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Original Article

Automated Convenient Wrist Mobilizer for Stretching Exercises

Jyotirmayee Sethi*[1], Aditya Alok Sahoo[2], Dewendra Prasad[1], Parthasarathi Swain[3]

[1]*Department of Medical Science (Unit: Material Development- Aids and Appliances), National Institute for Empowerment of Persons with Multiple Disabilities (NIEPMD) (Divyangjan), Chennai, Tamil Nadu, India*
[2]*Department of Prosthetics and Orthotics, AIIMS, Raipur, Chhattisgarh, India.*
[3]*Deaprtment of Prosthetics and Orthotics, Composite Regional Centre for Skill Development, Rehabilitation and Empowerment of Persons with Disabilities (CRC), Patna, Bihar, India*

ABSTRACT

Background: The most prevalent long-term impairments seen due to Stroke or CVA are hemiparesis, which is weakness of the entire left or right side of the body, and hemiplegia, which is total or partial paralysis of one side of the body. These conditions tend to be accompanied by impaired motor coordination, muscle weakness, and impairment of the affected arm's sensory mechanism frequently exhibits spasticity and contractures of the elbow, wrist, and finger muscles. The new design of an automated convenient wrist mobilizer will improve positioning and provide therapeutic intervention in reducing spasticity. **Methods:** The prototype device was designed which combines a Dynamic Wrist Hand Orthosis with a servomotor, controlled by an ESP32 microcontroller to produce passive wrist flexion and extension through cable driven mechanism. The prototype is intended for patients with mild to moderate wrist spasticity. **Result:** The current design is a prototype automated convenient wrist mobilizer for stretching exercises and to relieve wrist spasticity without external assistance. It is lightweight, affordable and easy to operate, making it suitable for home-based rehabilitation. **Conclusion:** In conclusion, the automated convenient wrist mobilizer is a prototype design. It can improve Range of Motion and reduction of spasticity in patient suffering from wrist pain and spasticity.
Keywords: Stroke, Cerebral Vascular Accident (CVA), Hemiplegia, Spasticity

INTRODUCTION

Stroke or Cerebral Vascular Accident (CVA), caused by the occlusion or rupture of cerebral blood vessels is the leading cause of neurological disability worldwide. It has been estimated that among the children who survive, between 50% and 80% will exhibit permanent upper extremity sensorimotor deficits. The two most prevalent long-term impairments seen due to CVA are hemiparesis, which is weakness of the entire left or right side of the body, and hemiplegia, which is total or partial paralysis of one side of the body. These conditions tend to be accompanied by impaired motor coordination, muscle weakness, and impairment of the affected arm's sensory mechanisms. Functional loss of mobility due to hemiplegia has a significantly negative impact on the ability to perform activities of daily living such as reaching and grasping and object manipulation. CVA patients frequently exhibit spasticity and contractures of the elbow, wrist, and finger muscles in addition to hemiplegia.[1] Spasticity has been narrowly defined as a motor disorder characterized by velocity dependent increase in tonic stretch reflexes (muscle tone) with exaggerated tendon jerks.[2] Physical, occupational therapy and different type of spasticity reduction orthosis play significant roles in the management of spasticity. Several interventions with vastly different proposed mechanisms have been and continue to be utilized to decrease spasticity.[3] Stretching is a therapeutic intervention aimed at elongating pathologically shortened or tightened soft tissues to reduce spasticity and improve flexibility. Stretching techniques are broadly classified into passive stretching, proprioceptive neuromuscular facilitation (PNF), and self-stretching. Passive stretching may be

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performed manually by a therapist or mechanically using external devices; manual stretching is typically applied for 15–30 seconds, extendable up to 60 seconds based on patient tolerance, whereas mechanical stretching involves low-intensity, prolonged application ranging from 20 minutes to several hours using devices such as serial casts, pulleys, dynamic splints, traction, or tilting tables. PNF techniques utilize neuromuscular facilitation to enhance muscle extensibility and include hold-relax, contract-relax, and slow-reversal methods. Self-stretching is performed independently by the patient under therapeutic guidance and follows principles similar to passive stretching, contributing to improved neuromuscular facilitation and muscle relaxation[4]. There have been few reports on wrist stretching machines. Matthias Panny et al. (2020) developed a machine for restoring wrist function, offering wrist exercises incorporating pronation-supination and flexion-extension movement. The machine was designed for the assessment of joint stiffness in wrist and provide range of motion in two degrees of freedom.[5] V. Squeri et al. (2014) developed a machine for restoring wrist functionality in chronic stroke patients. A haptic three DOF (degree of freedom) robot has been used to quantify motor impairment and assist wrist and forearm articular movements: flexion/extension, abduction/ adduction, pronation/ supination.[6] Hassanin Al- Fahaam et al. (2016) developed a pneumatic soft wrist stretching device. It has three modes of rehabilitation exercises in the exoskeleton are involved: flexion/extension, radial/ulnar deviation, and circular movements.[7] The above-mentioned devices are very advanced, expensive and designed with complex mechanism. Due to high cost, it is very difficult to use in every clinical set up and not affordable to procure by the user. Keeping in view the above, it was decided to develop a wrist mobilizer prototype which is simple in design, operation and is lightweight and affordable to patients suffering from wrist spasticity.

METHODOLOGY:

The wrist mobilizer consists of the electrical components and the wrist hand orthosis which was fabricated of 3mm Polypropylene sheet designed to place the assembled electrical components. The orthosis was fabricated on a model of a wrist hand mold made from plaster casting and modification. For moulding, a dummy of the same dimension of the assembled electrical components was placed on the positive mold and was moulded. The wrist hand splint contains two parts, a dorsal forearm shell having space for accommodating the assembled electrical components and a palmar hand piece which is attached to the forearm shell near the wrist styloid process by rivets which acts as an articulation and helps in movement of the wrist joint with the splint. For fabrication of the electrical components for the wrist mobilizer following electrical components were selected which consists of ESP32 (microcontroller), Servomotor, Battery and an on/off switch.

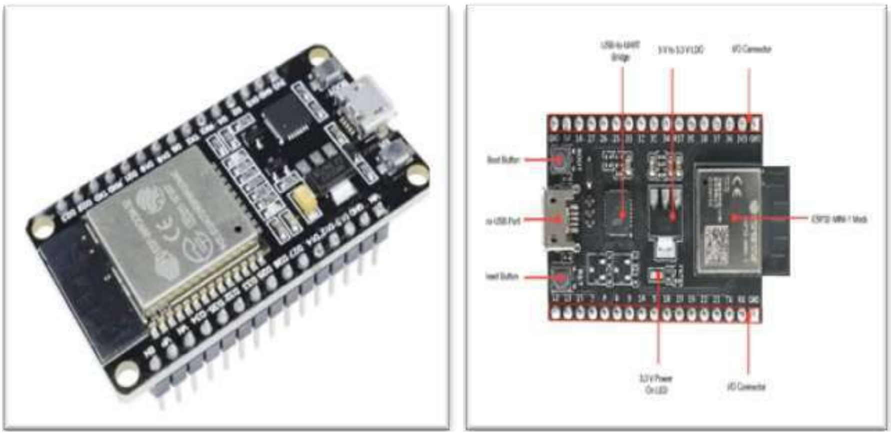

Figure.1: Parts of ESP32 Microcontroller

Figure.2: Servomotor (Sg 90) And Lithium Battery

Assembling of Electric Components

The servomotor has three wires (red, brown and orange), red wire connects at voltage input port, brown wire connects at the ground port, orange wire connects at the D25 port. On/ off switch was connected at the one end of two jumper wires and the other end of the wires connected to battery and 3V3 port of ESP32. A custom programme was uploaded into the ESP32 with the help of connecting cable which connects the ESP32 with computer. Later the connecting cable were ejected from the ESP32 and computer. The Lithium battery was connected at the ground port of the ESP32 to provide electrical energy to it which in turn runs the servomotor.

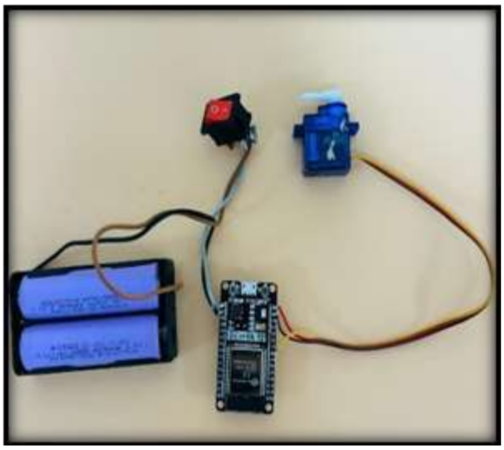

Figure.3: Alignment of Electronics Components

Final Finishing:

The assembled electric components were attached at the space inside the forearm shell and the servomotor attached on the forearm shell. A control cable was coiled to the rotating shaft of the servomotor on one end and to the dorsal side of the hand piece on the other end. This drives the control cable to move clockwise or anticlockwise according to the motion of the wrist required for mobilization. Once switched on, the servomotor starts pulling the hand piece into extension.

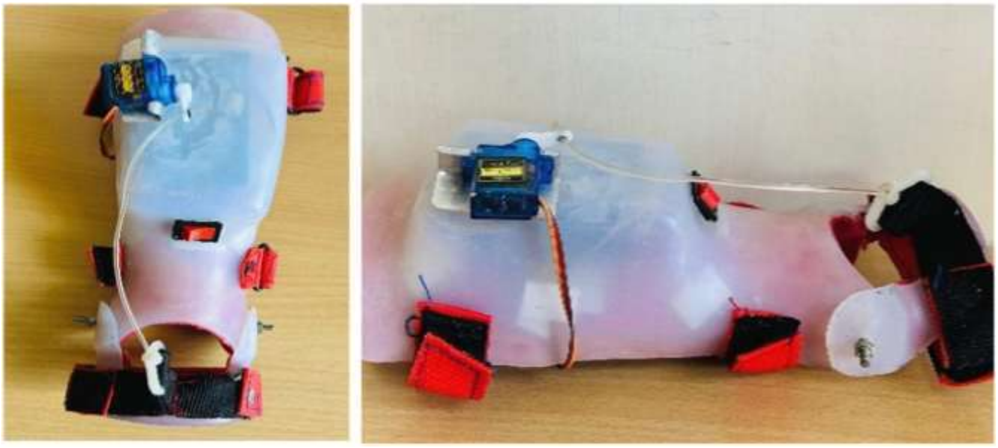

Figure.4: Final Finishing of the Automated Convenient Wrist Mobilizer

Working Principle:

This newly designed therapeutic device allows the patient to do independently the stretching exercises. Once the device is switched on, the servomotor starts pulling the hand upward from the neutral position as per the programme uploaded. The patient must voluntarily off the switch to stop the extension motion of the wrist. In this manner it helps the patients affected from stroke or CVA to perform wrist movement and to relieve wrist spasticity. With the proper user training, the wrist mobilizer can be used independently by the patient for therapeutic exercise at home premises.

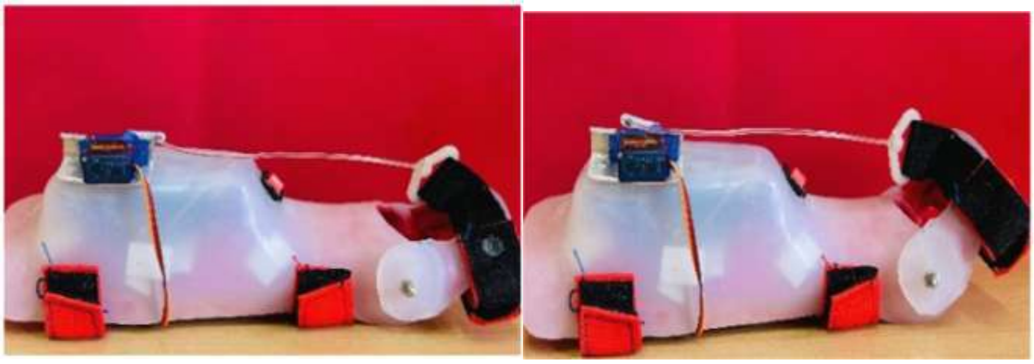

Figure.5: Prototype Movement Testing of the Automated Convenient Wrist Mobilizer

DISCUSSION:

The present study describes the development of a prototype of automated and user-friendly wrist mobilizer designed to facilitate stretching exercises and alleviate wrist spasticity without the need for external assistance. The device is intended for independent home therapy, enabling patients to perform therapeutic wrist mobilization safely and conveniently. Previous studies have reported the use of automated wrist mobilization devices for the management of pain, joint stiffness, reduced range of motion, and spasticity in patients with various wrist-related complications. These findings highlight the therapeutic potential of automated mobilization in wrist rehabilitation. The proposed device serves as an alternative therapeutic option for both clinicians and patients in the planning and implementation of home-based rehabilitation programs. Its use may significantly reduce the need for frequent visits to rehabilitation service centres, thereby improving patient compliance and reducing healthcare burden. Furthermore, the automated wrist mobilizer is expected to be effective in patients with wrist spasticity classified up to Grade 2 on the Modified Ashworth Scale (MAS), making it suitable for mild to moderate spasticity management.

CONCLUSION:

The automated convenient wrist mobilizer is a prototype design. It can improve Range of Motion and reduce spasticity in patient suffering from Stroke or CVA. However, this study found no evidence for the reliability or accuracy of wrist stretching, an area ripe for future research. The time and the frequency of ROM is not programmed. So, the user must manually switch off the motor at the end of therapeutic session. Clinical trial needs be done to know the effectiveness of the device. Also, cosmetic appearance needs consideration to improve user compliance.

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Ethical Approval: Approved from Ethical Committee of NIEPMD, Chennai.

AUTHOR'S CONTRIBUTION:

The entire clinical course of "AUTOMATED CONVENIENT WRIST MOBILIZER FOR STRETCHING EXERCISES" service delivery was done by Miss. Jyotirmayee Sethi towards the fulfilment of a bachelor's degree research project under the guidance of Shri Dewendra Prasad & Mr. Aditya Alok Sahoo. The manuscript preparation is done by Ms. Jyotirmayee Sethi. The research study was carried out in the premises of NIEPMD, Chennai.

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