions and its impact on quality of life in post-stroke patients.
Methodology: Different articles published between 2011 and 2022 were searched from online sources such as PUBMED, Google Scholar and Cochrane. In this review experimental study, clinical trial, preliminary investigation, pilot study, randomized control trial are included. A secondary search of the reference list of all identified articles was also conducted. Then each study was reviewed independently.
Result: A total of 30 articles were searched. Out of 30 studies, 10 of them were screened out of which 4 studies were excluded due to flaws in methodology. The remaining 6 supportive studies reported that combining effect of Functional Electrical Stimulation and Robotic Hand Glove were more beneficial than conventional therapy alone to improve hand functions.
Conclusion: Thus, it can be concluded that Functional Electrical Stimulation and Robotic Hand Glove were found to be more effective than conventional therapy to improve the specific task such as full reach, grasp, release, lifting tasks, drinking water, etc. in post-stroke patients.

Keywords: Functional Electrical Stimulation, Hand Rehabilitation, Robotic Hand Glove, Stroke.

INTRODUCTION

According to World Health Organization, stroke is defined as a clinical syndrome consisting of rapidly developing clinical signs of focal disturbance of cerebral function lasting more than 24 h or leading to death with no apparent cause other than a vascular origin.(1) According to the Global Burden of Disease (GBD) study in 1990, Stroke was the second leading cause of death worldwide.(2) Stroke survivors show impairments of body function such as significant deviation or loss in neuromusculoskeletal and movement related function, joint mobility, muscle power, muscle tone or/and involuntary movement.(3)

The patients who have had a stroke, a common course of recovery from hemiparesis reveals the development of uncontrolled flexion synergy and patients are unable to open the fingers.(4) Grasping, holding and manipulating objects are daily functions that remain deficient in 55% to 75% of patients 3 to 6 months post-stroke.(5) Conventional therapies used for improving hand function for post stroke patients are labor-intensive and time consuming. Along

with conventional therapies, there are variety of interventions have been introduced to overcome the limitations of conventional therapy to improve hand function and dexterity in stroke patients. [6]

One of them is Robot-assisted training using robotic devices which provide highly repetitive, intensive and task-specific training with less labour. [7] Previous study suggests that soft robotic hand could assist paretic hands in executing grasp, grip and pinch functions among sub-acute and chronic stroke patients. [8] Furthermore, it reduces the demand of physical work required and helps to target the specific movements more precisely. But it has been found that robotic hand requires complex mechanism and therefore not attractive for integrated hand and arm training. Also, there are limited range of motions possible with its application. [9]

Other one is Functional Electrical Stimulation (FES) technique which is used to restore impaired function through electrical stimulation, [10] resulting in inhibition of abnormal reflexes and inducing active movements. [11] It is also used with robotic assistance device for severe motor regulation. FES is prone to cause muscle fatigue when used with high intensity and may not generate enough torque for the desired motion. [12]

Combined use of FES and Robotic Technologies has been proposed as a solution to overcome their individual limitations, maintain safety and effectiveness. [13] This combined approach has been named as Hybrid Rehabilitation System. Aim of using this Hybrid System is to improve the individual functional independency by a) improving joint range of motion and b) improving the ability to close and open hand. Advantages of this system is to reduce pain at the stimulating side and delay fatigue. Aim of the present study was to review on use of Hybrid System for improve hand function and dexterity in patient with stroke.

MATERIALS & METHODS

- Search Strategy:

  Different articles published in English language between 2011 and 2022 were searched from various online data base. The search strategy included these types of keywords: Functional Electrical Stimulation (FES), Robotic Hand Glove, Hybrid system, Hand Rehabilitation, Stroke. A secondary search of the references list of all identified articles was also concluded. Then each study was reviewed independently.

- Selection Criteria:

1. Inclusion Criteria:

Study Design:

- Experimental Study
- Randomized Control Trial
- Clinical Trial
- Preliminary Study
- Pilot Study

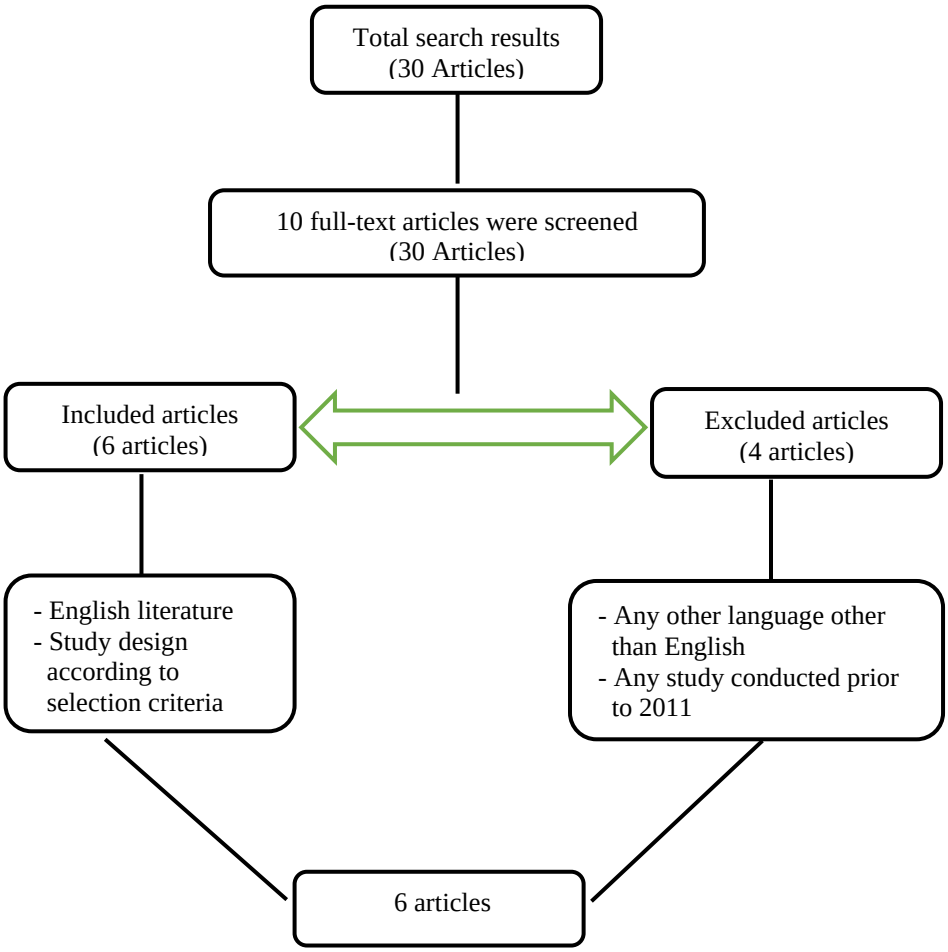
2. Exclusion Criteria:

- Any other language than English
- The study conducted prior to 2011
- Articles on other than stroke survivors
- In Hybrid System use other stimulation than Functional Electrical stimulation

- Screening and Data extraction

  Out of 30 search results, 10 full text articles were screen and 5 were selected for review on basis of selection criteria.

- Procedure:



RESULT

No.	Author's Name	Title Of the Study	Conclusion
1.	Yansong Wang (2020)	An Assistive System for Upper Limb Motion Combining Functional Electrical Stimulation and Robotic Exoskeleton	It can be concluded that a hybrid system combined FES and exoskeletal work together to facilitate an assistance in all the joints of upper limb. This device worked on divide and rule strategy.
2.	Sofia Straudi, MD (2019)	The Effects Of A Robot-assisted Arm Training Plus Hand Functional Electrical Stimulation On Recovery After Stroke: A Randomized Clinical Trial.	It can be concluded that an intensive arm training that combined RAT and hand-FES, seems to not be superior to a time matched intensive conventional arm training, even though people who received RAT + FES, at the same level of arm impairment and corticospinal tract integrity, reached a higher level of arm recovery.
3.	Antonio Ribas Neto (2019)	A Hybrid Control Strategy For Tendon-actuated Robotic Glove and Functional Electrical Stimulation – A Preliminary Study	This study concluded that a hybrid control system is capable to improve wrist joint range of motion and potential to decrease fatigue.
4.	Marian S. Poboroniuc (2015)	Preliminary Tests Of a New Hybrid FES-Exoskeleton Assisting Device For The Upper Limb In Stroke Patients.	This study shows that FES and Exoskeleton driven movements can result in improving muscle tone and prevent atrophy, reduce spasticity, increase blood circulation and skin health.
5.	Ard J. Westerveld (2014)	Passive Reach and Grasp With Functional Electrical Stimulation and Robotic Arm Support	It has been concluded that combination of FES and Robotic arm support can be successful in supporting functional task. This system has great potential for support of the movement during post stroke functional training.
6.	Sergiu Hartopanu (2014)	Towards Human Arm Rehabilitation In Stroke Patients By Means Of a Hybrid FES and Robotic Glove	It can be concluded that a hybrid system supports human hand and hand activities using a control architecture for dexterity, grip and handling.

DISCUSSION

In stroke patient's upper limb impairment is common in stroke and can have a devastating impact on the daily lives of stroke survivors. To increase functional independency of stroke patients'

rehabilitation of arm and hand function is very important.

Soft Robotic Hand and FES are two technologies that may either assist movement during tasks or accompany the convention protocol for hand function therapy. But both systems have their own limitations that ultimately leads to reduce their use to improve the hand function and dexterity. To overcome these nowadays hybrid system is more convenient for stroke patients to make them functionally independent. (12)

Neto et al. said that how the Hybrid System is used to overcome the limitations of individual application of FES and Soft Robotic Hand. He said that in this system, initially FES is used to close the hand, then FES will be switched off and Robot-driven-orthosis is used to maintain the close hand posture. Similar procedure will be followed for open hand posture. Due to this, fatigue is delayed by reduction in time required to use FES which in turn results in improved grasping and releasing capabilities. (14)

Yansong Wang also suggested that there are two types of Hybrid Exoskeletons: Active Exoskeleton and Passive Exoskeleton. So Hybrid Exoskeleton can not only useful in stroke patients but also useful to treat disorders of muscles, joints and skeleton. He also said that Exoskeleton hold the finger position to prevent non-volitional movement when FES is delivered to the fore arm to assist the wrist movement. So the Hybrid System works on "divide and rule" principle and assist upper limb functions such as reaching, grasping and lifting objects.

The present review complied the available articles that reported functional outcome obtained through the use of the hybrid system in people living with stroke. In present articles they focused on different clinical goals and use multiple assessment tools to evaluated functional outcome such as Wolf Motor Function Test (WMET), Box and Block Test, Fugl-Meyer Motor Assessment Scale of Upper Extremity (FMA-UE) and Action Research Arm Test (ARAT), etc.

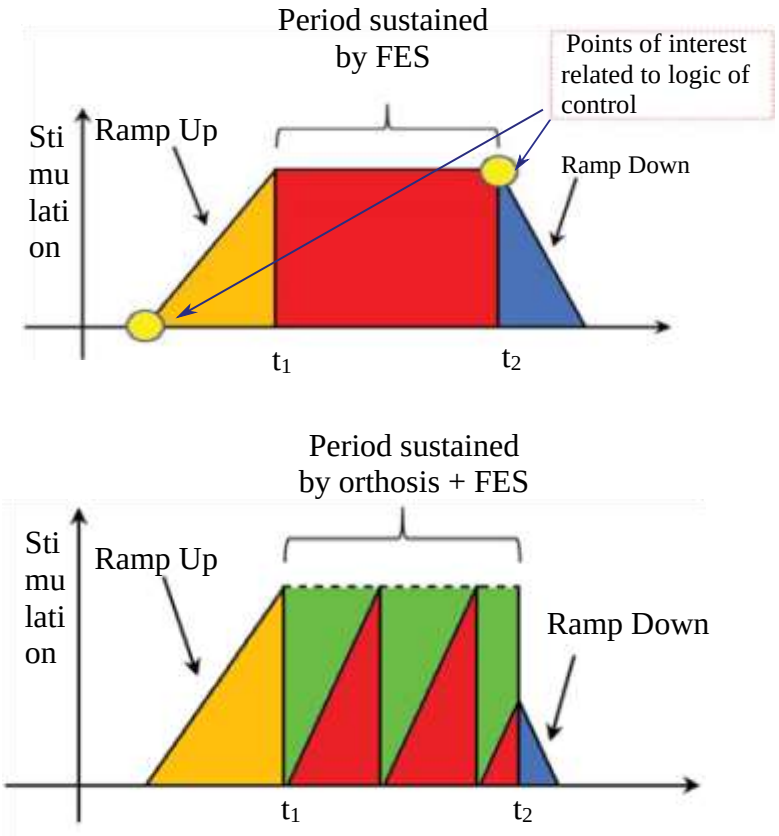


Fig. 1. (a) Generic waveform of FES, and (b) the new proposed waveform for FES and/plus tendon-driven orthosis.

CONCLUSION

Thus, it can be concluded that combined use of Functional Electrical Stimulation and Robotic Hand Glove were found to be more effective than individual use of these interventions to improve the specific tasks such as full reach, grasp, release, lifting tasks, drinking water, etc. in post-stroke patients.

Declaration by Authors

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Conflict of Interest: The authors declare no conflict of interest.

REFERENCES

1. Nair SP, Gardas SS, Mithaiwala R. Efficacy of chest expansion resistance exercise on respiratory function, trunk control and dynamic balance in patients with chronic stroke: A Comparative study. Bulletin of Faculty of Physical Therapy. 2021 Dec;26(1):1-8. https://doi.org/10.1186/s43161-021-00041-z.
2. Kamalakannan S, Gudlavalleti AS, Gudlavalleti VS, Goenka S, Kuper H. Incidence & prevalence of stroke in India: A systematic review. The Indian journal of medical research. 2017 Aug;146(2):175. https://doi.org/10.4103%2Fijmr.IJMR_516_15.
3. Raghavan P. Upper limb motor impairment after stroke. Physical Medicine and Rehabilitation Clinics. 2015 Nov 1;26(4):599-610.
4. Hara Y. Neurorehabilitation with new functional electrical stimulation for hemiparetic upper extremity in stroke patients. Journal of Nippon Medical School. 2008;75(1):4-14. https://doi.org/10.1272/jnms.75.4.
5. Alon G, Levitt AF, McCarthy PA. Functional electrical stimulation enhancement of upper extremity functional recovery during stroke rehabilitation: a pilot study. Neurorehabilitation and neural repair. 2007 May;21(3):207-15. https://doi.org/10.1177/1545968306297871.
6. Guo N, Wang X, Duanmu D, Huang X, Li X, Fan Y, Li H, Liu Y, Yeung EH, To MK, Gu J. SSVEP-Based Brain Computer Interface Controlled Soft Robotic Glove for Post-Stroke Hand Function Rehabilitation. IEEE Transactions on Neural Systems and Rehabilitation Engineering. 2022 Jun 22; 30:1737-44. DOI: 10.1109/TNSRE.2022.3185262
7. Ed Multicenter RandoKang MG, Yun SJ, Lee SY, Oh BM, Lee HH, Lee SU, Seo HG. Effects of Upper-Extremity Rehabilitation Using Smart Glove in Patients with Subacute Stroke: Results of a Prematurely Terminatmized Controlled Trial. Frontiers in Neurology. 2020 Nov 9; 11:580393. https://doi.org/10.3389/fneur.2020.580393.
8. Thimabut W, Terachinda P, Kitisomprayoonkul W. Effectiveness of a Soft Robotic Glove to Assist Hand Function in Stroke Patients: A Cross-Sectional Pilot Study. Rehabilitation Research and Practice. 2022 Apr 25;2022. https://doi.org/10.1155/2022/3738219.
9. Westerveld AJ, Schouten AC, Veltink PH, van der Kooij H. Passive reach and grasp with functional electrical stimulation and robotic arm support. In2014 36th Annual International Conference of the IEEE Engineering in Medicine and Biology Society 2014 Aug 26 (pp. 3085-3089). IEEE.
10. Teferra M. Functional electrical stimulation (FeS). IJLRET. 2017; 3:95-101.
11. Wu FC, Lin YT, Kuo TS, Luh JJ, Lai JS. Clinical effects of combined bilateral arm training with functional electrical stimulation in patients with stroke. In2011 IEEE International Conference on Rehabilitation Robotics 2011 Jun 29 (pp. 1-7). IEEE. https://doi.org/10.1109/ICORR.2011.5975367.
12. Wang Y, Metcalfe B, Zhao Y, Zhang D. An assistive system for upper limb motion combining functional electrical stimulation and robotic exoskeleton. IEEE Transactions on Medical Robotics and Bionics. 2020 Apr 24;2(2):260-8.
13. Resquín F, Gómez AC, Gonzalez-Vargas J, Brunetti F, Torricelli D, Rueda FM, de la Cuerda RC, Miangolarra JC, Pons JL. Hybrid robotic systems for upper limb rehabilitation after stroke: A review. Medical engineering & physics. 2016 Nov 1;38(11):1279-88.

14. Neto AR, Fajardo J, Ferman V, Fujiwara E, Rohmer E. A hybrid control strategy for tendon-actuated robotic glove and functional electrical stimulation–a preliminary study. In2019 IEEE 4th International Conference on Advanced Robotics and Mechatronics (ICARM) 2019 Jul 3 (pp. 244-249). IEEE.

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